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Using a videogame to facilitate nursing and medical students' first visit to the operating theatre. A randomized controlled trial☆

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ABSTRACT

Background: First experiences in the operating theatre with real patients are always stressful and intimidating for students. We hypothesized that a game-like simulation could improve perceptions and performance of novices.
Methods: A videogame was developed, combining pictures and short videos, by which students are interactively instructed on acting at the surgical block. Moreover, the game includes detailed descriptive information. After playing, students are given feedback on their performance.

A randomized controlled trial was conducted with 132 nursing and medical students with no previous experience in surgery. Sixty two (47.0%) were allocated to a control group (CG) and 70 (53.0%) to an experimental group (EG). Subjects in EG played the game the day prior to their first experience in the theatre; CG had no access to the application. On the day after their experience at surgery, all students filled in a questionnaire in a 7-point Likert format collecting subjective data about their experience in the surgical block.

Four constructs related to students' feelings, emotions and attitudes were measured through self-reported subjective scales, i.e. C1: fear to make mistakes, C2: perceived knowledge on how to behave, C3: perceived errors committed, and C4: attitude/behaviour towards patients and staff. The main research question was formulated as follows: do students show differences in constructs C1–C4 by exposure to the game?
Results: EG reported statistically significant higher scores on the four aspects measured than CG ($p < 0.05$; Mann-Whitney U tests; Cohen's d standardized effect size d1 = 0.30; d2 = 1.05; d3 = 0.39; d4 = 0.49).
Conclusions: Results show clear evidence that the exposure to the game-like simulation had a significant positive effect on all the constructs. After their first visit to the theatre, students in EG showed less fear (C1) and also perceived to have committed fewer errors (C3), while they showed higher perceived knowledge (C2) and a more collaborative attitude (C4).

1. Introduction

First experiences of nursing and medical students in the operating theatre (OT) with real patients are always stressful and intimidating. Novices, without a defined role, feel the high-pressure of such a dynamic environment with many health professionals working at once. The student, conscious that he or she may compromise patient's safety, tends to remain passive to avoid making mistakes. As a result, novices feel they are unproductive with a possible negative impact on their future career decisions.

While in the surgical block, students have to learn through three domains, (Lyon, 2003), i.e. i) managing the demands of the working environment, ii) the educational tasks, and iii) the learning and social relations of the operating theatre. Students able to successfully manage these will have an enhanced experience.

Novice's knowledge, skills and attitudes may be improved implementing an OT induction curriculum, as shown by Patel et al. (2012) who compared the results of implementing a didactic lecture, an online Second Life operating room, or a simulated operating suite. This study was the first to address primary exposure of novices to the OT. Novices' knowledge, skills and attitudes were assessed using a behavioural observation scale and a self-report scale, as well as a multiple-choice questions test. The introduction of an OT induction curriculum demonstrated a significant improvement in novices' performance, regardless of the methodology used. The use of a simulated operating suite has been demonstrated to be the most expensive of these training interventions. The use of a didactic lecture displayed promising results. However, it would be necessary to repeat the lecture several times to

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different groups of students being exposed to the OT at varying times. The less expensive alternative was the Second Life operating theatre, which also demonstrated favorable results.

Accordingly, we developed a game-like simulation (freely accessible at http://e-adventure.appspot.com/redirect/operating-theater-game-es) where the real environment is reproduced (Del Blanco et al., 2013). In the game, students are instructed by practicing on how to act in the surgical area in different situations and extensive feedback is provided at the end. Also, the game includes detailed descriptive information on structure, elements and personnel of the OT.

The first game prototype was evaluated by experts using Likert scales to assess game's utility, application and feedback. Comments received were used to continuously improve the successive versions of the videogame. Then, the game was validated with students. For this purpose, a prospective randomized controlled trial (RCT) was conducted. Half of novices played the game the day prior to their first experience in OT; the other half (control group), had no access to the application. All students filled in a questionnaire the day after their first OT experience with a series of items about the different aspects contemplated in the game. Our results show how the exposure to the game-like simulation had a significant positive effect on the first experience of novices to the OT.

2. Methods, Materials, Participants and Settings

2.1. Ethics Statement

Students' participation was entirely voluntary and was performed with the informed consent of the participants. Students were orally informed about the nature of the study in which a new instructional method was investigated to the benefit of the students prior to its routine deployment. The intervention of the study (game playing and filling in a questionnaire) was not part of any examination, so that a participation or non-participation would have no consequences on their grades.

The ethics committee at our institution (*COMITE ETICO DE INVESTIGACION CLINICA*, Hospital Clínico San Carlos, Área 7, 28040-Madrid, Spain; tel.: + 34 913303819, e-mail: ceic.hcsc@salud.madrid.org) reviewed and approved the project concluding that a full formal ethics committee statement was not required, due to the educational nature of the study. Data analysis was anonymous. When participating in the study, the students agreed to the anonymous analysis of their data. Students who would not like to participate in the study could choose to deny participation without further consequences. Anonymous participation is document of the oral agreement of the students. This type of orally agreement employed in our study was discussed with the ethics committee which agreed on it. Due to practical reasons, a formal written consent prior to the study was not feasible.

Since we did not think that a clinical trial registration was required for this type of educational study, it was not sought before enrolment of participants started. Instead, registration has been obtained post hoc as requested. The authors confirm that all ongoing and related trials for this intervention are registered.

2.2. Objectives and Hypotheses

The goal was to assess the potential of a self-developed game-like simulation to enhance the experience of visiting the surgical block for the first time. Four subjective constructs related to students' feelings, emotions and attitudes were measured through students self-reported data. These constructs serve as quality indicators of the first OT visit experience:

- C1: Fear to interfere in clinical activity through incorrect interaction with patients, equipment, environment or staff.
- C2: Perceived knowledge on how they have to behave in the clinical area and how to interact with patients, equipment, environment and staff.
- C3: Perceived errors committed while in the clinical area.
- C4: Attitude/behavior towards patients and staff while in the clinical area.

A separate analysis for each of the constructs was proposed in the aim of answering the main research question: do students show any significant difference in the constructs C1–C4 caused by the exposure to the game-like simulation developed before attending their first visit to the operating theatre?

The hypotheses formulated are that the game would decrease negative constructs C1 and C3 (perceived fear to interfere in clinical activity and perceived errors committed) and increase positive constructs C2 and C4 (perceived knowledge and attitude).

2.3. Participants

Throughout an academic term, 132 students were recruited that successfully completed the study. Sixty two (47.0%) were allocated to a control group (CG) and 70 (53.0%) to an experimental group (EG). Ninety six (72.7%) were females and 36 (27.3%) were males. They were recruited from 2nd and 3rd year at the Nursing and Medical Schools respectively of the Complutense University of Madrid, with no previous experience in the OT. Pearson's χ^2 test showed there were no statistically significant differences between CG and EG in gender or institution of origin.

2.4. Method and Settings

The study was performed completely online. Students provided researchers the scheduled date for their first experience in the OT. Researchers sent detailed instructions to EG students on how to access and play the game to ensure they played the day before their first experience in the OT. The day after the first visit, researchers administered all students (EG and CG) the questionnaire used to measure the four constructs of the study.

2.5. Materials and Instruments

A videogame was developed using pictures and short videos (Del Blanco et al., 2013). In the game, players adopt the role of a student who visits the operating theatre for the first time. Students learn through a first-person experience (the videogame shows what the player is seeing; Fig. 1) how to act in the surgical block in situations such as: getting correctly equipped, interacting with patients and relatives, entering and leaving the surgical block and the theatre, maintaining sterility, leaving the theatre if they feel sick, assisting in small tasks (e.g. tying the surgeon's gown, positioning the lamp, handing materials, etc.). Moreover, the game includes detailed information about i) structure and dependences of the surgical block; ii) common OT elements; and iii) scrubbed and non scrubbed surgical personnel. After completing the game, students receive feedback about

Fig. 1. Four screenshots of the game-like simulation developed. Top left: the user gets dressed and receives feedback. Top right: player experiences casual interaction with patients. Bottom left: player interacts with personnel in the OT. Bottom right: player exercises decision-making on a situation that arises.

their performance, being acquainted of any errors committed.

2.6. Data Collection and Statistical Analysis

To measure the defined subjective constructs, a questionnaire was designed and administered to the students the day after their first practice at the OT (see Appendices 1 and 2). The questionnaire had 15 items in a 7-point Likert format meaning 1 complete disagreement and 7 complete agreement with the given statement.

Items were summed to build a different scale for each subject construct. Table 1 describes the four resulting scales. One of the 15 items was discarded during analysis for ambiguous wording. Reliability of each scale was assessed through Cronbach's alpha tests also reported in Table 1. Items were formulated using positive wording if they were oriented to measure positive constructs C2 or C4 (e.g. "My attitude has been active and collaborative while in the operating theater") and negative wording if oriented to measure negative constructs C1 or C3 (e.g. "I haven't made any mistakes when I came into the operating theater"), resulting in the four scales having a positive orientation (i.e. the higher the values the better).

Data collected were analyzed using statistical software package IBM SPSS 19. Missing values were excluded from the analysis, resulting in lower valid N than the number of participants.

Table 1
Summary of scales used to estimate the four constructs considered in the study.

Scale	Construct	N items	Cronbach's alpha	Possible values [Min-Max]	Orientation
S1	Fear to make mistakes	4	0.844	[4-28]	*Negative* (Higher values show less perceived fear)
S2	Perceived knowledge	3	0.828	[3-21]	*Positive* (Higher values show more perceived knowledge)
S3	Perceived errors committed	4	0.776	[4-28]	*Negative* (Higher values show less subjective error rate)
S4	Adequate attitude	3	0.709	[3-21]	*Positive* (Higher values show better attitude)

Table 2
Summary of results obtained for scales S1–S4. (*) Highlights S1, where median differences between groups were not statistically significant. Independent-samples *t*-test run without outliers showed statistical significance.

Scale	Mean ± SD		Median		Min		Max		N valid		Normality (K-S)		Mann-Whitney *U* test		
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	*U*	Z	*p*
S1	**17.43 ± 5.96**	**19.14 ± 5.39**	19	20	5	6	28	28	56	58	$p = 0.005$	$p = 0.013$	1895.500	1.543	**0.123***
S2	**15.93 ± 4.32**	**19.56 ± 2.43**	17	20	4	10	21	21	59	61	$p = 0.010$	$p < 0.000$	2807.500	5.403	**< 0.000**
S3	**23.54 ± 4.41**	**25.19 ± 4.13**	25	26	11	8	28	28	54	57	$p < 0.000$	$p < 0.000$	1938.500	2.386	**0.017**
S4	**15.72 ± 4.22**	**17.60 ± 3.44**	16.50	18	8	5	21	21	54	57	$p = 0.055$	$p = 0.001$	1937.000	2.364	**0.018**

3. Results

As Table 2 and Fig. 2 show, students in EG reported higher mean and median scores on the four aspects measured as compared to students in CG. Standard deviation (SD) is also lower in EG, suggesting lower dispersion of the data. As assessed by a Kolmogorov-Smirnov test of normality, none of the scales could be considered close to the normal distribution ($p < 0.05$, see Table 2), impeding the use of parametric tests to determine statistical significance of the mean differences observed between groups. Mann-Whitney *U* tests for independent samples were run instead, showing that median differences between groups were statistically significant ($p < 0.05$) for scales S2–S4, but not for S1 ($p = 0.123 > 0.05$).

Twenty lower outliers (extreme values at least 1.5 times the SD below the mean of the intervention group) were found through inspection of boxplots for S1–S4 (see Fig. 2). No upper outliers were

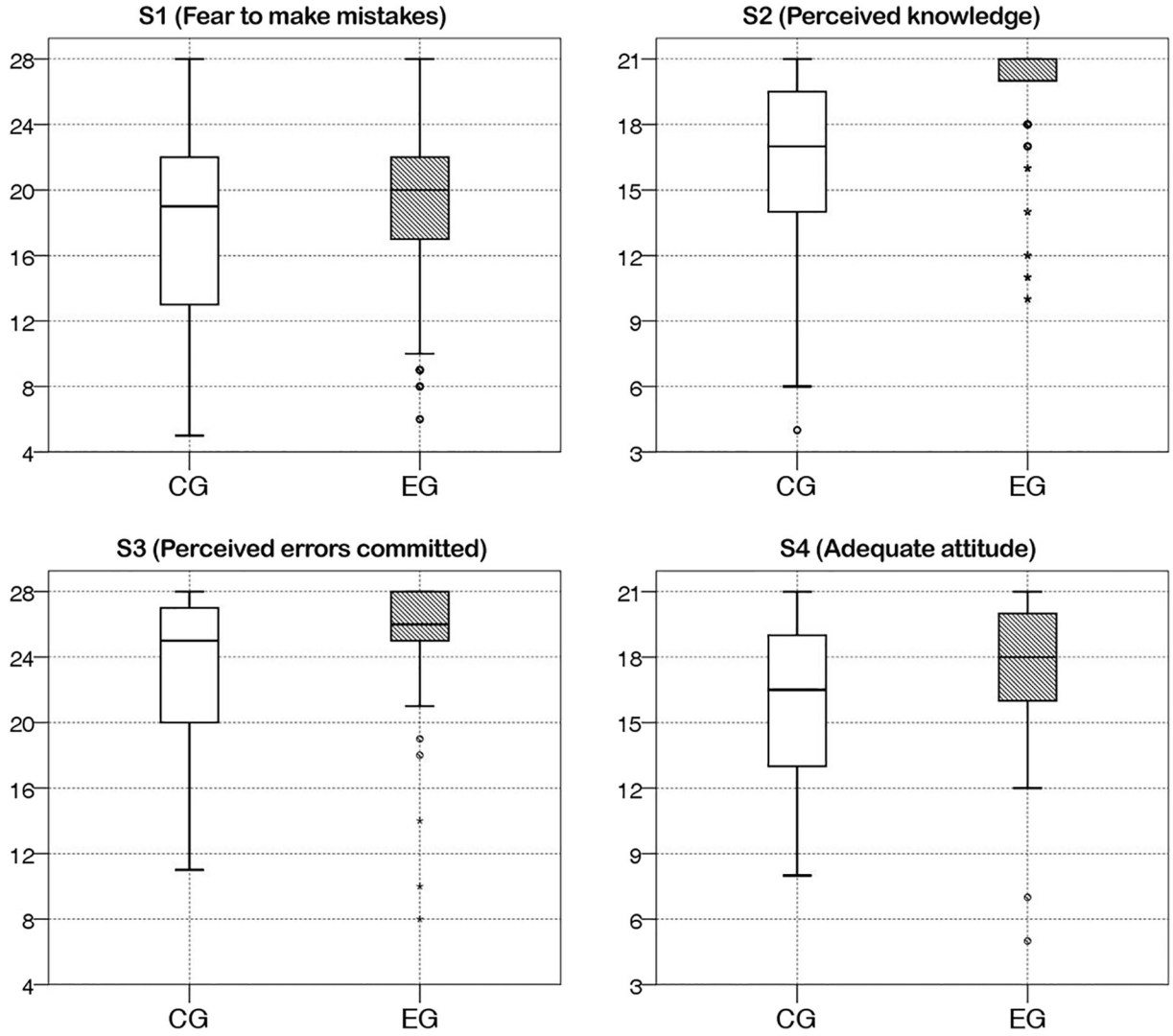

Fig. 2. Boxplot for S1, S2, S3 and S4 (left to right, up to down). For each group the box shows the Inter Quartile Range (50% of the distribution) and the median (horizontal line inside). Whiskers show the min and max value observed on a scale from 4 to 28 or 3 to 21 depending on the scale. The figure shows how EG scored higher than CG in all four constructs. It shows also that the improvement for S2 is higher than for the other three constructs.

Table 3
Individual results for each of the items of the scales.

		N	Min	Max	Mean	SD
I1.1	CG	61	1	7	3.7	1.764
	EG	68	1	7	**4.47**	**1.706**
I1.2	CG	57	1	7	4.89	1.77
	EG	61	1	7	**5.03**	**1.549**
I1.3	CG	60	1	7	4.48	1.742
	EG	66	1	7	**5.12**	**1.732**
I1.4	CG	62	1	7	4.1	1.956
	EG	64	1	7	**4.5**	**1.604**
I2.1	CG	62	1	7	5.23	1.634
	EG	69	4	7	**6.68**	**0.696**
I2.2	CG	59	1	7	5.29	1.733
	EG	64	2	7	**6.59**	**1.05**
I2.3	CG	62	1	7	5.42	1.742
	EG	68	2	7	**6.32**	**1.071**
I3.1	CG	62	1	7	5.45	1.715
	EG	68	1	7	**6.38**	**1.234**
I3.2	CG	54	2	7	6.24	1.345
	EG	61	1	7	**6.39**	**1.037**
I3.3	CG	60	2	7	5.83	**1.368***
	EG	66	1	7	**6.23**	1.507*
I3.4	CG	61	1	7	6.03	1.494
	EG	67	1	7	**6.31**	**1.104**
I4.1	CG	60	1	7	5.67	1.763
	EG	66	1	7	**5.89**	**1.337**
I4.2	CG	55	1	7	5.07	1.741
	EG	60	1	7	**5.65**	**1.56**
I4.3	CG	60	1	7	4.92	1.907
	EG	66	1	7	**5.97**	**1.488**
Valid N (listwise)	CG	51				
	EG	50				

found. Most of the outliers are concentrated in EG ($N = 16$). While most of these are only outliers for one of the scales ($N = 13$), others are in two scales ($N = 4$), three scales ($N = 2$) and even the four of them ($N = 1$). Inspection of outliers showed they were not caused by errors in data entry or to unusual demographics, compared to the study sample, suggesting that the game was not effective for a particular group of students whose characteristics remain unknown. In contrast, the game was very effective for the majority of the students.

The presence of outliers mostly concentrated in EG motivated a second analysis for S1 removing the 10 outliers previously identified. Mean and standard differences between EG (20.61 ± 3.83) and CG (18.09 ± 5.39) increased and a Kolmogorov-Smirnov test showed more proximity to the normal distribution for both groups ($Z = 1.153$, $p = 0.140$; CG: $Z = 0.979$, $p = 0.293$; EG: $Z = 0.600$, $p = 0.865$). These results allowed running an unpaired (independent samples) t-test showing a significant difference between groups ($t = 2.732$; $p = 0.007 < 0.05$). A second Mann-Whitney U test also showed median significant differences ($U = 1690.500$; $Z = 2.211$; $p = 0.027 < 0.05$) when outliers were not considered.

Looking at the individual items of each scale, scores in EG are also higher than in CG and with lower dispersion (Table 3).

High scores of perceived usability (N valid = 68; Mean = 11.94 ± 2.59 out of 14; Median = 13 out of 14) and perceived usefulness (N valid = 67; Mean = 52.37 ± 7.62 out of 63; Median = 54 out of 63) of the game reported in Fig. 3 also suggest that the game was well received by students who had the opportunity to use it (EG).

4. Discussion

Results show clear evidence that the exposure to the game-like simulation had a significant effect on all the constructs C1–C4 proposed for analysis. After their first visit to the OT, students in EG showed less fear to make mistakes (C1) that could interfere in the normal development of clinical activity and also perceived to have committed less errors (C3), while they showed higher perceived knowledge on how they had to behave and what they could and could not do while in the OT (C2) and showed a more collaborative attitude with patients and staff (C4).

The high number of lower outliers identified (22.8% of the cases in

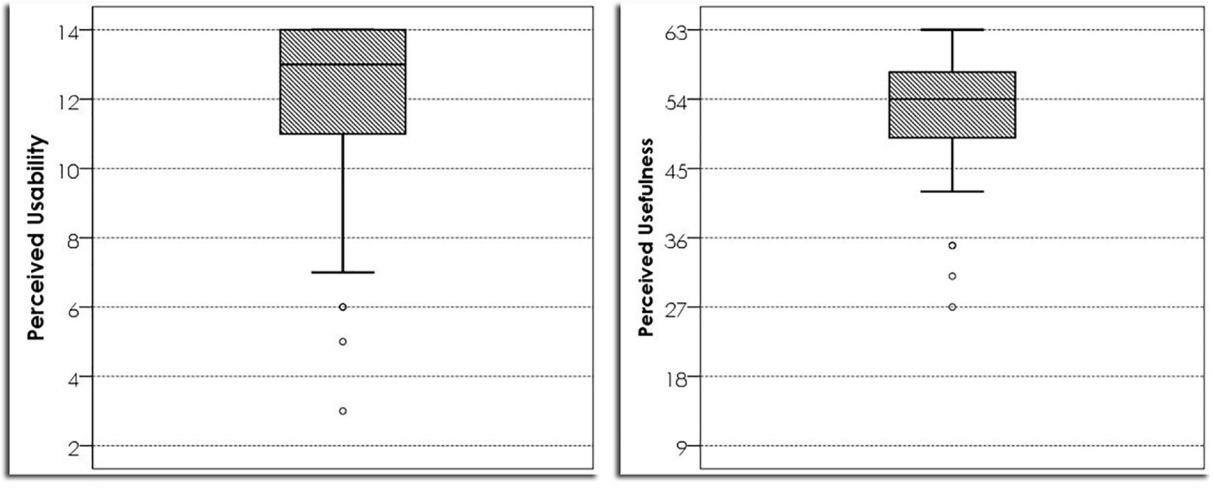

Fig. 3. Boxplots for the perceived usability and usefulness of the game reported by students in EG, showing high student acceptance of the game.

EG) deserves its own piece of discussion. This is especially notorious on C1 (perceived fear to interfere in clinical activity), where the differences observed between CG and EG were not statistically significant if outliers were included in the analysis. It suggests that the game was not so effective for a number of students and, although a minority, further analysis should be conducted to get a better understanding of under what circumstances the effectiveness of the game is lessened.

The results also clearly show that the game had not the same effect for all the constructs. To compare effect sizes, we calculated Cohen's d, an adimensional statistic that divides the difference between group means by the pooled standard deviation, resulting in d1 = 0.30; d2 = 1.05; d3 = 0.39; d4 = 0.49. Constructs C1, C3 and C4 show consistent "medium" effect sizes as defined by Cohen (1988) while C2 (perceived knowledge on how to behave in the surgical block) has a large effect size. This finding can also be observed in Fig. 2, where the distribution of S2 is significantly left-skewed (higher values predominate) compared to EG and also to other scales.

As in Patel's experience (2012), our videogame showed to be an effective OT induction curriculum to prevent stress and intimidation of novices. There are advantages to the implementation of a simulation or Second Life operating room. Primarily, it is accessible from users' desktops and would not require users or educators to be physically present for the training, and it also may be accessed at any time, so training would be repeatable.

Learning preferences have been strongly shaped by new media technologies (McCaughey and Traynor, 2010). A cross-sectional survey was conducted in two American universities to elucidate medical student experiences and attitudes about using new media technologies in medical education (Kron et al., 2010). Students, including many who do not play video games, held highly favorable views about the use of video games and related technology in medical education. The sparse but encouraging data on learning outcomes for video games in science, technology, engineering, and math disciplines, as well as the infrastructural obstacles to wider adoption of this new medium, was early reviewed (Mayo, 2009; Pike and O'Donnell, 2010).

Virtual worlds like Second Life and digital games and simulations in health professions education have been explored in the past, partly motivated by students' interest in these technologies with mixed results (Kron et al., 2010; Cook et al., 2011; Watson et al., 2012; Boeker et al., 2013; Shin et al., 2015; Au et al., 2016). Game-like simulations have been used in education research to allow medical and nursing students and trainees rehearse procedures that are tightly linked to a specific environment in a realistic but safe way, showing improved performance when conducting the procedure in the work place (Moreno-Ger et al., 2010; Samawi et al., 2014; Johnsen et al., 2016). In addition, it has been shown through a systematic literature review that technology-enhanced simulation in health professions education is consistently associated with large effects for outcomes of knowledge, skills, and behaviors and moderate effects for patient-related outcomes (Wang et al., 2016).

The effect of educational games on medical and nursing students' satisfaction, knowledge, skills, confidence, attitude, and behavior has been questioned. This issue was studied in a series of systematic reviews (Akl et al., 2010; Yuan et al., 2012a,b). Findings in the only three eligible RCT suggested but did not confirm a positive effect of the games on students' knowledge. More recently, other review conducted by the same group to assess the effect of educational games on health professionals' performance, knowledge, skills, attitude and satisfaction, as well as on patients' outcomes, neither confirm nor refute the utility of games as a teaching strategy for health professionals (Akl et al., 2013). In another review of serious games for medical education and surgical skills training, none of the games had completed a full validation process for the purpose of use (Graafland et al., 2012). All these data highlight the need for game designers and educators to cooperate in designing and validating serious games for specific educational problems. Only then, a serious game should be integrated as a teaching tool (Graafland et al., 2014).

Our game is consistent with the three domains, identified by Lyon (2003), through which students must learn while in the operating theatre. Also, students receive feedback about their performance. These design features are consistent with simulation best practices identified by McGaghie et al. (2011). After our experience, we believe in the effectiveness of educational games in nursing and medical education for particular purposes, as assessed in terms of students' satisfaction, knowledge, skills, attitude, and behavior (Akl et al., 2013; Levett-Jones et al., 2011). Our results show clear evidence that the exposure to the game-like simulation had a significant positive effect on all the constructs, facilitating and improving the performance of students first practice in the OT with real patients.

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Appendix 1

POST QUESTIONNAIRE
FIRST EXPERIENCE IN THE OPERATING ROOM (OR)

The aim of this questionnaire is to gather your perceptions about your first visit to the OR. Your answers will not be used for evaluation in any way, but for improving the learning processes and the educational contents used in this course. For this reason, we kindly ask you to answer the following questions to the best of your knowledge. The information extracted from this questionnaire will be treated confidentially and anonymously.

1. Before entering the clinical area	**(complete agreement 1 – complete disagreement 7, not applicable N/A)**
1.1- I knew the gear I needed to take before entering the clinical area (pajamas, shoe covers, surgical mask, etc.)	**1 2 3 4 5 6 7 N/A**
1.2- I did not fear to make mistakes when accessing the clinical area (Note: answer regardless you actually made mistakes or not)	**1 2 3 4 5 6 7 N/A**
1.3- I did not make significant mistakes when accessing the clinical area (Examples of mistakes: leaving the mobile phone switched on, not getting fully equipped, etc.)	**1 2 3 4 5 6 7 N/A**

2. On your way to the OR	**(complete agreement 1 – complete disagreement 7, not applicable N/A)**
2.a) Attitude towards the patients	
2.a).1- I did not feel intimidated by potential interaction with patients	**1 2 3 4 5 6 7 N/A**
2.a).2- I adopted an active attitude with patients (I tried to collaborate)	**1 2 3 4 5 6 7 N/A**
2.a).3- I did not fear to make mistakes with patients (Note: answer regardless you actually made mistakes or not)	**1 2 3 4 5 6 7 N/A**
2.a).4- I did not make significant mistakes with patients (e.g. avoid direct interaction deliberately or giving indications about patient's treatment that correspond to the doctor)	**1 2 3 4 5 6 7 N/A**
2.b) Accessing the OR	
2.b).1- I knew how to access the OR (look throw the fish-eye before entering, wear a mask, entering a different OR, etc.)	**1 2 3 4 5 6 7 N/A**
2.b).2- I did not fear to make mistakes when I entered the OR I was assigned to (Note: answer regardless you actually made mistakes or not)	**1 2 3 4 5 6 7 N/A**
2.b).3- I did not make mistakes when accessing the OR	**1 2 3 4 5 6 7 N/A**

3. Inside the OR	**(complete agreement 1 – complete disagreement 7, not applicable N/A)**
3.1- I introduced myself properly after entering into the OR (I said my name, the degree I'm studding and the course)	**1 2 3 4 5 6 7 N/A**
3.2- I knew what I could and couldn't do/touch in the OR to ensure sterility and avoid interfering with the work of the surgical team	**1 2 3 4 5 6 7 N/A**
3.3- My attitude was active and collaborative while in the operating theater	**1 2 3 4 5 6 7 N/A**
3.4- I did not fear to make mistakes when I interacted with the surgical team (Note: answer regardless you actually made mistakes or not)	**1 2 3 4 5 6 7 N/A**

Appendix 2

The questionnaire described in Appendix 1 has also four sections. The first three sections address aspects related to the different moments of the first visit to the OR while the fourth section addresses perceived utility (usefulness) and usability of the game. This annex provides guidelines for constructing the 6 scales discussed in the paper from the responses to the questionnaire:

Scale	Build by adding up responses to questions	
S1: Fear to make mistakes	1.2, 2.a).3, 2.b).2, 3.3	(4 items)
S2: Perceived knowledge	1.1, 2.b).1, 3.2	(3 items)
S3: Perceived errors committed	1.3, 2.a).4, 2.b).3, 3.4	(4 items)
S4: Adequate attitude	2.a).1, 2.a).2, 3.1	(3 items)
Usability	4.9, 4.10	(2 items)
Usefulness (utility)	4.1–4.8, 4.11	(9 items)

The following table also provides a direct mapping between the questions in the questionnaire and the items that compose each of the scales (IX.n – Item number n of the construct X; US – perceived usability; UT – perceived usefulness/utility):

# question		Item
1.1	→	I2.1
1.2	→	I1.1
1.3	→	I3.1
2.a).1	→	I4.1
2.a).2	→	I4.2
2.a).3	→	I1.2
2.a).4	→	I3.2
2.b).1	→	I2.2
2.b).2	→	I1.3
2.b).3	→	I3.3
3.1	→	I4.3
3.2	→	I2.3
3.3	→	I1.4
3.4	→	I3.4
4.1	→	UT1
4.2	→	UT2
4.3	→	UT3
4.4	→	UT4
4.5	→	UT5
4.6	→	UT6
4.7	→	UT7
4.8	→	UT8
4.9	→	US1
4.10	→	US2
4.11	→	UT9

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