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RESEARCH REPORT

Impact of compulsory participation of medical students in a multiuser online game to learn radiological anatomy and radiological signs within the virtual world Second Life

Teodoro Rudolphi-Solero[1] | **Rocio Lorenzo-Alvarez**[2] | **Miguel J. Ruiz-Gomez**[3] | **Francisco Sendra-Portero**[3]

[1]Department of Nuclear Medicine, Hospital Universitario Virgen de las Nieves, Granada, Spain

[2]Department of Emergency and Intensive Care, Hospital de la Serrania, Ronda, Spain

[3]Department of Radiology and Physical Medicine, Universidad de Málaga, Málaga, Spain

Correspondence
Dr. Francisco Sendra-Portero, Department of Radiology and Physical Medicine, Facultad de Medicina, Universidad de Málaga, Bvd. Luis Pasteur 32, 29071, Málaga, Spain.
Email: sendra@uma.es

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Abstract

Competitive game-based learning within Second Life enables effective teaching of basic radiological anatomy and radiological signs to medical students, with good acceptance and results when students participate voluntarily, but unknown in a compulsory context. The objectives of this study were to reproduce a competitive online game based on self-guided presentations and multiple-choice tests in a mandatory format, to evaluate its development and student perceptions compared to a voluntary edition in 2015 ($N = 90$). In 2016 and 2017, respectively, 191 and 182 third-year medical students participated in the game as a mandatory course activity. The mean (±SD) score of the game was 74.7% (±19.5%) in 2015, 71.2% (±21.5%) in 2016, and 67.5% (±21.5%) in 2017 ($P < 0.01$). Participants valued positively the organization and educational contents but found the virtual world less attractive and the game less interesting than in the voluntary edition. The experience globally was rated with 8.2 (±1.5), 7.8 (±1.5), and 7.1 (±1.7) mean points (±SD) in a ten-point scale, in the 2015, 2016, and 2017 editions, respectively ($P < 0.05$). Competitive learning games within virtual worlds like Second Life have great learning potential in radiology, but the mean score in the game decreased, acceptance of virtual world technology was lower, and opinion about the game was worse with a compulsory participation, and even worse when dropouts were not allowed. Under the conditions in which this study was conducted, learning games in three-dimensional virtual environments should be voluntary to maintain adequate motivation and engagement of medical students.

KEYWORDS
education research, e-learning/computers, game-based learning, gross anatomy education, radiology education, medical education, undergraduate education, virtual worlds

INTRODUCTION

Undergraduate radiology teaching in the 21st century focuses in part on interactive, online teaching, and learning models (Chew et al., 2020). Digital transformation can help teach radiology knowledge and skills to medical students (European Society of Radiology, 2019) through technology-enhanced solutions incorporated into the curriculum (Webb & Choi, 2014). Gamification and virtual worlds are two innovative learning approaches that fit well with the high level of technological literacy of today's medical students (McCoy et al., 2016) and their learning and entertainment preferences (Kron et al., 2010; Richardson-Hatcher et al., 2014). Interesting gamification experiences have been developed in virtual worlds through medical simulation role-playing games (Toro-Troconis et al., 2010; Vallance et al., 2014) or competitive radiology games with voluntary participation (Lorenzo-Alvarez et al., 2020), but the effect of incorporating this type of games into compulsory activities is unknown.

Game-based learning and virtual worlds

Gamification has been defined as the application of game design elements to non-gaming contexts (Yunyongying, 2014; Brigham, 2015) in areas as diverse as learning, computer–human interaction, health, and information studies (Seaborn & Fels, 2015). Serious games (Graafland et al., 2012; Wang et al., 2016; Gorbanev et al., 2018) are part of digital games where fun, entertainment, and enjoyment are strategies to fulfill real purposes, such as education or training. Game-based learning (Prensky, 2001; Erhel & Jamet, 2013) is a subset of serious games, in which a complete game is developed to offer immersive and engaging learning experiences to deliver specific learning objectives and outcomes (de Freitas, 2006).

Three-dimensional (3D) virtual worlds are environments displayed on a computer monitor, where users can enter and move through a representation of them, called avatars, interact with the objects in-world, and communicate with other users (Richardson et al., 2011; Veltman et al., 2012; Olteanu et al., 2014; Liaw et al., 2018). They have been recognized as having great potential for the creation and development of the next generation of teaching and learning environments (Ghanbarzadeh & Ghapanchi, 2020) and engaging educational games (Pellas & Mystakidis, 2020).

Second Life (Linden Research, Inc., San Francisco, CA) is considered the most popular virtual world among educators and the most widely used in higher education (Baker et al., 2009; Warburton, 2009; Inman et al., 2010; Potkonjak et al., 2016; Gong, 2018, Second Life, 2020a). Launched in 2003, Second Life is organized in multiple regions, mainly square plots of 256 × 256 meter resembling an island (Rymaszewski et al., 2007). Objects in Second Life can display web pages on their faces, which allows creating presentation panels through simple web pages (Sendra-Portero et al., 2018). Learning experiences in Second Life can facilitate innovation in pedagogy through: social interaction between individuals, visualization and contextualization of inaccessible or imaginary contents, individual and collective identity play, and immersion in a 3D environment with an augmented sense of presence (Warburton, 2009).

Students' motivation and engagement

Individual differences such as intelligence, motivation, and self-regulation may be important predictors of academic achievement (Hattie & Anderman, 2013). Motivation is a theoretical construct used to explain the initiation, direction, intensity, persistence, and quality of behavior (Maehr & Meyer, 1997). Considering the theory of self-determination (Ryan & Deci, 2000; Gagne & Deci, 2005), motivation has two components: intrinsic motivation, defined as participation in a certain activity because it is found intrinsically interesting and enjoyable, and extrinsic motivation, in which participation is due to reasons associated with external factors such as awards, promotions, or avoiding academic failure. Competition is a powerful extrinsic motivator although it is criticized for creating high-pressure environments that reduce intrinsic motivation and prevent optimal learning (Featherstone & Habgood, 2019). Motivation in using virtual world technology requires engaging in it to obtain positive outcomes. In this sense, engagement is defined as the degree to which students are cognitively, emotionally, and behaviorally involved in learning activities in a virtual world educational environment (Sun et al., 2014), and user acceptance of this technology is essential for the motivation and engagement of students.

The willingness or obligation to participate in learning activities influences the motivation of students and the subsequent transfer of knowledge, skills, and attitudes (Curado et al., 2015). Different motivational outcomes can be achieved with serious games depending on whether the game is voluntary or compulsory (Islas Sedano et al., 2013; Wouters et al., 2013). It is relevant to explore whether the voluntary or compulsory nature of participating could influence motivation and the way of living the game (Rodriguez-Aflecht et al., 2017). However, since the use of new online learning programs is often voluntary, it is desirable to obtain more information about user acceptance and game results with mandatory use (Back et al., 2014).

Background of this study

Radiology is taught in the Faculty of Medicine at the University of Málaga during the third year, in a 60-hours four-month course, and the sixth year, in a two-week clinical clerkship. The course includes a final oral examination in which the student must correctly interpret two radiological studies and expose two subjects from the course syllabus. Adequate anatomical knowledge is essential for learning radiology (European Society of Radiology, 2019). During the first and second years, students receive 210 hours of mandatory instruction in human anatomy, with little or no use of radiological imaging.

Since 2011 a space named The Medical Master Island was developed in Second Life (2020b), where teaching activities on radiology, such as courses, seminars, and practical workshops, have

been carried out with high student acceptance (Lorenzo-Alvarez et al., 2018, 2019a, b). In 2015, a competition-based learning game about radiological anatomy and radiological signs, named The League of Rays, was designed and effectively carried out in Second Life with voluntary participation of 90 third-year medical students (Lorenzo-Alvarez et al., 2020). The game was designed highlighting its relationship with formal radiology training and evaluating student perception about the project and the potential impact on learning (Pitt et al., 2015).

The objectives of this study were to reproduce the League of Rays game in a compulsory format, to evaluate the development of the game and the students' perceptions about the experience, and to compare these results with those of the previous voluntary edition. The authors hypothesize that compulsory participation in competitive gaming within the virtual world Second Life will affect students' perception of this educational activity, and their opinion of the game could be negative or even rejecting.

MATERIALS AND METHODS

This project received the approval of the ethics committee of experimentation of the University of Málaga (decision number 40-2021-H).

Structure, contents, and rules of the game

The game was played during two successive academic courses, from April 4 to May 15, 2016 and from March 20 to May 7, 2017. Six topics covering radiological anatomy and radiological signs of the thorax, abdomen, and musculoskeletal system were treated successively along six weekly stages (Figure 1).

The learning content for each topic consisted of a set of three 5.5 × 5.0 meter multimedia panels, each displaying web pages elaborated from 50 slides PowerPoint presentations (Microsoft Corp., Redmond, WA). During the first four days of each week, six sets of three panels were placed on the island for participants to review. The last three days, the learning panels were removed, and 24 panels were placed, displaying two copies of 12 presentations with 15 multiple-choice questions, selected from a dataset of 30 questions. Each multiple-choice question included a radiological image that the student had to analyze to answer correctly. The complete database consisted of 180 questions, including 126 radiographs (70%) and 54 cross-sectional images (30%): 47 computed tomography scans and seven magnetic resonance imaging. Participants had to find their assigned test variant (Figure 2) and send the answer by a notecard (an in-world text message that records the date and time of sending) to the teacher's avatar. The score of the correct answers determined the classification along the game. The game provided a cognitivist approach by encouraging students to apply their understanding of the representation of formal anatomy in diagnostic images to correctly identify pathology. The game multiple-choice tests provided a behavioral approach, allowing the game to be measurable, fast, timely, and easy to score (Williamson et al., 2004). The learning contents and multiple-choice tests of the game were identical to those used in the previous 2015 edition (Lorenzo-Alvarez et al., 2020).

The rules of the game were slightly modified compared to the 2015 edition. The participants were classified into six categories based on the accumulated points, the five radiological densities (metal, calcium, water, fat, and air) and a new sixth group called "immaterial," following the same scoring system in 2017 and 2016 (Table 1). There were no eliminations until the third stage, where those participants who still had zero points were eliminated. By prior agreement of the game organizers, after the fourth, fifth, and sixth stages, the participants with less than 41%, 52%, and 55% of the maximum cumulative points, respectively, were eliminated. The immaterial group was not included in the winners' classification (Figure 1). Unlike the 2016 edition, in the 2017 edition, those students who were eliminated from the game had to continue participating. As in 2015, the students who reached the final classification obtained a certificate recognizing 18 hours of participation and the winners obtained various prizes, such as multimedia CD-ROMs radiology books or free enrollment in radiology courses.

Participation

Third-year students received an introduction to Second Life and the League of Rays game, stating that participation was mandatory for first-time enrolled students in the course, but the results of the game tests would have no effect on their grades. Various measures were taken to minimize the extraneous cognitive load caused by learning to use the virtual platform (Van Nuland & Rogers, 2016). Before the game, the students were provided with several PDF tutorials to create an account in Second Life, download the viewer, access the Medical Master Island, operate the avatar's camera, and send notecards to another avatar. Additionally, these topics were explained in classroom, and the internal students of the department collaborated as consultants within Second Life helping the participants who needed it.

Evaluation of the experience and outcome measurements

During the game, participants took a weekly test to qualify for the game, providing the short-term knowledge profile of the students. After completing the game, students were asked to fill out the same perception questionnaire used in the previous voluntary edition (Lorenzo-Alvarez et al., 2020), with 23 statements about Second Life and the game to be answered using a five-point Likert scale, eight general aspects of the project to be evaluated on a ten-point scale, and a space to write "anything else" open comments. The results of the questionnaires of males and females, as well as those of the finalists and eliminated, were studied independently. The grades

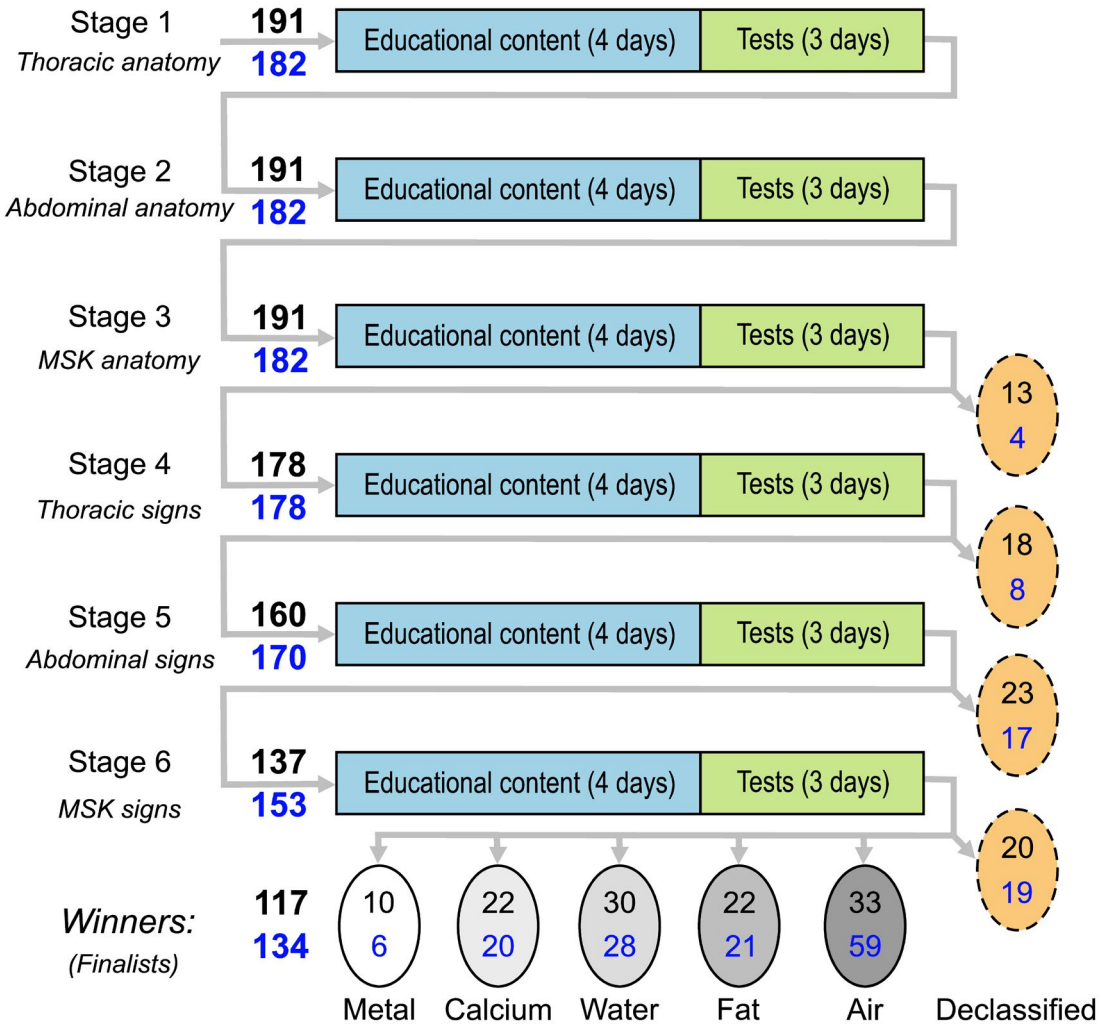

FIGURE 1 Flowchart showing the League of Rays game timeline in 2016 and 2017 editions. At each stage there were four days available to view educational content and the next three days to take assigned tests. The number of participants in each stage is shown on the left and the number of eliminated participants (declassified from the third stage) on the right. The winners were divided into five categories corresponding to radiological densities (air, fat, water, calcium, and metal). The upper numbers, in black, correspond to the 2016 participants, the lower ones, in blue, to those of 2017 edition of the game. MSK, musculoskeletal

from the final course examination, held in June, were collected to compare them with the results of the game tests.

Data analysis

The data were organized with Excel 2013 (Microsoft Corp., Redmond, WA) files and processed with the SPSS statistical package, version 24 (IBM Corp., Armonk, NY) for statistical analysis. The age of the participants, the results of the game and the grades, are continuous variables. These last two are presented as a percentage of results. The numerical results of the questionnaire are ordinal variables. Both continuous and ordinal variables are presented in terms of the mean ± standard deviation (± SD). The unpaired two-sample *t*-test was used to compare different groups of students for continuous numerical data, such as the age, game results, and grades. Pearson's correlation coefficient was used to assess the correlation between game results and course grades. The chi-squared test was used to compare differences in sex percentage between groups, since this is a categorical bi-valuated data. A Mann–Whitney *U* test was used to compare different groups of students in the five-point Likert scale and the ten-point global evaluation answers, since these are ordinal data. Statistical significance was considered with a probability of error $P < 0.05$.

The questions in the questionnaire were divided into three scales: (1) the student's experience in Second Life, (2) the student's perception of the game, and (3) overall evaluation of the project. The internal consistency on reliability of the questions was measured using Cronbach's alpha. The validity of the questions on each scale was evaluated using Kendall's Tau-b. Appropriateness of the factor analytic model was tested using Kaiser–Meyer–Olkin (KMO). To ensure that the correlation between items was sufficient, the Bartlett's test of sphericity was calculated.

The open-ended comments were analyzed by systematic collaborative "coding by committee" consensus (Saldaña, 2013). The two-layer hierarchical coding framework proposed for the previous study

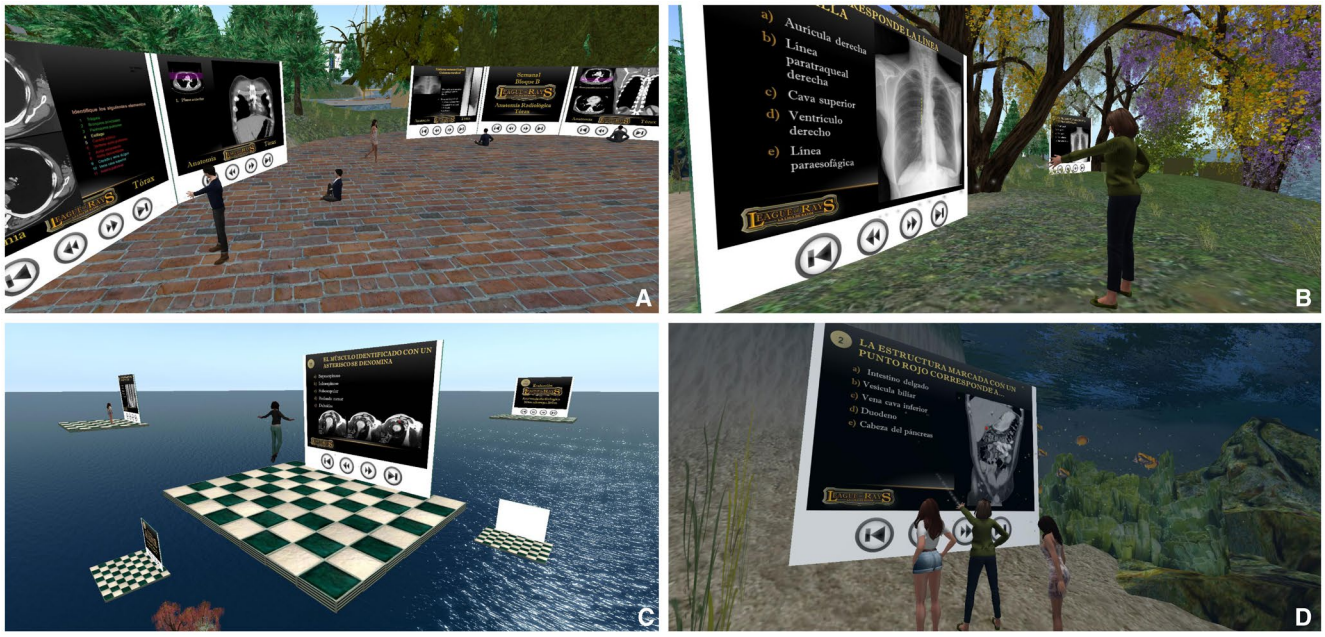

FIGURE 2 Screenshots representing several scenes of the game League of Rays in different places on the island. (A) Several students reviewing the educational content in sets of three panels on thoracic radiological anatomy in the central esplanade; (B) a student taking the test assigned to her, displayed in a panel between the trees of the island; (C) several students taking the game test on floating platforms in the air; (D) students in front of a test panel submerged under water

(Lorenzo-Alvarez et al., 2020), with four first layer codes (positive, negative, suggestion, and other) was used. The same comment could contain more than one code or subcode. After a detailed analysis during two consensus meetings, 24 subcodes were found in the second layer (Figure 3).

RESULTS

Participation, evolution, and results of the game

In the 2015 voluntary edition, 90 students participated (43 males and 47 females, 21.9 ± 2.4 year old). In 2016 and 2017, there were 191 (74 males and 117 females, 22.1 ± 2.7 year old) and 182 (61 males and 121 females, 22.3 ± 4.5 year old) participants, respectively. No age differences were found between the three cohorts. Differences in the proportion of males and females were only found between 2015 and 2017 (Table 2).

Seventy-four students (38.7%) from the 2016 group and 48 (26.3%) from the 2017 group were eliminated successively after the third stage (Figure 1). In general, the percentage of correct answers was lower in the two compulsory editions compared to the voluntary one, and in 2017 compared to 2016 (Table 3). There were no differences between males and females in any edition of the competition (see Appendix S1). The percentage of undelivered tests in 2016 was 12.3%, while in 2015 and 2017 were 5.1% and 2.7%, respectively.

TABLE 1 Scoring system to distribute the participants in different categories during the 2016 and 2017 editions of the League of Rays game

Stage	Maximum possible score	Categories						
		Metal	Calcium	Water	Fat	Air	Immaterial	Eliminated
Stage 1	15	12–15	11	9–10	7–8	4–6	0–3	–
Stage 2	30	26–30	24–25	22–23	18–21	13–17	0–12	–
Stage 3	45	40–45	38–39	35–37	30–34	23–29	1–22	0
Stage 4	60	52–60	49–51	45–48	39–44	33–38	25–32	1–24
Stage 5	75	66–75	62–65	58–61	52–57	45–51	39–44	25–38
Stage 6	90	81–90	75–80	69–74	63–68	50–62	–	40–49

Note: The participants were classified into six categories, the five radiological densities and a sixth group called "immaterial." The cells show the cumulative score range for each category. The maximum possible score in each stage are presented for reference. After the third stage, those participants who still had zero points were eliminated. After the fourth, fifth, and sixth stages, the participants with less than 41%, 52%, and 55% of the maximum accumulated points, respectively, were eliminated.

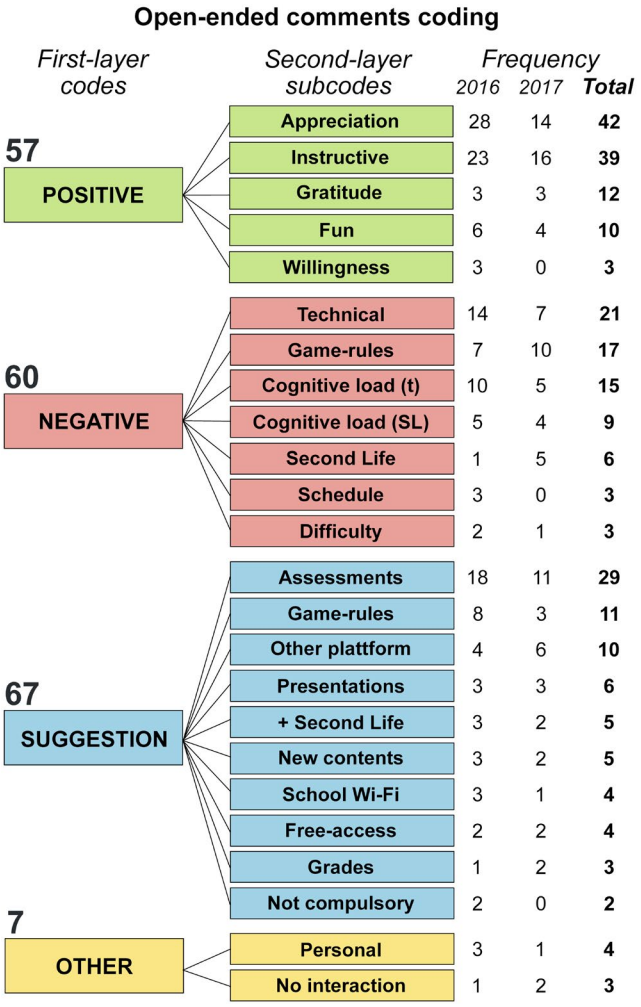

FIGURE 3 Flowchart showing two-layer hierarchical encoding and sub-coding classification of open comments provided by participants from the 2016 and 2017 editions of League of Rays. The corresponding subcode frequencies are also provided. Cognitive load (t) refers to the mental effort due to the time overload produced by the game. Cognitive load (SL) refers to the mental effort that occurs when handling Second Life

Course outcomes

One hundred and sixty-six students (86.9%) of the 2016 group and 158 (86.8%) of the 2017 group took the final examination of the course in June. The grades (mean % ±SD) were 75.7 ± 17.1 and 66.0 ± 23.5 for 2016 and 2017 groups, respectively ($P < 0.001$). No differences were found between males and females in any edition of the competition (see Appendix S1). The individual correlation of the course grades with the scores obtained in the game by the finalists showed a weak correlation, with Pearson's correlation coefficients of 0.150 and 0.303 for the 2016 and 2017 groups, respectively. In contrast, the correlation of the mean obtained by the five winner groups reached Pearson's correlation coefficients of 0.629 and 0.906, which are considered moderate and very strong correlations, respectively (Schober et al., 2018).

TABLE 2 Demographics of participants in the three editions of League of Rays compared in this study

Demographics	Game editions		
	2015	2016	2017
Participation	Voluntary	Compulsory	Compulsory
Participants	90 (100.0)	191 (100.0)	182 (100.0)
Male *N* (%)[a]	43 (47.8)	74 (38.7)	61 (33.5)
Female *N* (%)[a]	47 (52.2)	117 (61.2)	121 (66.4)
Age in years[b]			
Mean (±SD)	21.9 (±2.4)	22.1 (±2.7)	22.3 (±4.5)
Median	21	21	21
Min–Max	(21–37)	(21–43)	(20–68)

[a]The chi-squared test only showed significant differences in the percentages of male and female from 2015 and 2017 cohorts ($P = 0.004$); [b]The unpaired two-sampled *t*-test did not find significant differences in the age of the three cohorts ($P > 0.05$).

Abbreviations: Min–Max, minimum and maximum values; SD, standard deviation.

Validation of the questionnaire

The questionnaire was validated independently for 2016 and 2017 cohorts. Cronbach's alpha showed good reliability of the questionnaire for statements related to students' perception of the game (≥0.84) and global evaluation of the project (≥0.88). In contrast, the reliability for statements about the students' experience in Second Life was questionable (≥0.66) increasing to acceptable (≥0.70) by eliminating the statement number 3 ("*You knew Second Life before this experience*"). Kendall's Tau-b analysis showed a positive correlation among all pairwise statement comparisons related to the global evaluation of the game (Tau-b > 0.22, $P < 0.01$), the students' perception of the game (Tau-b > 0.15, $P < 0.05$), except for the statement 12 ("*The contents were very difficult for your current level of knowledge*"). The analysis of students' perception of Second Life revealed a positive correlation between statements 6 and 7, related to the capacity of users' computers and their Internet connection (Tau-b > 0.62, $P < 0.01$) and between statements 4 and 5, related with ease of management and handling within Second Life (Tau-b > 0.35, $P < 0.01$). The KMO factor analysis and Bartlett's test of sphericity for the statements related to the students' perception of the game (KMO = 0.847 and 0.915; $P < 0.001$) and the global evaluation of the experience (KMO = 0.875 and 0.900; $P < 0.001$) showed a meritorious to marvelous sampling adequacy. In contrast, statements related to the experience of the students in Second Life (KMO = 0.640 and 0.662; $P < 0.001$) showed a mediocre sampling adequacy (Dziuban & Shirkey, 1974).

Quantitative evaluation of the project

Seventy-seven (85%) students from the 2015 group, 114 (85.9%) from the 2016 group, and 166 (91.2%) from the 2017 group completed the evaluation questionnaire. Students reported little

TABLE 3 Comparison of academic performances between voluntary edition (2015) and two mandatory editions (2016 and 2017) of the League of Rays game

	Group 2015[a]		Group 2016[a]			Group 2017[a]			
Stage and subject	*N*[b]	Mean % (±SD)[c]	*N*[b]	Mean % (±SD)[c]	*P*-value[d]	*N*[b]	Mean % (±SD)[c]	*P*-value[d]	*P*-value[e]
Stage 1 Thoracic anatomy	83	65.9 (±15.5)	168	61.2 (±19.5)	0.054	176	60.2 (±18.9)	0.017	0.645
Stage 2 Abdominal anatomy	73	85.7 (±12.8)	172	83.2 (±16.6)	0.254	174	79.3 (±17.4)	0.005	0.033
Stage 3 MSK anatomy	67	87.5 (±11.2)	165	83.1 (±17.8)	0.065	174	82.0 (±16.4)	0.012	0.533
Stage 4 Thoracic signs	60	61.8 (±24.5)	155	61.1 (±24.2)	0.848	174	58.8 (±19.4)	0.337	0.340
Stage 5 Abdominal signs	47	78.2 (±16.5)	140	71.1 (±19.4)	0.028	169	62.6 (±23.8)	<0.001	0.001
Stage 6 MSK signs	40	67.0 (±18.7)	119	64.9 (±17.2)	0.509	151	61.6 (±19.4)	0.042	0.153
Total	370	74.7 (±19.5)	919	71.2 (±21.5)	0.006	1018	67.5 (±21.5)	<0.001	<0.001

Note: Comparison of the results of the tests carried out during the League of Rays game between the two mandatory editions and the previous voluntary edition in 2015 with data published by published by Lorenzo et al. (2020).

[a]Each stage test during the game had 15 random questions for each participant from a bank of 30 questions.; [b]*N*, number of tests provided by the participants.; [c]Score is presented in percentages with respect to a maximum of 15 correct questions.; [d]*P*-value for the change in means compared to the 2015 group determined with the unpaired *t*-test.; [e]*P*-value for the change in means compared to the 2016 group determined with the unpaired *t*-test.

Abbreviations: MSK, musculoskeletal; SD, standard deviation.

previous knowledge of Second Life (Figure 4). Students in the two mandatory groups generally showed less agreement with the questionnaire statements than those in the voluntary group, and those in the 2017 group showed less agreement than those in the 2016 group (Figures 4 and 5). The students of the two compulsory editions found the initiative less interesting than those of the voluntary edition, the island environment less attractive, the management in Second Life less easy and, remarkably, the contact with their peers less beneficial for their training. They agreed that the design of the contest was correct and the contents were adequate for their medical training, but they found the game contents less interesting, they disagreed more that playing in competitive settings helps them learn better, and especially they were less willing to participate in future Second Life experiences (Figures 4 and 5).

The rating on a ten-point scale was lower in both compulsory editions than in the voluntary edition, and even lower in 2017 (Table 4). The experience globally obtained in 2015, 2016, and 2017 was 8.2 (±1.5), 7.8 (±1.5), and 7.1 (±1.7) points, respectively ($P < 0.05$). Despite these differences, among the best scores for compulsory groups, it was worth highlighting the professor, the organization of the project, and the educational contents.

The questionnaire was sent by 38 males and 39 females in 2015, 64 males and 100 females in 2016, and 55 males and 111 females in 2017. No significant differences were found in 2015, except for a single statement about ease of management in Second Life. In 2016, females rated significantly higher only two statements of the five-point Likert scale (related to the game tests) and three items from the ten-point evaluation scale (the organization of the project, the island environment, and the professor). Notably, in 2017, females scored significantly higher than males on 13/23 five-point Likert statements, and gave significantly higher scores to all but one of the project rating items (see Appendix S2).

One hundred and fourteen finalists and 50 eliminated from the 2016 group and 126 finalists and 40 eliminated from the 2017 group completed the questionnaire. The eliminated students in 2016 gave significantly lower values in only three statements of the five-point Likert scale and only three items of the global evaluation on the the-point scale (the experience globally, the environment of the island, and the usefulness for their training). In 2017, the eliminated students gave significantly lower values in 12/23 statements on the five-point Likert scale and 6/10 items of the evaluation on the ten point scale (see Appendix S3).

Qualitative evaluation of the project

Respondents provided 100 open-ended comments, 56/164 questionnaires (36.6%) in 2016 and 44/166 questionnaires (26.5%) in 2017, which were coded and sub-coded in a two-layer hierarchical framework (see Figure 3 and Appendix S4 for detailed information). Fifty-seven comments included positive codes, distributed

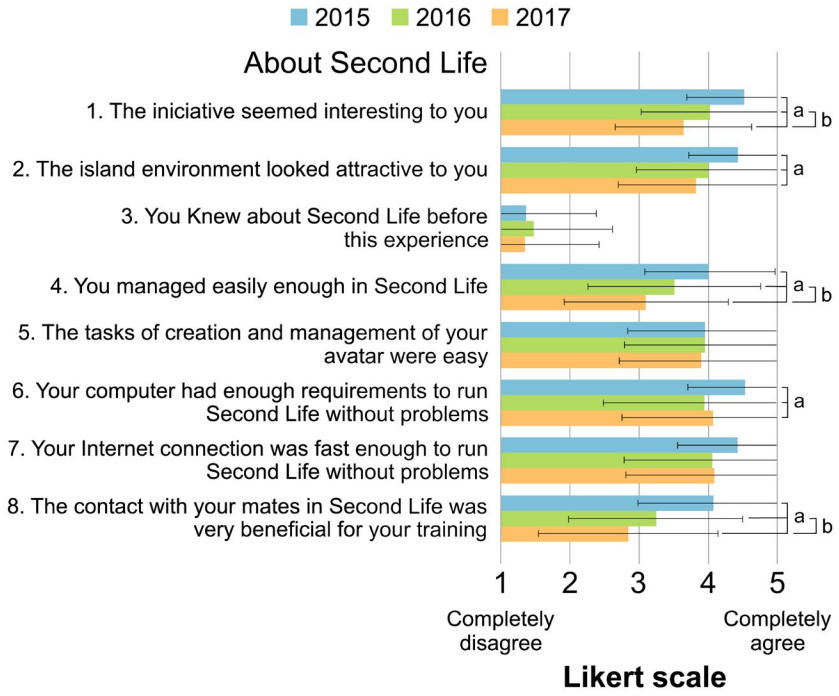

FIGURE 4 Students' perceptions of Second Life experience. The blue bars represent the 2015 group (number of respondents $n = 77$), the green bars represent the 2016 group (number of respondents $n = 164$), and the orange bars represent the 2017 group (number of respondents $n = 166$). Answers were reported on a five-point Likert scale, where 1 = completely disagree and 5 = completely agree. Bars and error bars indicators represent the mean ± standard deviation. [a]Statistically significant differences at $P < 0.05$ with respect to the 2015 group; [b]Statistically significant differences at $P < 0.05$ between 2016 and 2017 groups

in five subcodes. Forty-two (73.7%) indicated appreciation of the gaming experience, using terms such as "interesting," "attractive," "positive," "very good," or "great." Thirty-nine (59.5%) recognized the instructive value of the game, with terms such as "formative," "helpful," or "useful." Twelve expressed gratitude, acknowledging the work behind this learning activity. Ten were sub-coded as fun, indicating that the game was a fun or entertaining way to learn radiology. Finally, three comments expressed the willingness to participate in future experiences in Second Life. Positive feedback from compulsory participants in the League of Rays game indicates why they found it an engaging, efficient, and fun way to learn, for example: "*The effort to create attractive and innovative didactic content is highly appreciated, while demonstrating that there is great interest in getting students to practice their knowledge and thus learn in a different way. Thank you.*"

Sixty comments included negative codes, sub-coded into seven topics. Twenty-one (35.0%) were related to technical problems to run Second Life correctly. Seventeen (28.3%), sub-coded as game rules, disagreed with some rules of the game. Fifteen (25.0%), sub-coded as cognitive load (t), highlighted the amount of time invested in the game in conflict with the remaining academic activities. Nine, sub-coded as cognitive load (SL), indicated the handling difficulty in Second Life, moving the avatar or using the camera. Six comments expressly indicated they did not like the Second Life platform. Other negative subcodes were related to the game's schedule, warning that the final phase was very close to the final examination period, or to the difficulty of the tests.

Sixty-five comments coded as suggestion (to improve the experience), were divided into ten subcodes. Twenty-nine (44.6%) were related to the assessments, requesting that the correct answer to the tests be provided at each stage. Eleven (16.9%) provided varied proposals for the game rules. Ten comments (15.4%), sub-coded as other platform, indicated that the game should be played on a different platform. Other comments were sub-coded as presentations, suggesting avoiding interacting with a panel when someone else is using it; +Second Life, requesting additional uses of the virtual platform to receive seminars or lectures; new content, requesting to include other topics (e.g.,: central nervous system); school Wi-Fi, suggesting that the Wi-Fi connection of the medical school be improved; free-access, requesting that all game content be available on the Web; grades, proposing that the game had an impact on the course grades; and not-compulsory, stating directly that participation in League of Rays should not be mandatory. Finally, there were seven comments coded as other, including two subcodes: personal, expressing the lack of attraction to interactive online applications or radiology subject; and no-interaction, specifying the non-interaction with classmates, since it was an individual game.

DISCUSSION

In this study, the League of Rays game was played for two consecutive years, with mandatory student participation. The main findings of this study were that the results (short-term knowledge

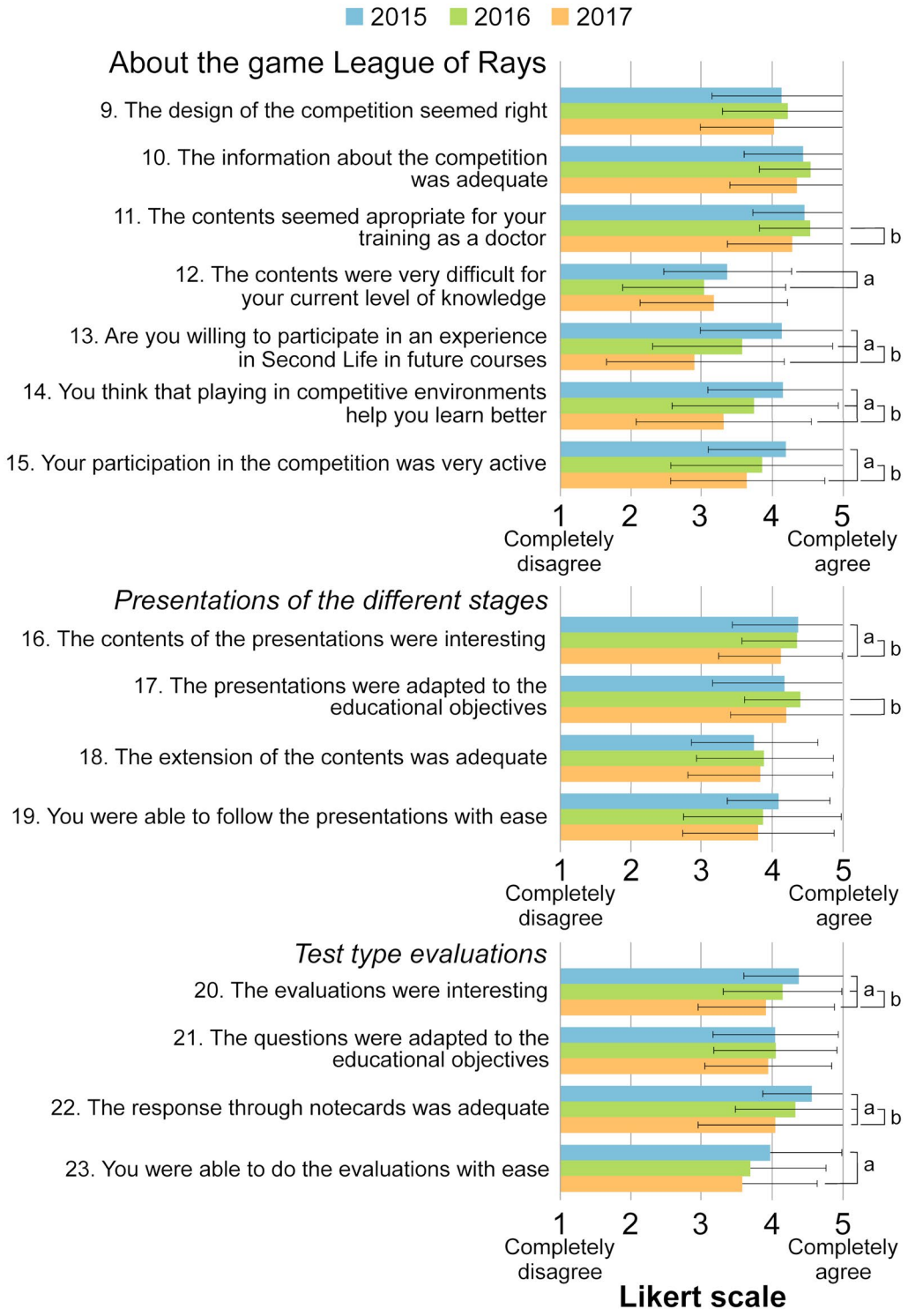

FIGURE 5 Students' perceptions of League of Rays experience. The blue bars represent the 2015 group (number of respondents $n = 77$), the green bars represent the 2016 group (number of respondents $n = 164$), and the orange bars represent the 2017 group (number of respondents $n = 166$). Answers were reported on a five-point Likert scale, where 1 = completely disagree and 5 = completely agree. Bars and error bars indicators represent the mean ± standard deviation. [a]Statistically significant differences at $P < 0.05$ with respect to the 2015 group; [b]Statistically significant differences at $P < 0.05$ between 2016 and 2017 groups

retention) and the evaluation of the game in both compulsory editions were lower than those of the previous voluntary edition; these differences were even greater in the second compulsory edition.

Compulsory game-based learning and motivation

Student motivation can be considered within a broad educational perspective, in which aspects such as social motivation, better future

TABLE 4 Comparison of experience opinion tests between voluntary edition (2015) and two mandatory editions (2016 and 2017) of the League of Rays game

	Group 2015[a]	Group 2016[b]		Group 2017[c]		
Evaluated item	Mean (±SD)	Mean (±SD)	*P*-value[d]	Mean (±SD)	*P*-value[d]	*P*-value[e]
The experience globally	8.2 (±1.5)	7.8 (±1.5)	0.031	7.1 (±1.7)	<0.001	0.001
The organization of the project	8.5 (±1.7)	8.8 (±1.3)	0.479	8.5 (±1.7)	0.697	0.173
The island environment	8.9 (±1.1)	8.2 (±1.7)	0.006	8.1 (±2.1)	0.004	0.812
The educational contents	8.6 (±1.2)	8.6 (±1.2)	0.675	8.4 (±1.4)	0.329	0.490
The profit for your education	8.6 (±1.7)	8.0 (±1.7)	0.006	7.6 (±1.9)	<0.001	0.095
The professor	9.5 (±1.1)	9.2 (±1.0)	0.022	9.1 (±1.1)	0.002	0.231
The interaction with your mates	8.1 (±2.1)	6.7 (±2.5)	<0.001	5.8 (±2.7)	<0.001	0.004
The presentations of each stage	8.4 (±1.2)	8.1 (±1.6)	0.183	7.7 (±1.8)	0.002	0.033
The evaluations	8.1 (±1.3)	8.0 (±1.4)	0.466	7.7 (±1.8)	0.067	0.192
The connectivity to Second Life	8.4 (±1.4)	7.7 (±2.2)	0.049	7.1 (±2.5)	0.001	0.067

Note: Comparison of the experience opinion tests during the League of Rays game between the two mandatory editions and the previous voluntary edition in 2015 with data published by Lorenzo et al. (2020). Data are reported as scores on a ten-point scale.

Abbreviation: SD, standard deviation.

[a]Number of participants in 2015 group that responded to questionnaire: $N = 77$ (85.5%).

[b]Number of participants in 2016 group that responded to questionnaire: $N = 163$ (85.3%).

[c]Number of participants in 2017 group that responded to questionnaire: $N = 166$ (91.2%).

[d]*P*-value for the change in means with respect to the 2015 group determined with the Mann–Whitney *U* test.

[e]*P*-value for the change in means with respect to the 2016 group determined with the Mann–Whitney *U* test.

expectations, greater participation in activities, even spirituality can lead to an improvement in academic motivation (Hattie & Anderman, 2013). But the results of this study must be evaluated from the perspective of the impact of compulsory participation in playful activities in 3D virtual environments on the extrinsic and intrinsic motivation of students. Compulsory activities are part of the extrinsic motivation of medical students, but in the case of "imposed" gamification there is a counterproductive factor, described as "mandatory fun" in work environment activities (Mollick & Rothbard, 2014). Learners may not find sufficient reward in compulsory learning games, considering the cognitive effort that virtual world driving, and new required tasks may entail.

In-game test results were lower in the compulsory editions than in the voluntary edition, even lower in the 2017 edition. Assuming that the most motivated students participated in the voluntary edition (Curado et al., 2015), compulsory participation could lead to a decrease in acceptance since more students with less intrinsic motivation would participate (Back et al., 2014), contributing a higher percentage of inattentive responses (Bahous et al., 2018). In the compulsory 2016 edition, unsubmitted tests amounted to 12.3%. As this could be a strategy so that students who did not want to participate in the game were eliminated and thus achieve their goal, in 2017 no dropouts were allowed. Unsubmitted tests decreased to 2.7%, but the results and evaluation of the experience were worse. Continuing to answer questionnaires despite having been eliminated could have reduced students' motivation and interest in the game.

Users' acceptance of the virtual world Second Life

The variables proposed in the technology acceptance model (Davis, 1989) developed for the acceptance of 3D virtual worlds (Ghanbarzadeh & Ghapanchi, 2020) are: visual attractiveness, perceived ease of use, perceived usefulness, perceived enjoyment, and computer self-efficacy. Visual attractiveness is defined as the degree to which users believe that a virtual environment is esthetically pleasing to the eye (Ghanbarzadeh & Ghapanchi, 2020). The students of both compulsory editions found the island environment attractive, with a high degree of agreement on the five-point Likert scale, but significantly lower than those of the voluntary edition (Figure 4). Perceived ease of use is defined as the degree to which users believe that using a particular system would be effortless (Davis, 1989). In both mandatory editions, participants showed less agreement with the statement "you managed easily enough in Second Life" than in the voluntary edition, being even less in the 2017 edition (Figure 4). Perceived usefulness is defined as the degree to which users believe that using a particular system would improve their job performance (Davis, 1989). The initiative seemed interesting to the participants in both compulsory editions, but to a lesser degree than to those of the voluntary edition (Figure 4). Likewise, in both compulsory editions the profit for their education was valued with high but lower scores than in the voluntary edition (Table 4). Perceived enjoyment has been defined as the extent to which the activity of using 3D virtual world technology was perceived as enjoyable for students (Ghanbarzadeh & Ghapanchi, 2020). The questionnaire

did not include direct statements about perceived enjoyment, but 10.0% of the open-ended comments of the compulsory participants made direct reference to it being a fun, entertaining, or enjoyable activity, while in the voluntary edition comments sub-coded as fun amounted to 22.2% (Lorenzo-Alvarez et al., 2020). Computer self-efficacy has been defined as the degree to which users believe they can perform difficult tasks using a computer (Compeau & Higgins, 1995). No questions were asked about the computer self-efficacy of the participants in the questionnaire, but in 9% of open-ended comments coded as "Cognitive Load (SL)" the students highlighted their handling difficulty in Second Life. Considering the results of this study, acceptance of 3D virtual world technology such as Second Life was lower when participation was mandatory.

Users' perception of the League of Rays game

The League of Rays game brings together elements of gamification that medical students identify as attractive: point systems that allow them to obtain results and achievements, leader boards to track their progress in relation to others, and module divisions to track their progress through different learning materials (Rojas et al., 2016). The competitive format and the use of leader boards relates the game with the Social Comparison Theory, a fundamental mechanism for modifying judgment and behavior through the internal drive that individuals have to obtain accurate self-assessments (van Gaalen et al., 2021). The Social Comparison Theory proposes that individuals compare their results with those of others to evaluate their abilities and seek personal improvement (van Gaalen et al., 2021). This explained student motivation and higher academic performance, since the inherent comparison with competition in gamified learning can increase motivation to excel (Van Nuland et al., 2015). The League of Rays is also based on the Learning Reinforcement Theory, related to a form of behavioral learning dependent on rewards and punishments (van Gaalen et al., 2021). According to the Learning Reinforcement Theory, a desired behavior or action followed by a reward will increase the tendency of individuals to take that action. In contrast, a sanction will decrease the tendency of people to take that action. Gamification activities based on this theory assume that rewards and punishments (e.g., receiving points and positive ratings or negative ratings and elimination, respectively), enhance the subjective learning experience and help students acquire skills in radiology (Chen et al., 2017).

The students who participated in this study agreed that the design of the competition was correct, and the information was adequate (Figure 5) and valued very positively the organization of the project and educational contents, without differences with the previous voluntary study (Table 4). But competition rules and leader boards can hamper learning when it is not liked by all students (van Gaalen et al., 2021) and even cause underestimation or rejection of the game among students, because the effect of "mandatory fun," discussed above. This justifies that in both compulsory editions the game was perceived worse than in the voluntary one, even worse when no dropouts were admitted, highlighting a lower agreement that playing in competitive environments helps to learn better, a less willingness to participate in future experiences in Second Life (Figure 5), and a worse score in the evaluation of the project. Additionally, the perception of the game was worse when comparing eliminated students with the winners (see Appendix S3). All this could imply a certain negative effect of the theories of Social Comparison and Learning Reinforcement (van Gaalen et al., 2021) when the game is imposed on students. In this sense, there were 60% negative comments, led by technical difficulties to use the 3D platform, disagreement with some rules of the game, and excessive cognitive load due to time overload when coinciding with other online academic tasks. Despite this, it should be noted that there were 57% positive comments, highlighting the appreciation of the project and the recognition of its instructive value, and 65% of comments providing interesting suggestions to improve the experience, which implies commitment to the project.

It should be noted that in the mandatory editions, females had a higher qualification of the League of Rays game, especially in the 2017 edition, with no dropouts allowed. This difference may be due in part to technology acceptance models, while males focus more on the usefulness of technology, females focus on the ease of use and enjoyment of the system and subjective norms (Codish & Ravid, 2017). Although the stereotype of the virtual game user often refers to young men, it has been found that females users appreciate the value of virtual worlds more, and they participate more actively in social life, information seeking, and constructive activities in virtual worlds than their male counterparts (Choi et al., 2012). Although it is not the central objective of this study, gender differences in the perception of virtual worlds and educational games deserve further analysis.

Limitations of the study

One of the main limitations posed by the participants in both mandatory editions were technical problems, such as insufficient computing capacity, graphics card, or data transfer speed. This type of problem to access Second Life has been reported in several previous studies, although constant technological improvement makes this problem less and less relevant (Baker et al. 2009; Gong, 2018). Although it would have been interesting to repeat a percentage of questions at some point after the game using them as a post-exposure test (Lorenzo-Alvarez et al., 2020), this medium-term knowledge test was not carried out due to logistical problems, but it has been considered for subsequent editions of the game. The time spent creating content and organizing teaching dynamics in Second Life has been mentioned as a limitation (Lorenzo-Alvarez et al., 2018, 2019a, b). In this study, the content created in a previous experience (Lorenzo-Alvarez et al., 2020) has been reused, allowing comparisons without content biases and minimizing this limitation (Antoniou et al., 2014).

Future perspectives

Subsequent editions of League of Rays, whose results are pending publication in detail, were devoted to testing a three-week game dedicated to radiological anatomy (in 2018), designing and running a

version of the game to compete for teams of four students (in 2019), and performing an inter-university team competition (in 2020 and 2021). Since March 2020, the Covid-19 pandemic modified university teaching, mainly by preventing or limiting attendance in classrooms. The effect that a mandatory game would have had on students during the pandemic is unknown, but the educational value of Second Life is well known, as it allowed for mandatory seminars on radiology, maintaining scheduled calendars, synchronous contact between teachers and students, and providing a situation of connection and continuity with academic activity, highly valued by students (Ravaei et al., 2020).

Differences among participants in the game results could be due to individual differences in their spatial abilities and stereopsis. The interpretation of cross-sectional images and radiographs in the game tests require spatial ability, imagining a 2D representation as a 3D structure, and analyzing the relationship between different spatial representations (van der Gijp et al., 2014). Spatial abilities enhance learning skills in anatomy (Langlois et al., 2020a) and radiology interpretation skills (Langlois et al., 2020b), and have been linked to the assessment of knowledge of anatomy (Langlois et al., 2017), performance in technical skills in health care (Maan et al., 2012; Langlois et al., 2015; Louridas et al., 2016) and video games (Uttal et al., 2013). Stereopsis, the visual sense of depth, plays an important role in the educational effectiveness of virtual or augmented reality, especially using 3D glasses (Luursema et al., 2008; Wainman et al., 2020; Bogomolova et al., 2020, 2021), but less important in virtual worlds like Second Life that, rendered on a computer screen, offer a binocular condition (Luursema et al., 2008). In future developments of this project, it might be interesting to explore the relationship of the game with the spatial ability and stereopsis of the participants.

CONCLUSIONS

Competitive learning games within 3D virtual worlds like Second Life have great learning potential in radiology, but the average score in the game decreased, the acceptance of virtual world technology was lower and the opinion about the game was worse when participation was compulsory, and even worse when dropout was not allowed. Under the conditions in which this study was carried out, learning games in 3D virtual environments should be voluntary to maintain adequate motivation and engagement of medical students. But it is necessary to deepen the development of strategies so that students know how to see the benefits of game-based learning for self-learning and find it attractive. Future research to improve the technical aspects of the game, motivation, cognitive load, and spatial abilities could potentially help improve the results and the perception of the game. Additionally, the Covid-19 pandemic may have changed the way medical students currently perceive mandatory online learning activities.

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ORCID

Teodoro Rudolphi-Solero https://orcid.org/0000-0001-7256-8787
Rocio Lorenzo-Alvarez https://orcid.org/0000-0002-3502-661X
Miguel J. Ruiz-Gomez https://orcid.org/0000-0003-4630-7588
Francisco Sendra-Portero https://orcid.org/0000-0001-9535-9806

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AUTHOR BIOGRAPHIES

Teodoro Rudolphi-Solero, M.D., is a resident in nuclear medicine in the Department of Nuclear Medicine at Hospital Universitario Virgen de las Nieves in Granada, Spain. He was a medical student in the Department of Radiology and Physical Medicine at the University of Málaga in Málaga, Spain during the implementation of this study, and he contributed to educational innovation projects, including learning radiology in Second Life. His final degree project and a subsequent final master's project encompass a large part of the contents of this study.

Rocio Lorenzo-Alvarez, M.D., Ph.D., is an adjunct physician in the Department of Emergency and Intensive Care at Hospital de la Serranía de Ronda, in Ronda, Spain, and an associate professor in the School of Nursing in Ronda at the University of Málaga, Spain. She was a medical student at the University of Málaga in Málaga, Spain. She contributed to educational innovation projects, including learning radiology in Second Life and her doctoral thesis, based on her work in the Department of Radiology and Physical Medicine, encompassed previous research on learning of radiology in the Second Life environment.

Miguel J. Ruiz-Gomez, Ph.D., is an associate professor of radiology and biomechanics in the Department of Radiology and Physical Medicine, Universidad de Málaga, Málaga, Spain. He teaches radiology and biomechanics to students of preclinical medicine. His research interests include the study of the biological effects of radiation and the implementation of innovative teaching and evaluation methodologies in medical education.

Francisco Sendra-Portero, M.D., Ph.D., is an associate professor of radiology and Director of the Department of Radiology and Physical Medicine at the Faculty of Medicine, University of Málaga, Málaga, Spain. He teaches radiology to preclinical and clinical medicine students. Since 2011, he coordinates several successive educational innovation projects on the learning of radiology in the virtual environment Second Life, and his research interests include breast imaging, image processing, and innovation in medical education.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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