Multimodal Technologies and Interaction

Article

Kids save lives by learning through serious game

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Abstract: This study focuses on the development and assessment of a serious game for health (SGH) aimed at educating children about cardiopulmonary resuscitation (CPR). A video game was created using the Berkeley Snap platform, employing block programming. Eye-tracking technology was utilized to validate the graphic design. To assess the tool's effectiveness, a pre-post analytical study was conducted with primary education children to measure their acquired knowledge.

The study involved 52 participants (59.6% girls, 40.4% boys) with a mean age of 9.38 years. The results from a custom questionnaire measuring theoretical knowledge about CPR showed significant improvements: I1 [pre 46%, post 91%, $p < 0.0001$], I2 [pre 32%, post 95%, $p < 0.0001$], I3 [pre 31%, post 77%, $p < 0.0001$], I5 [pre 48%, post 93%, $p < 0.0001$], I6 [pre 56%, post 98%, $p < 0.0001$], I7 [pre 21%, post 89%, $p < 0.0001$], I8 [pre 4%, post 4%, p=1,000]. Emotional responses improved as well: I9 [pre 21%, post 52%, $p = 0.004$] and I10 [pre 35%, post 81%, $p < 0.0001$]. [$\overline{x} = 108.54$ s, σ=26.527] and post [$\overline{x} = 56.65$ s, σ=15.285]. The video game received an average score of 5.25 out of 6. The eye-tracking analysis focused on a selected area, with 361.5 impacts out of 500 possible.

In conclusion, the utilization of SGH proves to be an effective method for educating children about CPR, providing them with fundamental knowledge relevant to their age group.

Keywords: training, cardiopulmonary resuscitation, serious game, eye tracking, children, videogames.

1. Introduction

The European Resuscitation Council [ERC] has underlined the need for cardiopulmonary resuscitation [CPR] learning programs directed towards non-health professionals **(1)**. Scientific dissemination societies have promoted and regulated CPR training in the non-health professional population, with great results due to the achievement of objectives, as well as the acquisition of skills and knowledge of students **(2)**. As this is non-health-professional collective, it is necessary for them to re-learn the knowledge acquired after a certain period of time to avoid forgetting, which can lead to inconvenient expenses due to the cost incurred**(1)** .

In the past few years in Spain, many initiatives have been implemented to train non-health professionals about CPR. These training events are performed and supervised by qualified health personnel, and their objective is to prevent situations of risk of the population**(3)**. Some of these activities are one-time and isolated, and others are better structured and part of education and health policies. This is the case of the "Programa Alertante" **(4)** of the SAMUR in Madrid, or the PROCES **(5)** program in Barcelona. In both cases, the number of sessions and contents taught are adapted to the needs of the soliciting center/institution. Likewise, the Spanish Society of Emergency Medicine

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[SEMES] also provides CPR training to teachers and students through programs deployed in autonomous communities. Recently, they have beat a record in Vigo [Galicia], by training an entire school, with a student body of almost 2000 students, in order to demand the need to teach the population at schools **(6)**.

The World Health Organization [WHO] supported the "Kids Save Lives" [KSL] declaration, pointing out that the most natural manner to teach CPR to the population was to integrate it into the mandatory teaching at schools. It has been demonstrated that it is simple, effective, and cheap way to teach the technique, with two hours a year deemed enough for the training starting at the age of 12 **(7)**. Afterwards, in the last update of the ERC, it was indicated that children should be taught at earlier ages, starting once they start attending school, by providing at least 1 hour a year during the entire schooling stage **(8)**. Recently, a review of the KSL declaration was published**(9)**, which indicated that the barriers against performing basic life support [BSL] identified by the children were similar to those observed in adults, and included fear of making mistakes and other determinant factors [i.e. sight of blood or vomit].

Presently, we find ourselves with a generation of digital natives who were born with the use of technology implemented in all tasks of daily life, even in the school curricula of many education centers **(10)**. Serious games for health [SGH] are games that have an educational, training, or informational aim, and have been carefully thought out for this **(11)**. These are considered game-like systems that are designed to achieve specific objectives, and can be found in the shape of board games, video games, escape rooms, etc. **(12)**. In the last few years, given the multiple benefits they provide for learning **(13)**, they have started to be utilized with other social aims, such as fighting against bullying **(14)**, or social responsibility **(15)**, and have been successfully implemented in some centers as a pedagogical tool. As the main axis of KSL, we find that motivation for learning CPR must be increased, through the use of SGH, underlining their importance as a powerful education resource equivalent to others, such as "face-to-face" training **(9)**.

These SGH intend to improve motivation, adherence, and/or adhesion of students in the learning experience **(16)**. The aim of this study was to design and analyze an SGH whose aim was to teach children aged between 9 and 10 years old about CPR. The secondary objectives were to analyze the fear and security perceived by the school children.

2. Materials and Methods

A comparative analytical study was conducted, with a pre-and post-intervention assessment, consisting of the acquisition of CPR competencies through a SGH developed as a videogame as a teaching resource.

Study population Students were voluntarily recruited from both classes that were part of the 4th year of Primary Education at the San Vicente Paul del Palmar school (Murcia, Spain), for a total of 52 children. The study was approved by the Ethics Committee from the Universidad Católica of Murcia (UCAM), registration number [7.986], and the parents/tutors provided their consent for the participation of the underage children.

Design and development of the videogame For the intervention, a videogame was developed with open-source platform Snap®, with an expanded implementation of Scratch®, developed in Berkeley, and based on block-based coding language, which is ideal for the creation of interactive applications and games**(17)**. To guide the player during the experience, two main characters were designed, a female student and a stuffed bear, with the aim of creating a conducive and familiar environment for the child. Throughout all the phases of each scenario, these characters are accompanied by other secondary characters

and objects with which they will be able to interact (Supplementary Material 1). Given the type of content and design, the recommended ages for the videogame were between 6 to 11 years old. Although it included a listening aid (voice over), it is necessary for the child to be able to read and write. It can be played in different platforms: PC, table, and mobile phone. The structure of the videogame consists of four levels and a final test. The contents and competences were supervised by health professionals with experience in CPR training, and education professionals who taught in the school stage to which the children who took part of the study belonged. The technical development was provided by a telecommunications engineer, given the complexity of developing a scoring system and data storage.

Assessment of the CPR competencies: As there is no validated questionnaire to assess CPR knowledge and competencies at these ages, an ad hoc questionnaire was created (Supplementary Material 2). The student had to provide answers to different issues, and given the decision, the videogame provided feedback to the player as a type of re-enforcement, to ensure that the concepts were correctly assimilated. In case of wrong answers, the participants were invited to rectify them, until arriving at the correct answer. Thus, aside from the assessment obtained, what is important is also that the student complete the 4 phases and receive CPR training.

Eye Tracking System: For the pedagogic and visual validation of SGH, functional tests (white testing) were conducted with a sample of 10 volunteer children (Figure 1). The aim of this test was to verify that in each phase and scenario, their attention was focused on the adequate characters and areas of the screen. For this, an eye-tracking system was utilized; more specifically, goggles from Tobii®. The data extracted from the goggles were analyzed with precision with software developed in Matlab® by UCAM researchers **(18)**. The tool allows for selecting regions of the image and to specifically find the fixation of the gaze within them, named impacts (Figure 1B).

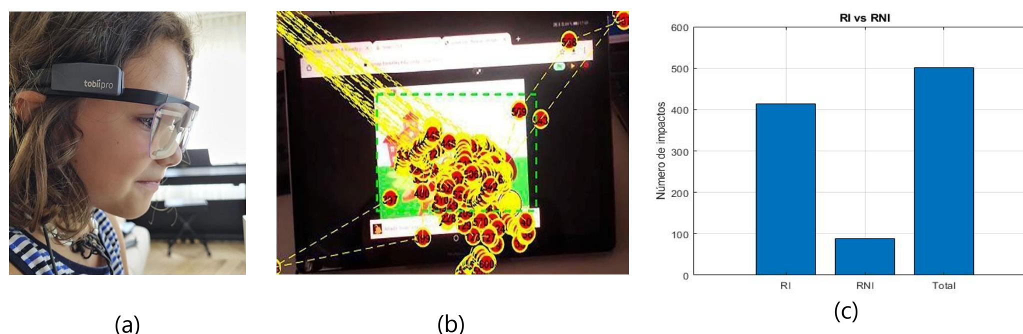


Figure 1. (a) child with eye tracking goggles during the experiment. (b) number of impacts during the viewing of the screen. (c)plot of the impact path sequence level 3.

Intervention (experiment): The experiment consisted of two work sessions with the volunteers. In the first session, two activities were performed, which consisted of:

- A preliminary assessment (Pre) on the knowledge about the action protocol for performing CPR. For this, a scene was recreated in the classroom, composed of a CPR manikin in the supine position and a telephone close to the victim (manikin). The recreated scenario consists in that the child is at the home of a family member, and the family member is unconscious on the floor. From this point on, the child is asked to act. The assessment is conducted through an analysis of the behavior and the reaction of the child, through a rubric shown in Table 1.

Table 1. Crosstab of pre-post items.

Question		Number of correct answer		Statistical significance
		Pre-test	**Post-test**	
I1. Talk or call the victim loudly		1	23	< 0.0001
I2. Move the shoulders of the victim vigorously		0	32	< 0.0001
I3. Verifies that the victim is not breathing		2	24	< 0,.001
I4. Asks for the phone		45	52	>1.000
I5. does he or she know the number to call?		0	23	< 0.0001
I6. Start CPR maneuvers		0	22	< 0.0001
I7. Places the arms and hands correctly		0	35	< 0.0001
I8. Asks for an AED		0	2	=1.000
I9. How did you feel during the situation?	Nervous	22	16	=0.004
	Calm	3	11	
I10. How did you feel during the situation?	Insecure	9	1	< 0.0001
	Secure	17	25	

I: items.

- The educational intervention took place after the preliminary assessment. Each child was invited to play the game, going through each of the 4 levels of its structure with assistance. The platform utilized was a computer with a mouse. A supervisor, in the role of assistant, ensured that each phase was satisfactorily completed, until arriving at the end of the game.
- A posterior assessment (Post); a session that took place a month after the first session, and consisting in repeating the assessment on the protocol and CPR (Post), and using the same scenario and the same rubric for its assessment.

Statistical analysis The variables analyzed were composed as 10 first-aid questions for the lay participants. Questions from one to eight assessed theoretical and physical skills, while questions nine and ten referred to the feelings the children described as having during that situation and after receiving the training. Another variable measured was the amount of time needed by the student to resolve the emergency situation recreated. Once all the study variables were collected, the data were analyzed with the statistical analysis tool SPSS, through the use of chi-square and McNemar tests, and descriptive statistics (mean, variance, standard deviation, etc.).

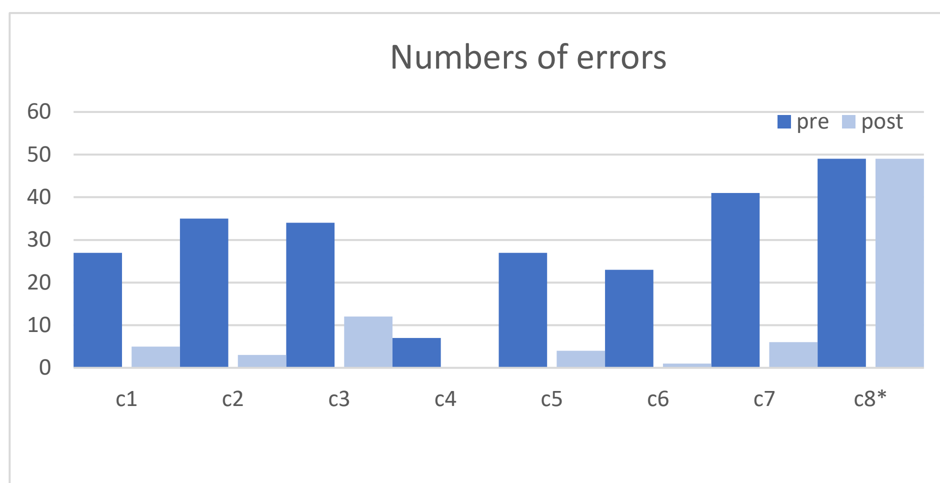
3. Results

This section provides a comprehensive overview of the study's results, including participant characteristics, changes in CPR knowledge, emotional responses, completion times, performance in the videogame exam, and eye-tracking analysis outcomes. These findings will be further discussed and interpreted in the following sections.

3.1. Participant Characteristics:

The final sample was composed of 52 participants, of which 59.6% were girls (31/52), and 40.4% boys (21/52). The mean age of the participants was 9.38. The results obtained in questions 1 through 8, which measured the theoretical knowledge on CPR, are shown in Figure 2.

Figure 2. Results of the number of mistakes before and after the intervention..



c: competence; * this item, referring to the defibrillator (AED) is not an indispensable competency for this age range *(1)*.

3.2. Knowledge on CPR (Questions 1-8):

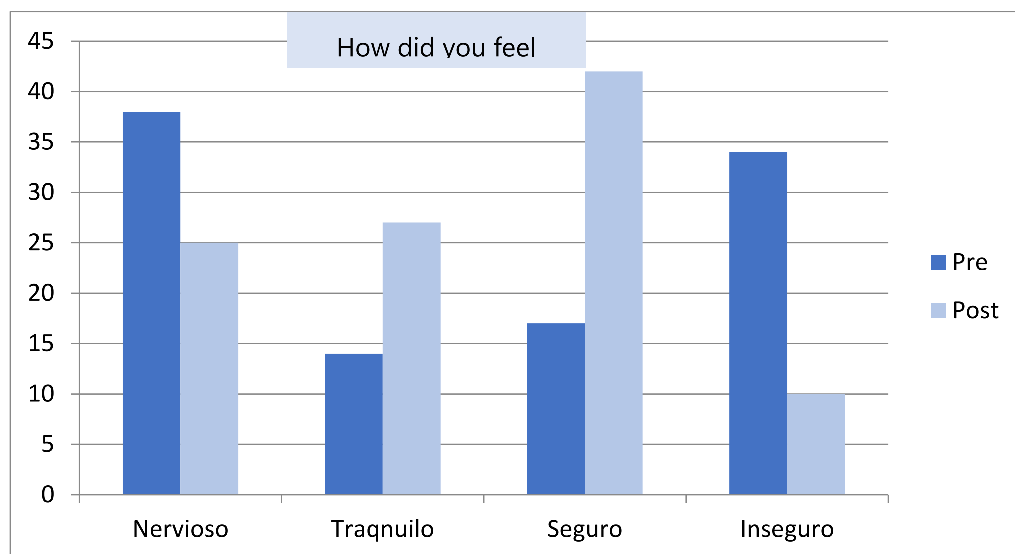
Before the intervention, item I1 obtained 46% (24/52) of right answers in the pre-test as compared to 91% (47/52) of the post-test, with statistically-significant differences ($p<0.0001$). Item I2 obtained 32% (17/52) in the pre-test and 95% (49/52) in the post-test. For item I3, the correct answers were obtained by 31% (16/52) of the students, as compared to 77% (40/52) in the post-test. Both of these results were statistically significant ($p<0.0001$). Item I4 did not obtain statistically significant differences; in the pre-test, the percentage of correct answers was 91% (47/52), and in the post-test, it was 100% (52/52). Item I5 obtained a percentage of right answer before the intervention of 48% (25/52), while after the intervention, this ascended to 93% (48/52). Item I6 obtained a value of 56% before the intervention (29/52), as compared to 98% after it (51/52). In item I7, 21% (11/52)

of the students answered correctly before the intervention, and 89% (46/52) did so in the post-test. In these last three items, the statistical difference was significant ($p<0.0001$). With respect to item I8, for both pre and post-test, the percentage was 4%, with $p=1.000$. This item, which referred to knowledge about the automated external defibrillator (AED), could be ignored, as it is not part of the basic learning results for the age of the participants.

3.3. Emotional Responses (Questions 9-10):

Results for item I9, measuring the calmness of the child, showed an increase from 21% (11/52) in the pre-test to 52% (27/52) in the post-test, $p=0.004$.Item I10, assessing how secure the child felt, displayed an increase from 35% (18/52) in the pre-test to 81% (42/52) in the post-test, $p<0.0001$.(Figure 3)

Figure 3. Results of the emotions expressed by the participants.



3.4.Completion Time:

The completion time before the intervention obtained a mean of 108.54 seconds and a standard deviation of 26.527. In the post test, the mean time utilized for the resolution of the same situation was 56.65, with a standard deviation of 15.285. The resolution times before and after the intervention were statistically significant with $p<0.0001$ (Figure 4).

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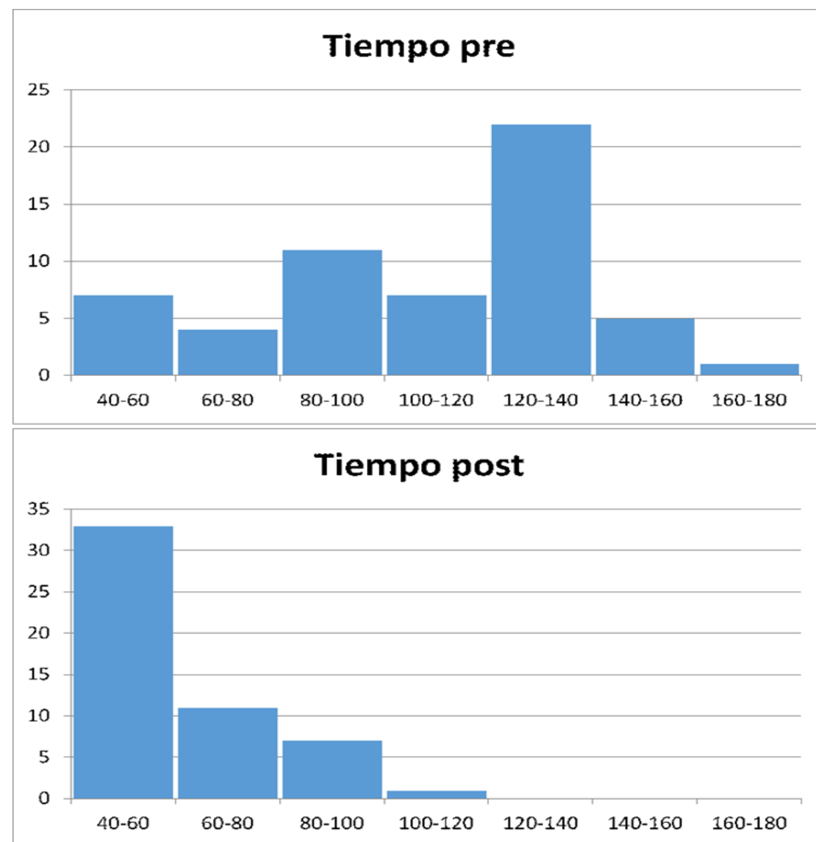
Figura 4. Resolution times of the emergency situation. 199



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3.5. Videogame Exam: 202

With respect to the exam in the last screen of the videogame, which was not part of the pre-post questionnaire of the intervention, the mean score obtained was 5.25 out of 6. The figure shows the exam score as compared to the time needed to finish the game (Table 2). 203 204 205

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Table 2. Scores obtained on the test as compared to the mean total play time. A greater percentage of students obtained a higher score on the test and less time was used in each turn 207 208

Test score	Mean game playing time (s)	% students
2 (minimum)	417.5	3.8
4	375.24	32.7
6 (maximum)	350.5	63.5

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3.6. Eye-Tracking Analysis: 210

In the eye-tracking analysis, 500 frames of the 10 participating subjects were analyzed to assess the quality of the resources, by counting an impact per frame, and an area of interest was established, with a resulting mean of 361.5 impacts within the area of interest (Figure 1c). 211 212 213 214

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4. Discussion 216

In the results obtained, it was observed that the simulation environment of this game favored controlled learning, in which users can manipulate their own learning curve, being able to improve each time the game is played (better score and shorter time as the game is played more often). In the study by Eugenio Marchiori et al. **(19)**, the authors already addressed the inclusion of educational games at schools as a new tool for CPR training of adolescents. Our post-intervention results support the usefulness of incorporating technological tools with an educational purpose, such as serious games, as a support for traditional methodologies. Also, our studies broaden the age range to children younger than 12 years old. In the article by Cristina Cerezo Espinosa et al. **(20)**, conducted with adolescents, and which used audiovisual materials as a tool for training on basic life support, the authors concluded that there were no differences between traditional teaching, in which an instructor teaches a course, and non-face-to-face learning, in which the students do not use a teacher, just as in our study. However, in our case, as the subjects were younger than 12 years old, we saw the need to use a supervisor, just as with any other activity in which technology is utilized with children **(21)**. 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231

The analysis of the results showed that 80% of the items assessed obtained a very high significance value ($p<0.0001$). Other studies, in which technologies were utilized (i.e. virtual reality) for learning CPR, also obtained significant results, which re-enforce their use**(21,22)**. 232 233 234 235

With respect to item 5, which referred to the emergency telephone number, it is important to point out that 50% of the students utilized 911 and not the Spanish 112. This was not learned at school or from health professionals. This could be due to the consumption of series and movies, most of which are American, through diverse platforms (i.e. Netflix, HBO, YouTube, etc.). After the interventions, the percentage of participants who interiorized the correct number increased to 85%. And for item 6, which alluded to the knowledge on the use of an AED, it can be considered irrelevant, as it is not considered to be a learning objective for these ages, according to the ERC**(1)** . 236 237 238 239 240 241 242 243

The children responded to the situation presented with greater security, more than twice, which had an effect on the time it took them to resolve the situation (Figure 4). This time decreased by 48% in the students who felt more secure. Despite the level of calmness not being as important, it did not incapacitate the users in the acquisition of competences. 244 245 246 247 248

Another interesting result was that the participants who took less time to finish the videogame obtained a greater score on the test. This could be due to a greater understanding of the material. The mean test score was high (5.25/6), and 63.5% obtained the highest score. 249 250 251 252

One of the strengths of the use of this technology is that it favors the learning of basic yet indispensable aspects of emergencies. We can mainly highlight that the child learned how to become aware and manage the situation, by identifying the scenario, learning to call 112, and even a learning about chest compressions (rhythm, hand and body positioning, area of compression, etc.). Thanks to the use of eye tracking technology, the graphic design of each scenario of the videogame was validated, to optimize the degree of attention and interaction of the subjects.

The availability of this type of tool at schools allows us to not only provide training during school hours, but it can also adapt to the needs of any student, and can even be used in flipped classroom methodologies**(22)** or as a re-enforcement to avoid a sharp forgetting curve.

In addition, as it is software product other conditions arise. This resource is useful, as it is easy to update (due to changes in regulations, different regulations between countries, etc.), it is very accessible (multi-platform), it is always available (always online), and the development and maintenance costs dissipate as the number of users grows **(23–25)**. Despite the benefits described, with respect to practical knowledge, a CPR manikin could serve as support, for becoming aware about the force needed for the compressions, the real speed they must use, etc.

5. Limitations, Future Work and Conclusions

The main conclusion of our work is that the design of this SGH is deemed an efficient method for CPR training of children, to satisfactorily initiate students on basic knowledge that experts recommend for their age. It is also concluded that the eye tracking technology is effective for assessing the areas of the screen where the children pay the most attention, which allows us to adapt the design of each screen to obtain the most efficiency. It would be recommendable that this theoretical training concludes with practical sessions taught by health professionals.

Future lines of work must focus on adapting the material according to age and condition, to be able to integrate children with special needs, and to also design experiences in which the child teaches individuals in a family setting, promote hybrid methodologies that combine traditional learning with ICT, and even compare the efficiency between different technologies.

Supplementary Materials:

Supplementary Material 1. Table with the questionnaire used in the assessment.

	PRE-POST Questionnaire
I1	Talk or call the victim loudly (the call is very loud or yelling to the victim).
I2	Move the shoulders of the victim vigorously (i.e. shakes the victim with all his or her strength, until becoming tired and having to stop).
I3	Verifies that the victim is not breathing.

I4	Asks for the phone to make a phone call.
I5	If asking for a telephone does he or she know the number to call (emergencies)?
I6	Start CPR maneuvers
I7	If CPR is initiated: places the arms in the correct position and the hands at the center of the chest.
I8	Asks for an AED
I9	How did you feel during the situation? Nervous Calm
I10	How did you feel during the situation? Secure Insecure

Supplementary Material 2. Frames of the videogame screen, levels 3 and 4.

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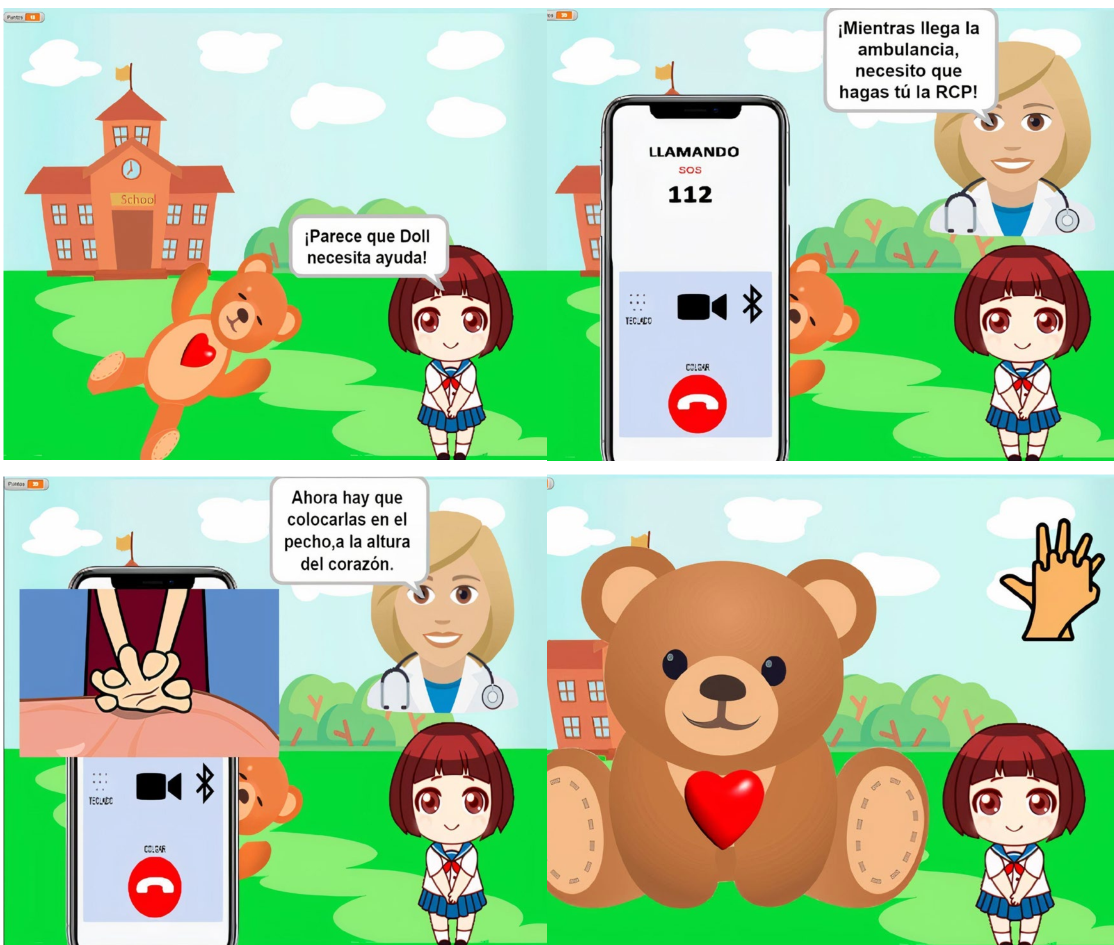

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Institutional Review Board Statement: The study was approved by the Ethics Committee from the Universidad Catholic of Murcia (UCAM), registration number [7.986]. 299 300

Informed Consent Statement: and the parents/tutors provided their consent for the participation of the underage children 301 302

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Data Availability Statement: The data presented in this study is available on request from corresponding author. The data is not publicly available due to privacy regulations 304 305

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Conflicts of Interest: The authors declare no conflict of interest. 307

Appendix A 308

Table 3. Summary table of the videogame levels, objectives, and score. 309

Level	Scenario	Objectives	Learning results	Score
1	Forest with interactive characters	Familiarize the player with the device and the characters	Knowledge of the environment	+10 If the character is found
2	Pantry with healthy and non-healthy foods	Feed the bear	Become responsible. Distinguish healthy food	+2 Healthy foods +1 Less healthy foods Maximum of 4 foods
3	Phase 1: Video Phase 2: Game	Learn about first aid	Instructions on the technique *with the following order*: 1. VERIFY 2. CALL 3. COMPRESS	Total of 25 points: 8 questions Correct answer add +2 and +5 Incorrect substract -1
4	The bear suffers a cardiac arrest	Know the CPR technique	Correctly execute the position and rhythm of compressions	Total of 36 points Correct placement +1

	Call from a mobile phone without the need to unlock it	

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