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Comparative study of a simulated incident with multiple victims and immersive virtual reality

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A R T I C L E I N F O

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A B S T R A C T

Objectives: The main objective of the study is to determine the efficiency in the execution of the START (Simple Triage and Rapid Treatment) triage, comparing Virtual Reality (VR) to Clinical Simulation (CS) in a Mass Casualty Incident (MCI). The secondary objective is to determine the stress produced in the health professionals in the two situations described.

Materials: A comparative study on the efficiency and the stress during triage in a MSI was conducted. The basal and post levels of salivary α-amylase (sAA) activity were measured in all the participants before and after the simulation.

Results: The percentage of victims that were triaged correctly was 87.65% (SD = 8.3); 88.3% (SD = 9.65) for the Clinical Simulation with Actors (CSA) group and 87.2% (SD = 7.2) for the Virtual Reality Simulation (VRG) group, without any significant differences (p = 0.612) between both groups. The basal sAA was 103.26 (SD = 79.13) U/L with a significant increase ($p < 0.001$) with respect to the post-simulation levels (182.22, SD = 148.65 U/L). The increase of sAA was 80.70 (SD = 109.67) U/mL, being greater for the CSA group than the VRG group.

Conclusion: The results show that virtual reality method is as efficient as clinical simulation for training on the execution of basic triage (START model). Also, based on the sAA results, we can attest that clinical simulation creates a more stressful training experience for the student, so that is should not be substituted by the use of virtual reality, although the latter could be used as a complementary activity.

1. Introduction

Multiple Casualty Incidents (MCI) are characterized for being situations that surpass the capacity of the medical system or the local health care system, to satisfy the medical needs of the victims. These MCI usually involve various patients who are treated with everyday resources (without a great emergency response) and can lead to the temporary collapse of the local Emergency Medical Response (EMR) and the emergency medical attention resources (Park et al., 2016).

Despite the MCI not always being the same, the need for assistance overwhelms the professional resources available, leading to an increase of the levels of stress of the workers.

The preparedness of the Emergency Services (ES) personnel for disasters is difficult due to their variability, either due to the type of incident, number and seriousness of the victims or the number and the types of resources available, the different models of classification, etc. (Nieto et al., 2017). Triage consists on the evaluation of the probability of survival of each victim, and each one is classified as a function of the extent of the injury and medical situation in order to prioritize and provide the appropriate medical attention afterwards. The knowledge of the adequate triage protocols is an important skill for the health personnel that provide attention to MCI patients (Andreatta et al.,

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2010). Medical research point to the fact that although there is no training that can completely prepare the ES for performing triage in a real MCI, familiarity with the process helps to increase the efficiency in the performing of the triage tasks that can determine the survival of the critically-injured (Galante et al., 2006).

Learning and research in situations of disaster is very difficult; Cuartas et al. (2014), only found results on the application of START (Simple Triage and Rapid Treatment) in very few MCI and/or catastrophes. Clinical Simulations (CS) will never be able to replace real events, but they can provide an environment in which the students can understand and successfully master clinical abilities without risk for the students, health personnel or the patients. Also, they allow the tasks to be structured within the segments of learning through stages, and provide controlled and safe environments for learning from mistakes (Maran and Glavin, 2003).

The modern era of simulation in medicine has its roots towards the end of the 20th century, after the development of Resusci Annie, a mannequin created by Sigmund Laerdal, a Norwegian toymaker (Tjomsland and Baskett, 2002). CS have evolved exponentially from the first high-fidelity mannequin designed by Denson Abrahamson, Sim One (Hall et al., 2005). At present, the high-fidelity simulators allow for the interaction with the mannequin and the possibility of working on different technical and non-technical skills. One of the options in the simulation is the performing of *Role-Playing* with the participation of actors (Nieto et al., 2017). Although the simulation limits the conducting of invasive techniques, it provides advantages for the interaction, expression of emotions and simulation of workloads and realistic joint movements.

The development of Immersive Technologies (IT), among which we note Virtual Reality (VR), Augmented Reality (AR) and 360° Video, implies a new dimension for simulation. The IT provide numerous advantages as compared to other didactic resources in the health sciences such as degree of interaction and reproducibility, allowing for training anywhere and anytime. From the start, is it unknown whether or not the effects of stress, which are found in activities of simulation through the introduction of real actors or high-fidelity simulators, and which affect learning, also appear in VR training. However, it is a fact that technology allows for the modulation of the sense of presence in virtual environments. The main mechanisms for defining it are the regulation of the entrance of stimuli from the real environment, and the definition of the degree of interaction with the virtual environment. In any case, the speed of response of the system will always be important for attaining the greatest sensation of reality (Gutiérrez Maldonado, 2002). Simulation can be the bridge that spans the divide between the theory and simulations with actors, with the advantage that one can train multiple times without causing damage to patients (Foronda et al., 2016).

With pedagogic evolution, the intent is to foment the critical thinking skills of the students through interaction in real time and the constant re-evaluation with the objective of learning from mistakes (De Miguel, 2005). Thus, learning has an influence on the activation and retention of knowledge, and so that long-term memory is favored, emotion-based learning has to be conducted in which positive emotions under stress facilitate the greater retention of data (https://bioinformaticamedicablog.wordpress.com/2017/11/07/simuladores-de-realidad-virtual/, n.d.).

The success of the simulation depends on the existence of a high physical fidelity, in which the manual abilities are developed, as well as a high conceptual fidelity, in which the clinical reasoning and the problem-solving skills are developed, and lastly a high emotional or experiential fidelity, which favors the retention of information through the management of complex processes that involve knowledge or emotions (Rocco and Silva, 2012). Due to all of this, VR is defined as the most-complete tool for the training in a holistic training of health interventions. On the other hand, Brady (2013) concluded that the research on the effectiveness of the different degrees of fidelity in simulation were scarce, so that the addition of these resources should be backed by data on its usefulness.

In aviation, virtual reality training has been standardized and virtual reality simulators have demonstrated their benefits, objectives, needs and means of virtual reality simulation are still a matter of investigation. The effect of training virtual reality simulators on the acquisition of basic surgical skills does not seem to be different from the effect of physical simulators (Yiannakopoulou et al., 2015). Some authors advocate designing educational centers based on VR training, professional skills units, CS rooms and the development of virtual reality learning programs (Lee et al., 2010; Kilmon et al., 2010). The VR can provide objective metrics for the performance of the task and provide explanations of the tasks performed. Current disasters involving multiple casualties occur rarely, offering little opportunity for gaining experience and competence assessment. For these reasons, new trends in disaster training are focusing on the use of VR in order to mitigate the mortality and morbidity associated with disasters (Kizakevich et al., 2007; Farra et al., 2015).

The main objective of this study was to determine the efficiency in the performing of the START triage, comparing virtual reality with clinical simulation in a MCI. It is important that the CS is as close as possible to reality. The design of the room, the use of actors and the design of the simulation scenario aim to make the student experience as realistic as possible. For all this, we set out to explore, as a secondary objective, to compare the stress caused by the two different situations described.

2. Materials and Methods

A comparative study was conducted on the efficacy and the stress during the performing of triage in a MCI between a group that performed a CSA, and another who performed a Virtual Reality Simulation (VRS) with a VR device, (Fig. 1). The same simulation cases carried out by the CSA group were reproduced one year later for the VRS group. This research project was approved by the Ethics Committee from the Catholic University of Murcia (UCAM) and the Emergencies Services 061 of Murcia. All the participants (actors and health professionals) participated voluntarily and signed an informed consent form.

In 2016, a simulation exercise with 20 characterized victims (2 green, 5 yellow, 8 red and 5 black) was conducted. The objective of the professionals was to perform basic triage in all the victims, using the START (*Simple Triage and Rapid Treatment*) system, including the performing of the life-saving maneuvers: Opening of an Airway (OA) and Hemorrhage Compression (HC).

The scenarios required OA in 15% of the cases (3/20), and the HC maneuver in 10% of the cases (2/20). The design of the scenarios and the evaluation of the correct triage and techniques were conducted by four health professionals (the authors A.N.F, L.J.R., N.P.A and M.F.P.).

For the recording of the exercise, and due to the script containing high-movement scenes, the video capture process was supported with gimbal-type image stabilizers. These devices consisted of a motorized platform with three axes controlled with algorithms that received information from various sensors (accelerometers, magnetic compass, etc.) attached to their structure, whose objective was to isolate the camera from abrupt movements or unwanted turns. Thus, the correct tracking of the action scenes was guaranteed, eliminating bothersome effects for the final spectator such as vibration and unfocused scenes. To increase the fidelity of the recording, and to avoid image distortions in the image, a wide-angle lens (fish-eye) was chosen, due to the extension of the Field of View taken up by the action. In order to obtain a good image quality, the original recording was done with a Sony A6300® camera, with 4K resolution (3840 × 2160 pixels). From this, and with remapping, two spherical 8K videos were obtained. Lastly, these remapped sources were processed to obtain the final equirectangular .mp4 format in 4K, which was needed for its playback with standard 360° video systems.

Fig. 1. Images of the simulation with actors (A) and immersion with virtual reality (B).

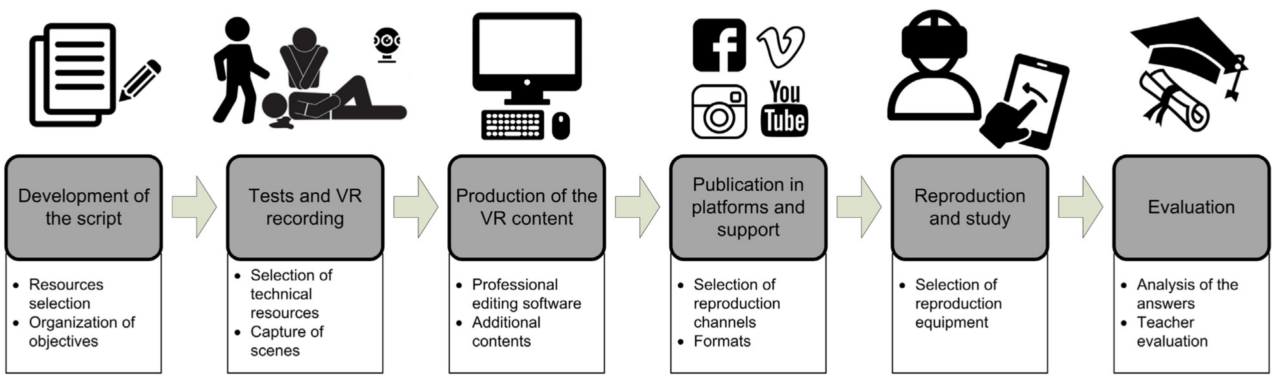

Fig. 2. Process of creation, use and evaluation of a Virtual Reality simulation (VRS).

For the viewing of the videos by the students, Head Mounted Displays (HMD) were utilized. These viewing devices are similar to eyeglasses or a helmet, that allow for the reproduction of VR and 360° images and videos. For the 2016/2017 academic year, a Samsung Gear VR® helmet was used, which increased the portability of the system as the playback of the video was not dependent on a computer, but instead on an advanced smartphone such as the Samsung Galaxy S6, equipped with an Octa Core processor (2.1 GHz) and a 5.1″ screen with Quad HD resolution of 16 megapixels, based on super AMOLED technology. This hardware ensured a smooth viewing of the VR content, improving the experience of immersion by the spectator.

After the viewing process, the instructors (authors M.F.P and A.N.F.) asked the student to perform maneuvers for their evaluation and contrasting.

Fig. 2 chronologically describes the methodology described for the conducting of the VRS. In first place, it was necessary to transfer the requirements of the study to an immersive audio-visual production, creating a special script for its capture with 360° technology. Afterwards, the technical mediums needed were selected, and the scenes were recorded, after adjustments and rehearsals by real actors. The content recorded were processed and edited under the supervision by the research team, who inserted special labels within them. When the content was finished, it was exported using different qualities and formats, and were published in multimedia platforms (i.e. YouTube). Once the devices for the playback and viewing of the VR and 360° were chosen, the last stage consisted on the conducting of the VRS exercise by the students, whose response would be later analyzed and evaluated by the training team.

2.1. Sample Selection

The health professionals who participated as volunteers in the study were Official Emergency and Special Care Nursing Master's Degree students from the Catholic University of Murcia (UCAM). The volunteers from the 2015–2016 class ($n = 35$) took part in the CSA, and the volunteers from the 2016–2017 class took part in the VRS. All the students were trained by the same group of instructors, with the same number of hours and content.

The people who acted as victims were third-year students from the Superior School of Dramatic Arts of Murcia (ESAD) from academic year 2015–2016, who were characterized by the Characterization Service of the ESAD and trained in the corresponding role (symptoms, act, communication, etc.) by the Coordinator of Training and Research from the Management of Urgencies and Emergencies Services 061 of Murcia, Mr. Jesus Abrisqueta Garcia.

2.2. Measurement of Stress and Activation

The activity of salivary α-amylase (sAA) was determined from all the participants before (basal) and after (posterior) the simulation, with the saliva collected through a system of passive diffusion, in a tube, with an extraction time of 1 min. The processing and analysis of the sample was conducted following the same procedure as previous studies (Brady, 2013). The method resulted in an inter-assay coefficient of

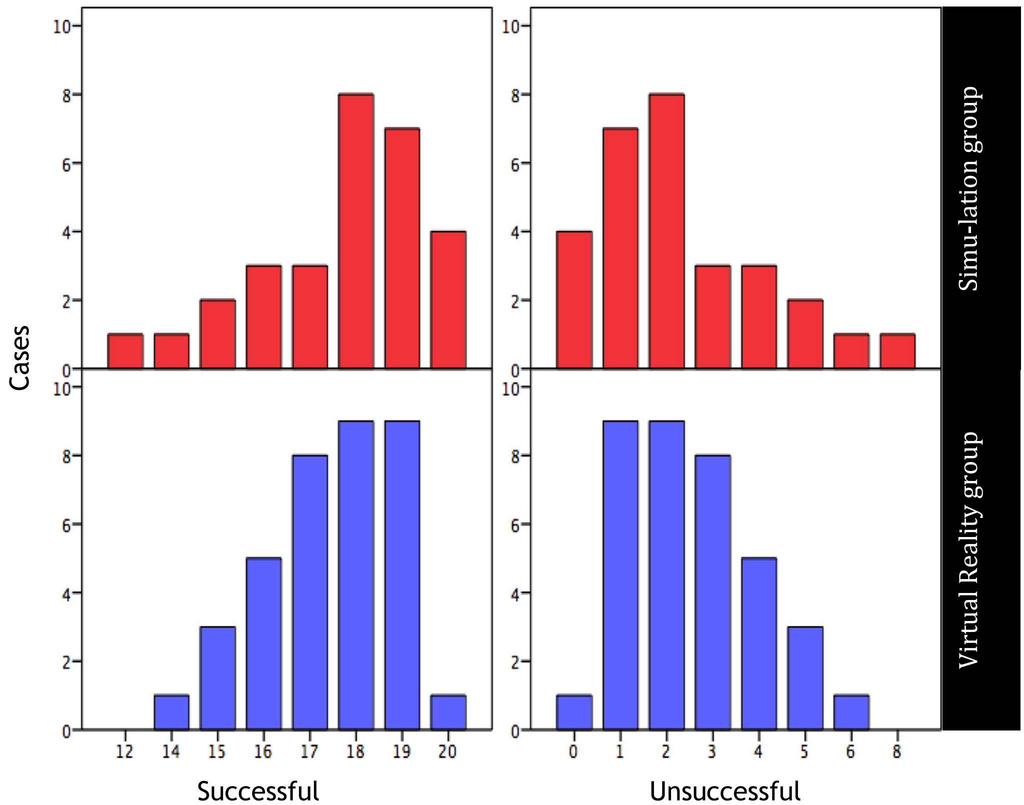

Fig. 3. Results of the successes and errors for each of the groups studied.

variation below 3%, and a linear regression coefficient of 0.991. Also, Heart Rate (HR) was monitored during the exercise, thus obtaining a mean and a maximum, as well as the Systolic Arterial Pressure (SAP) and Diastolic Arterial Pressure (DAP).

2.3. Statistical Study

The main variable of the study was the percent of victims that were correctly-triaged (V1). The other variables analyzed were: request for OA (V2), request for HC (V3), over-triage (V4) and under-triage (V5). Also, the age, weight, height, Body Mass Index (BMI = weight in kg/height in m^2), weekly physical activity in hours, Medical History of Interest (MHI), dental problems, presence or lack of tartar and/or gingivitis, medication, use of vitamins or antioxidants, smoker or non-smoker, time since the last meal, basal α-amylase, posterior α-amylase, increase of α-amylase, calculated as: Increase = Basal − Posterior. The data are shown as frequency, mean (Standard Deviation: SD). In order to compare the results between the two groups studied, the Wilcoxon (W) signed-rank test was used for those cases in which normality did not exist, and the Student's *t*-test for those in which normality was found. In the case of nominal variables, the Chi-squared test (X^2) was used, with the Yates correction. All the statistical results were obtained with the SPSS® statistical package version 21. The results were considered statistically-significant with a Confidence Interval of 95% ($p < 0.05$).

3. Results

The average age of the 67 students and health professionals who participated in this study was 29 (SD = 5), the average weight was 68 (SD = 14) kg, an average height of 1.71 (SD = 0.11) meters, an average BMI of 22.98 (SD = 2.96), and 4 h 30 m (SD = 3 h 15 m) of physical activity/week. The average length of professional experience was 13 (SD = 3) years, of which 10 (SD = 1) were in Emergency care. There were no significant differences found between the two study groups (CSA and VRS), or the pathologies or medicines declared to have an influence on the hormonal determination through the saliva.

The percentage of correctly-triaged victims was 87.65% (SD = 8.3), with a percentage of 88.3% (SD = 9.65) for the CSA group and 87.2% (SD = 7.2) for the VRS group, without any significant differences ($p = 0.612$) between both groups (Fig. 3). The basal sAA was 103.26 (SD = 79.13) U/L, with a significant increase ($p < 0.001$) with respect to the posterior levels of 185.22 (SD = 148.65) U/L. For all the participants, the average increase of sAA was 80.70 (SD = 109.67) U/mL, being greater for the CSA than for the VRS group (Fig. 4A). There were no significant differences ($p = 0.279$) between the basal levels of both CSA and VRS groups, but there were statistically-significant differences ($p = 0.010$) in the posterior levels, being greater for the VRS group. When analyzing the relationship between the level of stress and the percentage of correct triage, there was no relationship between them ($r = 0.42$; $p = 0.746$). Also, there were no relationships found between the number of correctly-triaged victims, physiological indicators of stress, age, BMI, physical activity, years of professional experience or years of experience in emergency care.

The basal-HR was 77.06 (SD = 15.8) beats/min, with a significant increase ($p = 0.022$) with respect to the posterior-HR of 80.06 (SD = 18.44) beats/min. For basal-HR and posterior-HR between the CSA and VRS groups (Fig. 4B), there were no significant differences between both groups ($p = 0.492$ and $p = 0.447$, respectively). The basal-SAP was 123.65 (SD = 13.02) mm Hg with a significant increase ($p < 0.001$) with respect to the posterior-SAP of 140.31 (SD 17.83) mm Hg. For the basal-SAP and posterior-SAP between the CSA and VRS groups (Fig. 4C), there were no significant differences between both groups ($p = 0.221$ and $p = 0.402$, respectively). The basal-DAP was 74.65 (SD = 7.89) mm Hg, with a significant increase ($p = 0.004$) with respect to the posterior-DAP of 77.32 (SD = 9.05) mm Hg. For the basal-DAP and posterior-DAP between the CSA and VRS (Fig. 4D), no significant differences were found between both groups ($p = 0.853$ and

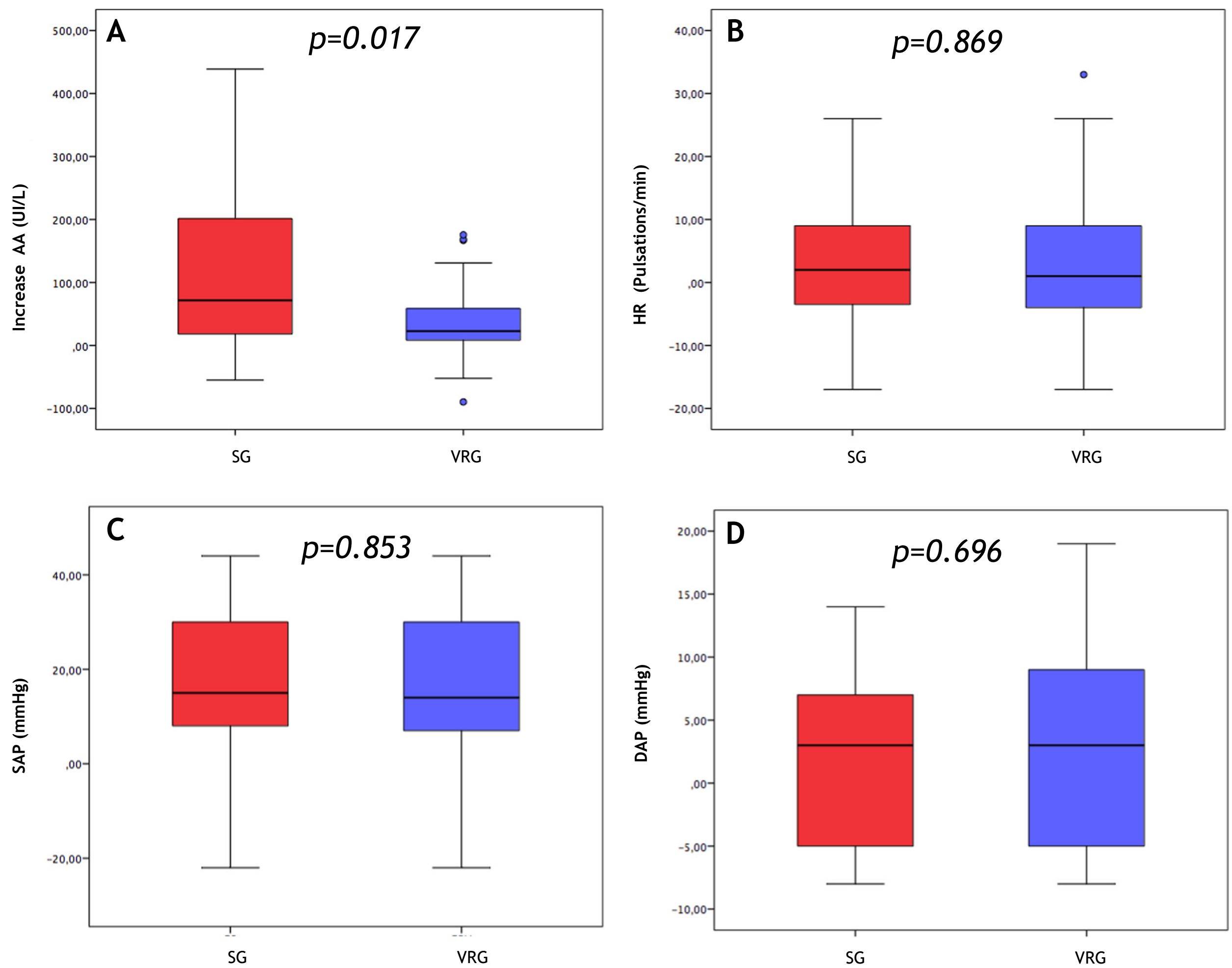

Fig. 4. Results of the increases of: α-amylase (A), heart rate (B) and systolic (C) and diastolic (D) arterial pressures.

p = 0.771, respectively).

4. Discussion

The results of our study showed similar values of successes/errors in the triage for both groups in the CSA and VRS study. This could indicate that VR could be used as a pedagogic resource for the training of professional health workers, in agreement with Gundry et al. (2010), defined VR as the best tool for reaching the objective in emergency medicine. Numerous studies have described similar results, such as the one by Stansfield et al. (2000), in which the training of professional health workers and/or students from different health fields were compared, concluding that VR allowed for the training of the making of decisions but not the practical triage skills such as the opening of an airway or control of a hemorrhage, nevertheless increasing the patient's safety. In our study, we found the same limitation when simulating the performing of practical skills.

Roy et al. (2006) compared simulations with standardized patients and VR in military catastrophe settings. They concluded that VR, apart from being an educational tool, was also therapeutic in the context of post-traumatic stress disorder. The training with CSA and VRS has raised doubts on their ability to improve assistance in real situations. In this sense, Abelsson et al. (2014) determined that the simulation was positive, and improved assistance in the care of the poly-traumatized patients by EM personnel.

Andreatta et al. (2010) compared the efficiency of training basic START with VR and CS, reporting learning values that were similar to those presented by Luigi Ingrassia et al. (2015). Also, they concluded that the effects of training in START triage in a MCI were the same with VR and CSA (Andreatta et al., 2010). In the studies that compared training with VRS and CSA, biochemical variables of stress have not been determined in the context of triage training in a MCI. A small number of studies have investigated the degrees of stress of doctors playing different roles in simulated scenarios (Daglius-Dias and Scalabrini-Neto, 2016). Thus, in our study, the secondary objective was to analyze this aspect, which we considered to be important. As of today, there is no Gold Standard for measuring the response to stress. sAA is one of the main salivary enzymes that is secreted as a response to sympathetic stimuli, so that it is considered to be the biomarker of choice for situations of psychologically-stressful stimuli (Takai et al., 2004). Valentin et al. (2015) and Daglius-Dias and Scalabrini-Neto (2017), in the study of a high-fidelity simulation, concluded that after the study of different physiological markers that were susceptible to change after situations of stress, sAA provided a more sensitive measurement to the levels of stress as compared to cortisol, for doctors under emergency situations. Luigi Ingrassia et al. (2015) compared live simulations and VR in a MCI and evaluated START triage, concluding that VR was comparable to the live simulation.

The results of our study showed a significant increase of sAA (comparing the basal and posterior levels), which indicated that the participants suffered sympathetic activation due to stress. In this sense, the study by Valentin et al. (2015) concluded that the high-fidelity simulation trainings, and those with standardized patients, produced stress in the emergency health professionals. With these results, we could observe that both systems created stress in the students. In this sense, Daglius-Dias and Scalabrini-Neto (2016) concluded that the CS in emergency situations created an environment of high psychological fidelity, as shown by the study on the levels of sAA.

No significant differences were found in the basal levels of sAA between both groups, which evidenced the similarity of both before the experiment, and thus an anticipatory stress was not observed in the participants. As for the posterior-sAA levels, there was a greater increase in the sAA levels in the CSA groups, signifying a greater degree of stress. These differences show that experience, as regards to stress, that the student perceived, was different for both groups. In view of these results, VR should be thought of as a substitute for CS in triage, as it seems to cause a lower degree of stress. However, CSA is a type of simulation that has a greater consumption of resources (human, economic, preparation time, etc.). On the other hand, the use of virtual reality could allow students to train independently. The student before the simulations in the classroom could do this training. Once designed and produced a library of situations and cases, the cost is relatively cheap because it can be reproduced as many times as necessary, just put a VR goggles or an adapter for smart phones and software (Youngblood et al., 2008). In our opinion, VR should be considered as a complementary pedagogic resource, as a prior step to the CS in a MCI, which could allow the student to train in an independent manner and to become prepared to face the next level of training and/or education.

In our study, we have also found significant differences between the prior and post HR measurement and the arterial pressure of the study participants. Other authors, such as Daglius-Dias and Scalabrini-Neto (2017) also obtained statistically-significant increases in HR as a stress marker in emergency situations. However, as opposed to the sAA, the analysis between groups of these physiological variables did not show significant differences.

The main limitation of this study what that both groups were not comprised by the same individuals, so that there could be a variability due to the possible individual variations, although as shown in the Results section, there were no statistically-significant differences between both groups. This design was programmed with this structure in order to avoid the learning effect on the performing of the triage of a group that would conduct one exercise and then another. Another limitation of this study is the use of a test ad hoc designed for this study, so we cannot provide data on the efficiency of it.

The results of this study allowed us to conclude that VR is an equally-efficient method as CS for the training on the use of basic triage (START model) in a MCI. Also, due to the sAA results, we can verify that CS creates a more stressful training experience, so that it should not be substituted by the use of VR, but should be complemented with it. Future lines on the use of VR for the training of health professionals should be aimed at improving gamification, the creation of case libraries, with greater autonomy for the student and allowing telematic monitoring of student progress.

Funding and Conflict of Interests

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