Introduction

Simulation training has been applied to the training of healthcare personnel to handle emergency conditions, as it replaces real experiences with guided experiences by replicating the real world in a fully interactive approach and allows medical trainees to acquire clinical competence without involving real patients, both through basic procedural practice and through scenarios of complex tasks and team training. Available full-scale simulators are a powerful training tool, which can be further improved by increasing the fidelity of the simulated patient by eliminating problems such as absence of overall body animation, particularly facial interaction and expression, absence of skin changes (e.g., colour, temperature, dampness, sweating, etc.), which preclude the automatic acquisition of information from clinical signs or a reliable physical examination. We hypothesized that the existing HeartSim 4000 mannequin (utilized for ALS training) could be improved by the addition of a virtual reality (VR) system, increasing the involvement and participation of the trainees and, thereby, the effectiveness of the learning experience. To this end, we developed a prototype of virtual reality enhanced mannequin (VREM).

Virtual reality may represent a powerful tool for allowing the addition of plausible features of patient aspect, facilitating interaction to mannequin simulators. The level of interaction between the participant and virtual characters does not currently play an important enough role, as demonstrated by the studies on sense of presence experiences induced by the virtual environment. Interaction devices (data-gloves and head mounted display) represent the necessary link to allow for physical interaction with virtual objects but, although widely utilized for specific task trainers, these have not been exploited for full-scale simulation.

The acceptance of such devices by trainees needed to be verified. The opportunity for such evaluation was offered by the Italian Resuscitation Council 2008 annual congress, which gathered
participants interested in the issues of CPR and related training, among which a large number of CPR instructors. The goal of this study was to test the acceptance of and interest in a VREM prototype among a sample of congress attendees who volunteered to participate in the evaluation session and to respond to a specifically designed questionnaire.

Materials and methods

The VREM was developed at the PERCRO laboratory, Scuola Sant’Anna of Pisa, utilizing a commercial Laerdal HeartSim 4000 mannequin connected with VR technologies (data-gloves, head mounted display and tracking devices) specifically designed for this application. The VREM prototype tested was able to render the main clinical signs and patient’s reactions in an immersive VR scenario and with a first person perspective. The detailed description of VR technologies is available in the e-version of the article.

The subject was able to touch the patient, hold the head of the patient in his hands, and check the carotid pulse. Real-time animations were implemented in order to simulate some of the typical clinical findings indicative of a cardiac arrest, including progressive skin colour changes and mydriasis. These reverted once the manoeuvre of the external cardiac compression was successful.

The evaluation session involved one trainee and two instructors with a standardized procedure and scenario (Figure 1):

1. The operator was invited to wear the data-gloves and the head mounted display and was briefly introduced to the scope of the simulation.
2. The instructor helped the operator become familiarized with the virtual environment in relationship with himself and the patient.
3. The patient’s voice was then heard in the room. The patient said “I am not feeling well, really bad, I think I’m fainting.”
4. The operator was asked to check the patient’s clinical signs.
5. After beginning CPR, the patient started to recover signs of circulation (acute pallor was reverted and the pupils became myotic).
6. The evaluation session was concluded.

Each participant was then asked to respond to a questionnaire. The questionnaire, formulated based on a 7-point Likert scale (LS), was designed to explore the trainee’s perception in the areas of user-friendliness, realism, and interaction/immersion.

Results

The VREM was tried by 39 users. The sample consisted of 27 (69.2%) men and 12 (30.8%) women, with an average age of 41.9 ± 10.8 years. Only 20.5% had previous experience with Virtual Reality, 51.3% had a previous experience of training in simulation centres. The sample included 54% medical doctors, 23% nurses and 23% lay rescuers. Sixty-seven percent were CPR instructors. The evaluation for each question is reported in detail in Table 1 and questions are grouped according to three areas: user-friendliness, realism, and interaction/immersion.

User-friendliness

The difficulty in using and wearing the devices (Q5) was judged variably with 8 participants judging it difficult (LS > 4), 2 judging it neither easy nor difficult (LS = 4), and 29 judging it easy (LS < 4). The difficulty in practicing the cardiac compression (Q8) was judged as difficult by 11 participants (LS > 4) and easy by 28 participants (LS < 4).

Realism

The overall feeling that the patient was present in front of the person (Q6) and that the virtual hands were moving like the real hands (Q7, Q10) were both high. The overall realism of cardiac arrest signs was judged well (Q9) and the hospital environment was judged as good (Q11, Q12).

Figure 1. Two evaluation sessions, Naples IRC 2008 Congress.
User responses to VREM manikin. Participants rated the following statements using a 7-point Likert scale (1 = completely disagree, 7 = completely agree).

### Interaction/immersion

The perception of the three-dimensional space was evaluated as high (Q13), interaction with the patient was judged realistic (Q15), and the involvement in the intervention manoeuvres high (Q16).

The difficulty in reaching and touching the patient (Q14) was evaluated very variably, but the overall answers judged the interaction/immersion to be high.

Overall, 84.6% of the sample evaluated the VR experience as interesting and believed that its development could be very useful for healthcare training.

The VR system was found to be very well-liked, as was the feeling of immersion and the realism of the environment and simulation.

### Discussion

This study demonstrates the feasibility of combining VR technology with a traditional training mannequin for use during emergency care training. The resulting VREM prototype was able to enhance the perception of realism and extend the physiological response to treatment beyond that available with traditional mannequins used during resuscitation training.

The 39 subjects who participated in the session reported the use of devices to be acceptable, the realism to be very high, and the interaction/immersion realistic, leading to a positive overall evaluation of VREM. Subjects judged the development of this technology as very useful for healthcare training.

The addition of VR to traditional emergency care training may improve diagnostic orientation by adding information by the reproduction of clinical signs in the virtual patient, provide feedback on the effect of treatment (e.g., skin colour as index of perfusion) and help task performance training.

The extensive use of VR for surgical training has been recently reviewed. The review concluded that for laparoscopic surgery, VR training decreased the time needed to complete a task, increased accuracy, and decreased errors compared to no training and standard laparoscopic training, and was more accurate than video training.

Emergency care training, in addition, needs team performance training, which has been shown to be effectively achieved by crisis resource management (CRM) with high-fidelity simulation, with ‘providing feedback’ being the most important feature.

The effect of the addition of VR will need to be tested also exploring the hypothesis that feedback provided by changes in clinical signs of virtual patients may improve the effectiveness of the video-assisted debriefing.

### Conclusion

In conclusion, the addition of VR to existing mannequins is possible and represents an interesting field for future research. The prototype of a virtual reality enhanced mannequin was met with enthusiastic interest, unaffected by the need of utilizing interaction devices and deserves full technological development (for example finger movements, improvement of facial signs, and animation in different clinical scenarios) and validation in emergency care training.

### Conflict of interest

No relationship exists between any of the authors and any commercial entity or product mentioned in this manuscript that might represent a conflict of interest.

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### Appendix A. Supplementary data


### References


