Design and implementation of 3D Web-based interactive medical devices for educational purposes

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ABSTRACT

Medical devices play a crucial role in all diagnosis, care and treatment of patients and the number and variety of medical devices is huge and increasing annually. Healthcare professionals handle a wide range of devices every day.

In this paper 3D Web-based interactive learning applications, which provide a helpful background, reminder and practical training to medical devices, have been developed. This article presents the production cycle of these interactive learning objects and the study conducted to measure the students' perception of the objects' effectiveness for learning. Three 3D Web-based interactive medical devices (sphygmomanometer, an electrocardiogram and a defibrillator) are described. Each of these applications introduces elements of interactivity with the learning content, and provides a practical training to the use of the medical devices. This e-learning package is aimed at all medical, nursing and allied healthcare professionals working in all healthcare settings and environments. It is also for all pharmacists in any environment and all community care workers in nursing and private healthcare settings. This training will also be useful to all staff working in a patient or patient supporting area, either someone new to the role or to a long standing professional as a reminder of best practice.

KEYWORDS

3D Web-based interactive medical devices; interactive learning environments; learning and training applications; virtual reality; medical education

INTRODUCTION

Rapid and far-reaching technological advances on healthcare are changing the ways in which people relate, communicate and live. From the time when there was the development of methods of electronic communication, clinicians have been using information and communication technologies in health care (Riva, 2003; Vezzetti & Marcolin, 2012, 2014; Westwood, 2004; Williamson Shaffer, Gordon, & Bennett, 2004). In the last years there has been an increase in interest in the potential impact of new technologies, such as interactive technologies, on health care for education and training. A main observation of that is that people find it very hard to learn by following sets of instructions in a manual text. Instead, they much prefer to "learn by doing". Interactivity is at the heart of learning systems design for the influential role it plays in the effectiveness of the learning process (Kearsley & Moore, 1996) and as a fundamental mechanism for knowledge acquisition (Barker, 1994). One of the main benefits of interactive technologies, such as web-based, multimedia, and virtual reality, is that they provide alternative ways of representing and interacting with information that are not possible with traditional technologies (e.g., books, video). In so doing, they have the potential of offering learners the ability to explore ideas and concepts in different ways and to help learners to "learn by doing". Using an interactive web-based learning program can increase the learning enjoyment level, which in turn may increase students' understanding and the effectiveness of learning in a longer timeframe in terms of information retention (Street & Goodman, 1998). The use of interactive learning systems can be an effective way to learn creating a high-quality learning experience, if they have a good interactive design. The design of a good interactive system requires an integrated design approach that incorporates system-related factors, student-related factors (user-centric design) and of interactions between these factors (human computer interaction). This paper incorporates these design strategies for the development of the interactive medical devices, according to the definition of interactivity that focuses on the type of learner/system response (Domagk, Schwartz,

& Plass, 2010; Laurillard, 2013; Mareš, 2011; Violante & Vezzetti, 2014, 2015). Domagk et al. define interactivity in the context of computer-based multimedia learning as the reciprocal activity between a learner and a multimedia learning system, in which the [re]action of the learner is dependent upon the [re]-action of the system and vice versa (Domagk et al., 2010). Also according to Mareš, the concept “interactivity” means a reciprocal activity between the learning man and the e-learning system (Mareš, 2011). Action/reaction of the learning man depends on the action/reaction of the system itself (Mareš, 2011). This definition emphasizes the dynamic relationship between learner and learning system. Since interactivity in e-learning is a two-way communication between a learner and the computer system, it is important to focus on both components as potential sources to enhance the training of users through experience in virtual environments. So the interactivity of the virtual medical devices designed in this paper has certain features or mechanisms that allow students to act in order to achieve certain tasks, receive relevant intrinsic feedback on their actions and observe change as a result of their reactions (Laurillard, 2013), (Sabry & Barker, 2009). These Web-based interactive instruments allow the acquisition of the necessary competences required for the use of the device since, when the user interacts with these virtual instruments, the application simulates the procedure as it is executed in the real world.

1. VIRTUAL REALITY TRAINING FOR MEDICAL PROCEDURES

Recent advances in educational and training technology are offering an increasing number of innovative and promising learning tools. These include three-dimensional virtual worlds and computer simulations, which can provide an opportunity to enhance the training of health-care professionals through experience in virtual environments (Jenson & Forsyth, 2012).

The interaction is important in this context because the communication between the user (health professional) and the Virtual Environment (VE) or VR system can offer necessary experiences and knowledge in the execution of a procedure. In addition the change in medical practice that limits education time and patient availability, and the increase in medical legal awareness, have contributed to the greater use of simulators in medical training and education. Monova et al. (Monova, Alexeev, & Kossekova, 2010) have stated that the use of the simulation-based training is also important because the present students at the universities belong to a new generation, born after 1981, the so named net-generation (Prensky, 2001) or digital natives (Koch, Grøndal, & Schei, 2008). This generation is unique because they use computer and Internet technology since they were children and they were grown up with digital technologies. For this reason the Virtual Reality is relevant to their style of thinking and perception.

According to Heim (Heim, 1998), VR is “an immersive, interactive system based on computable information, it is an experience that describes many life activities in the information age”. In particular Heim (Heim, 1998) describes the VR experience around its “three I’s”: immersion, interactivity and information intensity. Developing this position, Bricken (Bricken, 1990) identifies “the core characteristic of VR in the inclusive relationship between the participant and the virtual environment, where direct experience of the immersive environment constitutes communication. Following this approach, it is also possible to define VR in terms of human experience “a real or simulated environment in which a perceiver experiences telepresence”, where telepresence can be described as the “experience of presence in an environment by means of a communication medium” (Riva, 2003; Steuer, 1992). This position better clarifies the possible role of VR in medicine: a communication interface based on interactive 3D visualization, able to collect and integrate different inputs and data sets in a single real-like experience (Riva, 2003).

VR is applied to a wide range of medical areas, including medical education and training (Troccaz et al., 2000); treatment of phobias and other causes of psychological distress (Parsons &

Mitchell, 2002); pain reduction (Malloy & Milling, 2010), obesity and diabetes (Morie & Chance, 2011), endourology (Kuo, Delvecchio, & Preminger, 2001). In addition numerous cases using VR technology in surgery can be easily found in medical literature such as surgery planning (Sørensen, Therkildsen, Makowski, Knudsen, & Pedersen, 2001), virtual endoscopy (Schijven & Jakimowicz, 2003), arthroscopic knee surgery (Cannon, Eckhoff, Garrett Jr, Hunter, & Sweeney, 2006), bone marrow harvest (dos Santos Machado, De Mello, de Deus Lopes, Filho, & Zuffo, 2001).

Generally the Virtual Reality in medical education can be used to teach surgical tasks, anatomy and medical devices. In the area of simulation of surgical skills, the science of Virtual Reality provides an entirely new opportunity (Liu, Tendick, Cleary, & Kaufmann, 2003). Surgical simulation offers the opportunity for trainees to practice their surgical skills prior to entering the operating theatre, allowing detailed feedback and objective assessment of their performance. The ability to acquire surgical skills requires consistent practice, and evidence suggests that many of these technical skills can be learnt away from the operating theatre (Hanna, 2010). This enables better patient safety and standards of care. In fact the trainee can make mistakes without exposing the patient to risk, unlike in vivo. High-profile cases of medical errors in the world and major reports from organizations have sensitized the public and medical profession. Training is a key area that must be tackled to positively affect the problem of medical errors, especially in surgery (Fried et al., 2004).

Today more and more sophisticated VR simulators exist for endoscopy (Neubauer, Brooks, Brouwer, Debergue, & Laroche, 2012), gynecology (Goff, 2010), laparoscopy (Kahol, French, McDaniel, Panchanathan, & Smith, 2007), orthopedics (Tsai, Hsieh, & Jou, 2001), otolaryngology (Caversaccio, Eichenberger, & Hausler, 2003), urology (Schenkman, 2008), dermatology (Gladstone et al., 2000), ophthalmology (Verma, Wills, & Verma, 2003), endovascular surgery (Tsang et al., 2008).

The application of Virtual Reality to teach anatomy using Virtual Humans (VHs) has already been shown to be beneficial for training feedback since it is mainly illustrative (Alexandrova et al., 2011; Brenton et al., 2007; Park, Shim, Park, Kang, & Kim, 2013).

Alexandrova IV et al. (Alexandrova et al., 2011) affirm that when generating VR applications for training purposes, both the Virtual Environment and the Virtual Humans should be as realistic as possible. In order to appear natural, the VHs involved in the application should have realistic motions, ability to express emotions, and synchronized body and facial animations, including human-like gaze behaviour. Through 3-D visualization of massive volumes of information and databases, clinicians and students can understand important physiological principles or basic anatomy (Alcañiz et al., 2000; Riva, 2003). In fact with the Virtual Reality it is possible to explore the organs by “flying” around, behind, or even inside them. In this way it is allowed a deeper understanding of the interrelationship of anatomical structures that cannot be achieved by any other means, including cadaver dissection (Riva, 2003)

Apart from anatomical training, VR can be used for the teaching the skill of performing medical instruments (Jeffries, Woolf, & Linde, 2003). Users of medical instruments in hospitals and clinics (e.g., nurse, technician, laboratory staff, or physician) must be professional, experienced staff who operate the equipment on patients. All stages from deciding or remembering to perform the procedure, through its execution, reading the data, documenting and interpreting the results must be performed by trained personnel (van den Berge et al., 2013).

2. INTERACTIVE MEDICAL DEVICES: WHY?

As shown earlier, VR is rapidly growing as a very powerful educational tool in the medical education. At the moment, it is well-established in the surgery and in the teaching of the anatomy but, less so in the performing of virtual medical instruments. In order to fulfil this gap, this paper proposes the development of medical devices based on the VR technology. The paper shows the design and the implementation of the most useful and common medical instruments, dedicated to the heart care, such as Electrocardiogramm (ECG), Automatic External defibrillator (AED) and blood pressure meter (or sphygmomanometer or sphygmometer). These Web-based interactive instruments allow the acquisition of necessary technical skills required for the device. The user manipulates virtual instruments and the application simulates the procedure as it is executed in the real world, providing an effective training.

The authors have drawn up the following reasons that justify the use of these virtual medical instruments as training tool.

Reasons related to University

In order to perform an ECG, Defibrillator and Sphygmometer correctly, the trainers need to have access to the real machine for the practical work at the hospital, clinical faculty, healthcare institutes, etc. This requires a high machine-to-student ratio and a high teacher-to-student ratio to allow for closely monitored practice. In addition it is not uncommon to have to repeat the training content different times in a week and in a day. Repetitive content is ideal material to move from traditional instructional methodology to computer-based instruction. In addition, for delivery of repetitive content, the use of web-based 3D models for ECG or EEG training can be very reductive cost. It is also important to point out that, from financial point of view, restricted budget justifies the use of virtual models. At the same time, resident work hour reforms and changes in staff compensation make it increasingly difficult for both trainees and clinical faculty to balance their service obligations with time for education and evaluation (Fincher & Lewis, 2002; Scalese & Obeso, 2008). The virtual medical devices, by contrast, are ideally suited for independent learning and, thus, can save faculty time.

Reasons related to Patient availability

The use of virtual medical devices can be justified by changes in healthcare delivery too (e.g., shorter hospital stays for patients who are admitted). They have reduced patient availability as learning opportunities at academic medical institute (Scalese & Obeso, 2008). Moreover, unlike real patients who are frequently "off the ward" when instructors and learners arrive to perform their assessments, the virtual medical devices can be readily available at any time. The virtual medical devices provide a standardized experience for all because they do not interact with real, especially ill, patients often tired, embarrassed or unpredictably behaved.

Reasons related to safety

Scalese & Obeso (Scalese & Obeso, 2008) have stated that mastery of clinical tasks involving innovative diagnostic and therapeutic technologies and deployment of medical devices via minimally invasive or endovascular techniques, often follows a steep learning curve; this has obvious implications for patient safety, particularly when novices are performing invasive procedures on real patients.

Scalese & Obeso (Scalese & Obeso, 2008) have highlighted the problem of medical errors and the need not only to prevent mistakes by individuals, but also to correct faults in the systems of care. For these reasons, the virtual medical devices can improve skills acquisition by placing trainees in lifelike situations.

According to the American Heart Association (AHA), automated external defibrillators (AEDs) are important because they strengthen the chain of survival (http://www.heart.org/HEARTORG/). When a person has a cardiac arrest, his or her chances of survival decrease by 7 to 10 percent for each minute that passes without defibrillation. AEDs are designed with multiple safeguards and warnings and are programmed to deliver a shock only when ventricular fibrillation (VF) has been detected. However, potential dangers are associated with AED use. Untrained users may not know when to use an AED, and they may not use the device safely, exposing themselves and others to electric shock or burns. The AHA stated that an AED is safe to use by anyone who's been trained to operate it (http://www.heart.org/HEARTORG/). So training should be encouraged to help improve the time to shock delivery and correct pad placement. Studies have shown that the incorrect position of the defibrillation paddles influences the defibrillation success (Heames, Sado, & Deakin, 2001).

Reasons related to community and home settings.

In parallel to the increasing specialization and sophistication of hospital equipment, a whole range of medical devices and products is moving out of hospitals and clinics into community and residual settings for use by the general public (Bitterman, 2011). According to American Heart Association (AHA), with defibrillators becoming more prevalent in communities, the number of deaths each year from sudden cardiac arrest can be dramatically reduced (http://www.heart.org/HEARTORG/). Target consumers of home medical device (such as sphygmomanometer) and automated external defibrillators, on the other hand, are a heterogeneous, primarily non-professional group. This may include patients operating the equipment on themselves (self-care) or their proxies family members (ranging from spouses to grandchildren), caregivers who operate the equipment for the patient and first-aiders. Use of these virtual medical devices allow to became familiar with the medical instrumentation permitting the transfer of health care services from hospitals to the community and home settings.

Reason related to on-line training course

In the last years, although many web-based training applications on medical devices have been developed, the learning content doesn't show any element of interactivity. The self-paced online courses in ECG, for example, offer spectacular animations of cardiovascular system at work, the electrophysiologic mechanisms involved, the pathophysiology of cardiovascular diseases, and hundreds of ECG tracings. Nevertheless, the trainers will need to have access to real ECG machine for the practical work, to became competent in its use. Use of virtual medical devices within an on-line training course allow the trainers to became familiar with the medical instrumentation, reducing the necessity of a real access to the instrumentation, and increase the student' learning, concentration, attention, interest and reinforce retention.

This paper focuses on virtual environments methods and techniques, whose application in the design of assistive devices or medical tools can improve the human condition in everyday life with the aim of expand the actual research in this context (Gironimo & Lanzotti, 2011). Till now, although many web-based training applications on medical devices have been developed, they doesn't show any element of interactivity and they are mainly addressed to the training of medical personnel. Since learning environments are particularly interesting as artificial worlds with which learners can interact in order to learn about the behaviour of certain real systems, in this paper we describe in more detail the design approach and the benefits of using these interactive learning environments by users without medical knowledge too. The findings proposed by this study can assist instructors and system designers in understanding more clearly user reactions to learn the real functionality of medical devices by mean of interactive virtual devices, so that they can design systems that meet user needs in situations or emergences of real and daily life. In this way, we hope to provide some directions to design interactive virtual learning environments that caters to the needs of whatever users for their daily lives helping them to acquire experience with the functionality of common medical systems useful for their health.

3. METHODOLOGY

Monova T. et al. (Monova et al., 2010) have stated that creation of virtual models is in unison with the requirements of the World Global standards in Medical education for implementation of information and communication technologies (ICT) in teaching, learning and accessing information.

The virtual models of medical instrumentations have been developed within the Leonardo da Vinci project WEBD (Web based training of biomedical specialists) whose partners are Gazi university, Aachen university and Politecnico di Torino (http://www.webd.gazi.edu.tr/about.html). The aim of the project is to propose the use of advanced distance learning technologies and provides professional education for Biomedical Engineers (BME's), Biomedical Equipment Technicians (BMET's), and Medical Device Technology Teachers (MDTT's). One of the most important needs for hospitals and medical sector is the qualified medical device technologists such as BME's, BMET's, and MDTT's. In order to help understanding and learning of instructions for the use of different medical devices, web-based 3D models for medical device training has been proved to enhance the education process. Besides in the project, such 3D models are used as part of an integrated training package that includes theoretical contents, such as instrumentations descriptions, and self-assessment tools.

In this paper the authors show the design and the implementation of virtual medical instrumentations for cardiac diagnostic and monitoring purposes. They have been designed to train students, health professionals and non-medical personnel how to perform an Electrocardiogramm (ECG), an Automatic External defibrillator (AED) and a blood pressure device. These applications ensure interactive e-learning in Medical Education with the aim to imitate real patients, anatomic regions and clinical tasks and to mirror the real life circumstances in which this medical services is rendered. These virtual applications allow to be manipulated with intuitive immediacy similar to that of real objects, the viewer to "enter" the visualizations to take up any viewpoint, the objects to be dynamic in response to viewer actions. They incorporate dynamic animations, interactivity, and visual design to stimulate, challenge, and test students. These multimedia modules can visually stimulate a student and transform learning into an active, engaging process. These virtual instrumentations are accessible anytime, anywhere, at any place. In this way students can became familiar with the instrumentations even without access to real instrumentation. The applications promote learning by doing and enhance learning by reinforcing cognitive knowledge and improving retention. They increase the interest, attention and concentration in the learning activity.

3.1 Design and implementation of the virtual medical devices

To produce the Web-based 3D models of Medical Devices, the authors have used Viewpoint Enliven Software. Viewpoint provides an incredibly easy method of compiling and creating interactive 3D and streaming media for the Internet (http://www.viewpoint.com/technologies/enliven.shtml). Enliven supports an enormous amount of functionality from the favourite creative applications. For any 3D assets, it is possible to import an incredible array of file formats directly into Enliven using the Deep Exploration module. Deep Exploration is Right Hemisphere's standalone application that allows to explore, view, translate, optimize, animate and publish in a broad range of formats. Viewpoint Corporation provides a computer graphics platform called viewpoint Experience Technology (VET). VET integrates photo-realistic 3D models, high-resolution 2D images, flash vector graphics, audio and video for practical, dynamic, interactive, and emotionally compelling content. The main components of VET are Enliven, which enables you to produce interactive content and the Viewpoint Media Player (VMP) for displaying it. After having completed the VET scene with the necessary animation and interactivity, it is possible to publish the final VET scene to a web page. When a VET scene is published from Enliven two files are generated: a .MTX file and a .MTS file. The .MTX file is a Viewpoint XML scene file that describes hierarchical relationships between objects and other elements in the scene. This file is the script for staging the scene elements and usually references a .MTS file. The .MTS file is a binary resource file containing all geometry and bitmap texture information for the VET scene. An MTS file can also contain audio and video. After you publish the VET scene, a visitor to the web site can view the VET content so long as the computer has the Viewpoint Media Player installed. If a visitor does not have the VMP installed, they are prompted to install the VMP the first time they encounter a page with VET content.

In order to produce the interactive 3D devices, the following steps, shown in the figure 1, are necessary:

- Modelling of 3D hospital-like room, the medical equipments and the Virtual Human in Autodesk 3DS Max.
- Using Deep Exploration module to import these assets into Enliven where they have been assembled into a VET scene, adding interactivity and animations.
- Publishing the final VET scene to a web page.

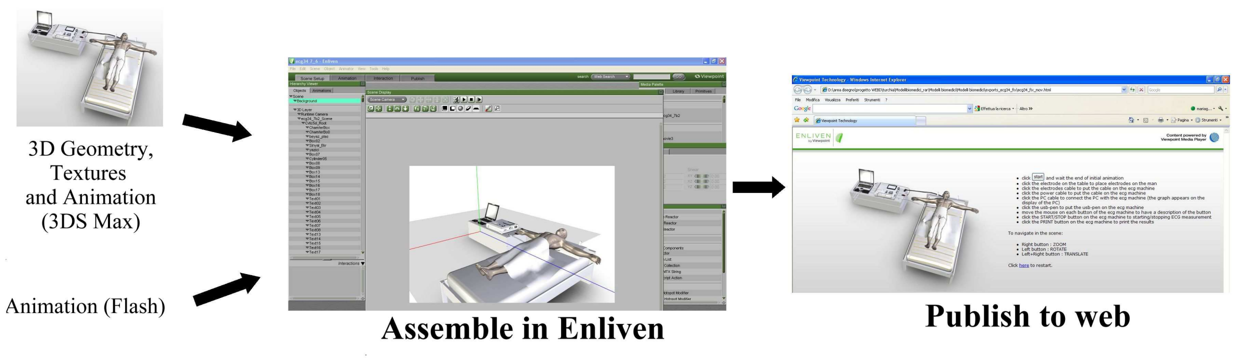


Figure 1. Development Steps

Each virtual applications contains a brief descriptions of the sequence of tasks necessary to perform the virtual device. The sequence of tasks attached to the virtual model gives to students the possibility to learn the functionality of the medical device without the exigency to consult a manual text (fig. 2, fig.3, fig.4). These notes are written in English language even if it is possible that some medical students, specialists, technicians do not know well English. Therefore translation of instructions for use from English into native languages could be necessary to allow more effective and efficient use of the models.

In these applications the navigation and exploration is facilitated. In fact users can navigate around the virtual model, create or modify point of views. Users can interact with the objects, to look behind or under them and to examine them from different points of view, as if they were in the physical world. The application enables the student to use his/her mouse to change the view of 3D model: in fact it is possible to use left-click and drag to rotate view, right-click and drag (or CTRL + left-click) to zoom, both-click and drag (or SHFT + left-click) to move the 3D model within the window, to go to starting page by using ‘‘back’’ function. It is important to have a working internet connection to access these Web-based applications. It is not required any software to be installed on computer, only a plug-in is required to be installed once.

Figure 2 – Sequence of the tasks and Virtual model (ECG device and VH)

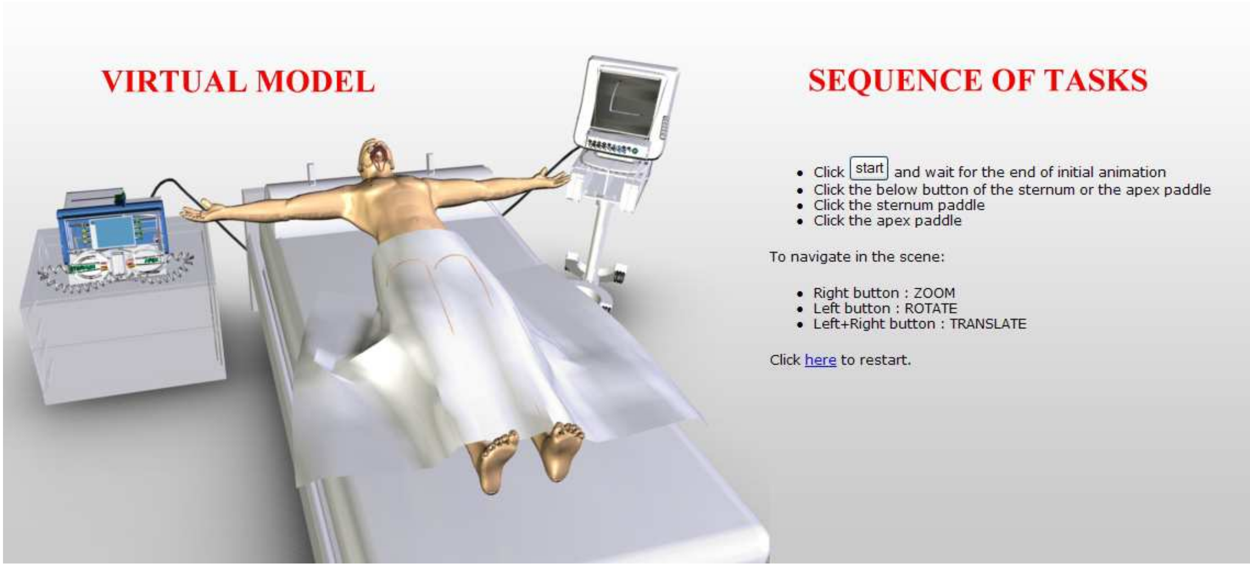


Figure 3 – Sequence of the tasks and Virtual model (AED device and VH)

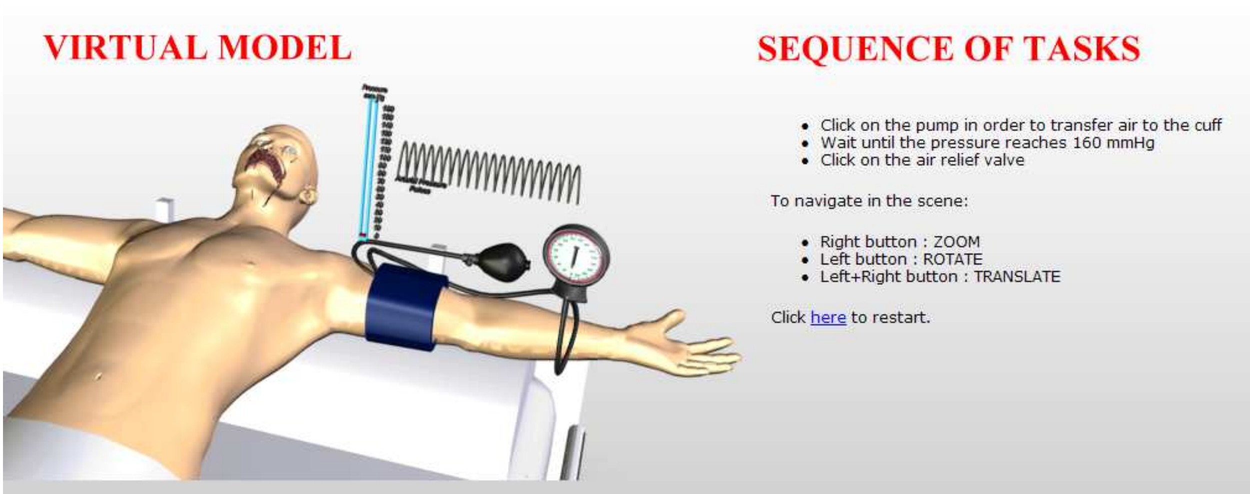


Figure 4 – Sequence of the tasks and Virtual model (sphygmomanometer and VH)

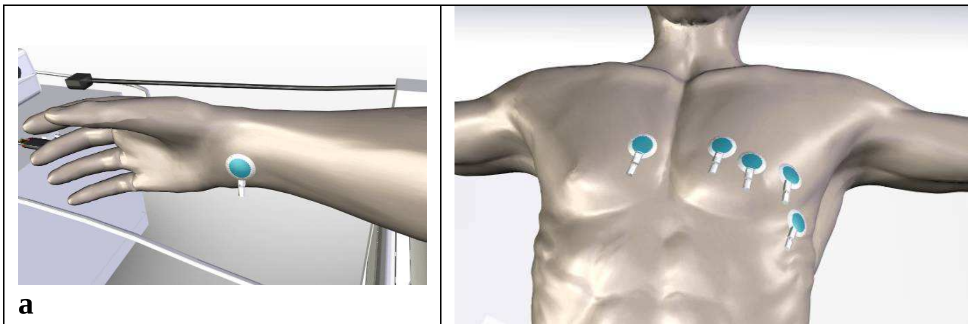
3.2 ECG Application

A correct delivery of an ECG procedure requires accurate electrode placement as well as proper skin preparation, proper patient. Electrode placement is so important that the American Association for the Advancement of Medical Instrumentation has outlined standardized electrode placement guidelines (http://www.aami.org/). When performing a ECG, a small mistake in electrode placement can make a big difference, distorting interpretation and diagnosis. For example, precordial electrodes just 2 cm out of position can significantly distort the waveforms, causing a wrong interpretation and, potentially, leading to a wrong diagnosis or treatment. In order to avoid mistakes in electrode placement, in our 3D model, by clicking the electrode on the table, it is possible to visualize the correct placement the electrodes in the virtual human (fig.5a). By clicking the electrode cables, PC cable and USB, it is possible to visualize their position in the device (fig.5b).

a b

Figure 5 –ECG device, PC, Cables, USB and Electrode (a) before clicking cables and after (b)

In order to visualize the placement of the electrodes in the virtual human, different cameras have been setup in Enliven at the VHs' hands-height, chest-height and feet-height (fig.6).



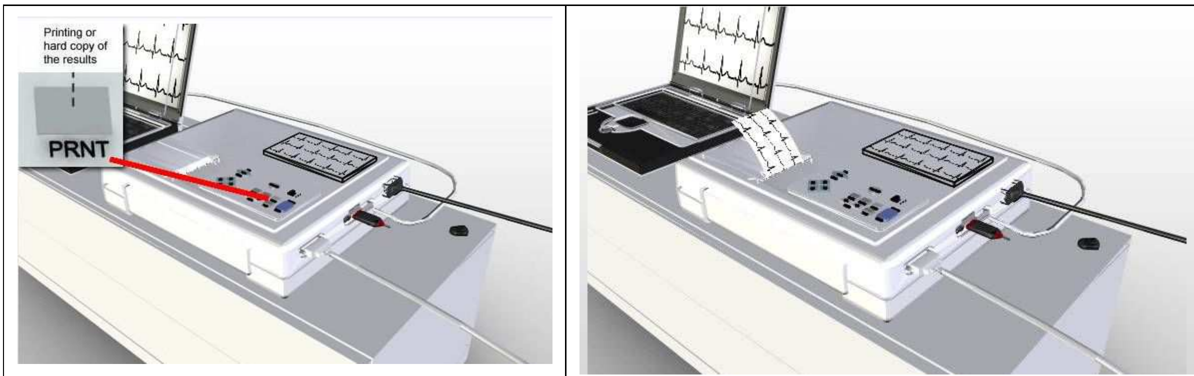
a **b**

e d

Figure 6 – Electrodes place in the wrists (a-e), in the chest (b), in the ankles (d)

The output of an ECG recorder is a graph with time represented on the x-axis and voltage represented on the y-axis. In our virtual model, by clicking the START/STOP button of the ECG device, it is possible to start/stop the ECG measurement and to visualize the representation of the ECG graph in the monitor of the pc and the ECG device.

A dedicated ECG machine would usually print onto graph paper which has a background pattern of 1mm squares (often in red or green), with bold divisions every 5 mm in both vertical and horizontal directions. In our model by clicking the PRINT button, it is possible to print the ECG results (fig.7).

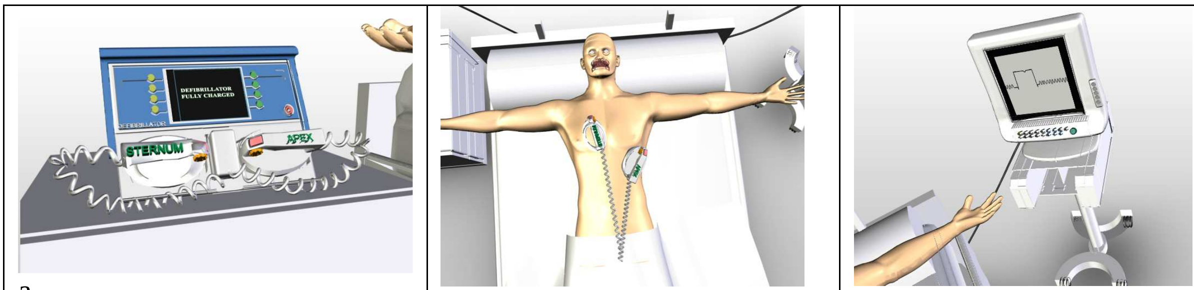


a b

Figure 7 – PRINT Button (a) prints the ECG results (b)

3.3 Automatic External Defibrillator application

An external defibrillator is a device that delivers an electric shock to the heart through the chest wall. This shock helps restore the heart to a regular, healthy rhythm. The device consists of a power control unit, paddle electrodes, and various accessories. Since studies have shown that a rapid and correct position of the defibrillation paddles improve the time to shock deliver, an “ad hoc training” is necessary to a correct pad placement. In order to perform a real AED device, the first operation is to apply a conductive gel to the paddle electrodes or patient's chest and to turn on the machine. In this way the energy level is selected and the instrument is charged. In our application in order to turn on the machine, it is necessary to click the orange button of the device (fig. 10a). In the monitor of the device the note “defibrillator fully charged” appears. It indicates the switching on the device.



a b c

Figure 10 – The AED device (a), Placement of the paddle electrodes (b) and visualization of the heart rhythm (c)

In this Web-based interactive application, in order to place the paddle electrodes on the patient’s chest, it is necessary to click the STERNUM paddle (10b). After the placement of the paddles on the patient's unclothed, the buttons on the electrodes have to be pressed simultaneously to deliver the electric shock. In our 3D interactive model, pressing the orange button of the electrodes, the first shock is delivered and a body movement of the virtual human is observed. The heart rhythm is visualized on the display device (fig. 10c).

3. 4 Sphygmomanometer application

A sphygmomanometer is a device used for measuring arterial pressure. A sphygmomanometer usually consists of a pump or bulb, a gauge or an aneroid dial, a cuff and a valve. In our model, the authors have performed a blood pressure test using a manometer sphygmomanometer. In the figure 11a it is possible to observe the 3D interactive model of manometer sphygmomanometer we have modelled.

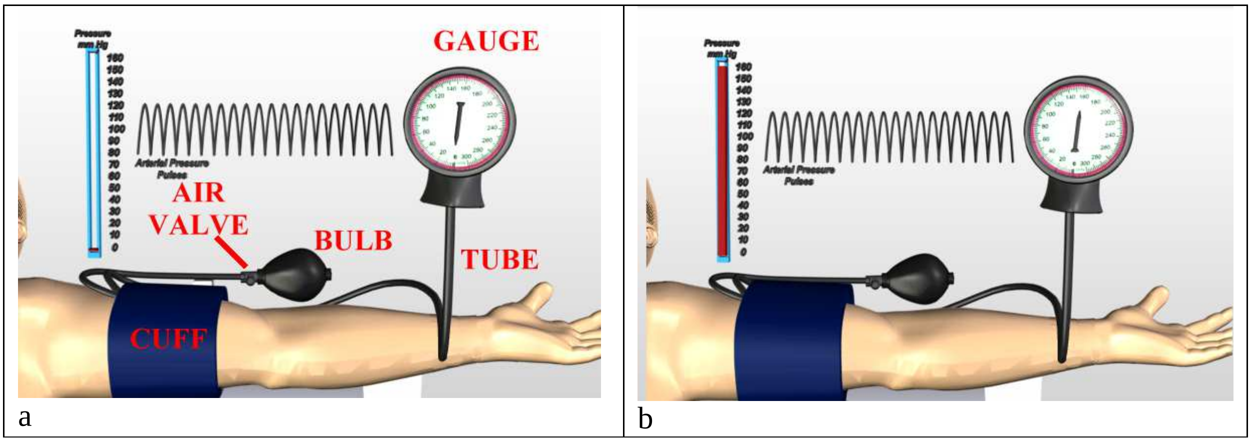


Figure 11. 3D manometer sphygmomanometer (a) and End of the inflation of the cuff (b)

To perform the blood pressure test, a cuff is wrapped around one of the patient's arms above the elbow and then slightly inflated by the clinician, usually at a point between 150 and 200 millimeters of mercury. A stethoscope is used to hear the sound of blood rushing back through the artery. A gauge measures the blood pressure. In our 3D interactive model, clicking the bulb, the inflation of the cuff starts. The rubber squeeze bulb simulates the pumping of the air into cuff until the needle of the gauge stops moving at 160 millimetres of mercury (fig.11b).

It is interesting to highlight that during this animation the bulb changes its dimensions as if it is really squeezed and released and, while the needle of the gauge goes on moving from 0 to 180 millimetres of mercury, the related level of pressure displayed in a red colour increases (fig.12a, fig.12b).

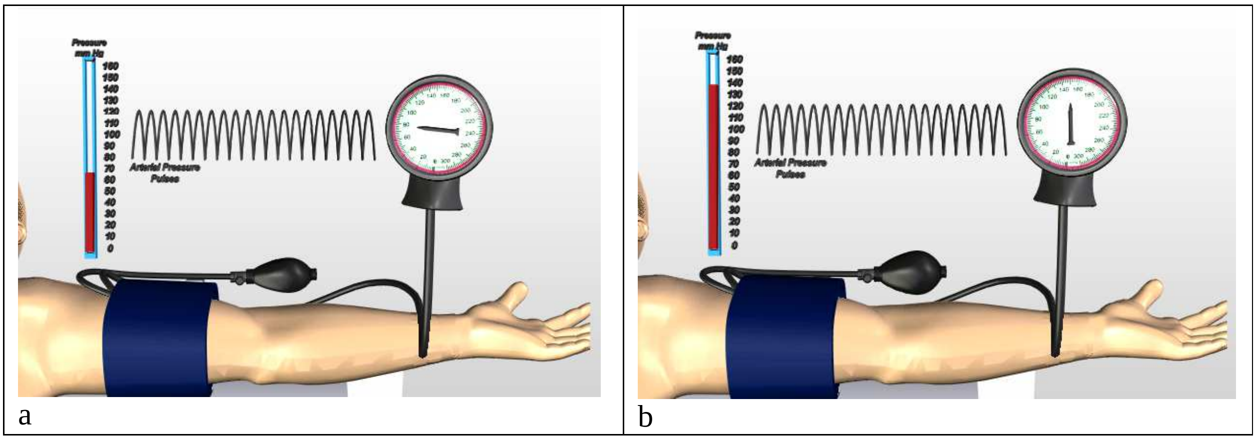


Figure 12. The bulb appears in a squeezed way with the needle of the gauge is at 80 millimetres of mercury (a) and in a released way with the needle of the gauge is at 140 millimetres of mercury (b)

By clicking the small valve attached to the bulb, it is possible to observe as the air escapes and the pressure indicator (or cuff pressure) correspondingly declines (fig.13a).

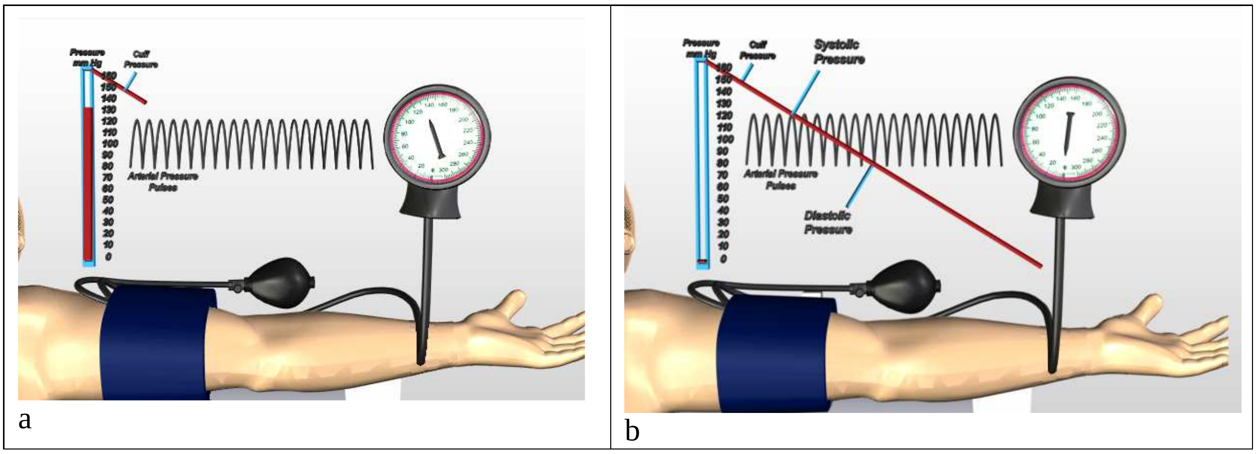


Figure 13. The air valve releases slowly the air from the system (a) and Pressure indicator declines at 0 level (b)

While the pressure indicator declines, it is possible to read two numbers from the gauge while air is released from the cuff. The two numbers represent your blood pressure. The first number indicates the systolic pressure. It measures the pressure inside your blood vessels at the moment your heart beats. The second number indicates the diastolic pressure. It measures the pressure in your blood vessels between heartbeats, when your heart is resting. For example, a "normal" blood pressure would be read as 120/80. At the end of the animation, the 3D manometer sphygmomanometer appears as the one is showed in the figure 13b.

4. RESULTS

Some studies identify several factors (such as initial computer skills and age) as significant predictors of the performance and satisfaction of Web-based interactive learning applications (Hong, 2002; Hong, Lai, & Holton, 2003; Ong & Lai, 2006; Sun, Tsai, Finger, Chen, & Yeh, 2008; Thurmond, Wambach, Connors, & Frey, 2002).

Students' ***experiences with computers*** can affect their learning in a Web-based course (Leasure, Davis, & Thievon, 2000; Stocks & Freddolino, 1999; Wilson & Weiser, 2001). Other studies reported that students' experiences or skill level with computers did not influence their overall satisfaction with the course (Leong, Ho, & Saromines-Ganne, 2002; Thurmond et al., 2002).

Some authors found that students with high levels of initial computer skills were no more satisfied with Web-based courses and reported similar achievement with students reported having little or no computer experience (Fredericksen, Pickett, Shea, Pelz, & Swan, 2000; Jiang & Ting, 1998; Sturgill, Martin, & Gay, 1999; Swan et al., 2000).

Sturgill et al. (Sturgill et al., 1999) noted that students without adequate computer skills experienced frustration working collaboratively using computer-mediated communication.

However, difficulty with interacting with the technology did not always lead to negative outcomes (Kenny, 2002; Leasure et al., 2000) but it can help to improve the students computer skills (Atack & Rankin, 2002) and increase the students confidence in using a computer (Kenny, 2002).

The influence of ***age*** is not so evident even if it is generally believed that younger students are more likely to ‘‘surf’’ the Web than older students (Karuppan, 2001).

Several studies found no relationship between students’ learning in Web-based courses and age (Hong, 2002; Hong et al., 2003; Jiang & Ting, 1998). Furthermore, the findings of Fredericksen et al. (Fredericksen et al., 2000) and Swan et al.(Swan et al., 2000) reported that the youngest students learned the least and were the least satisfied with Web-based learning.

The findings concerning relationships between students’ characteristics (computer skills and age) and students’ achievement and satisfaction with a Web-based course are varied and, at times, contradictory. For this reason, in this paper it has been conducted an evaluation to explore relationships between students’ characteristics and success in the Web-based learning applications.

Thus, prior computer skills and age differences are considered in the following hypotheses formulated to investigate the effectiveness of the Web-based interactive medical applications.

H1. The level of satisfaction of students with higher computer skills will be higher than that of the students with lower computer skills when using the Web-based interactive medical applications.

H2. The level of satisfaction of younger students will be different than that of older students when using the Web-based interactive medical applications.

The evaluation was carried out on 50 lay persons without any medical competences to how operate the devices correctly. These people aged between 14-65 years were classified in base of their levels of computer skills (base, medium, high) (Table 1). A quiz was administered to the applicants in order to test their initial computer experience.

Table 1. Subject demographic (n=50)

Measure and Items			Frequenty
Levels of computer skills	b	base	10
	m	medium	25
	h	high	15
Age	i	14-25	14
	ii	26-50	18
	iii	51-65	18

In order to gauge the impact that the three applications have had on the learning outcomes of the participants who used them, the authors deployed a questionnaire. Five opinion scale or Likert questions were designed to investigate the perceived level of effectiveness that the participants experienced in using the applications. Participants were asked to give a vote between 1 and 5, with 1 indicating strong disagreement, 3 indicating a neutral opinion and 5 indicating strong agreement. Table 2 shows the list of questions given to the participants.

Table 2. Participants' Questionnaire

Questions	
The application provides sufficient realism: operating the web-based interactive application is extremely similar to operating the actual medical device	Q1
The application provides high level of interactivity	Q2
The application is easy to use	Q3

The application is innovative	Q4
The application doesn't require medical knowledge or skill	Q5
The application can be used even if one doesn't have technical skills and doesn't know a programming language	Q6
The application stimulates the development of intellectual skills such as learning by doing	Q7
The application enables you to improve your interest and to reinforce your retention	Q8
The application enables you to acquire more rapidly the technical skills than in an equivalent training in the real environment	Q9
The application enables you to familiarize with medical equipment: it is a great help in understanding the sequence of tasks to be performed in order to use the medical equipment	Q10

For each questions the mean of the results obtained by the 50 interviewers has been calculated. Table 3 shows the statistical study with the mean and the standard deviation of the different items in the opinion survey.

Table 3 - Mean (M) and Standard deviation (SD) calculated for each questions about students' opinion on the Web-based medical applications

Questions	Mean	SD
The application provides sufficient realism: operating the web-based interactive application is extremely similar to operating the actual medical device	4,16	0,618
The application provides high level of interactivity	4,04	0,669
The application is easy to use	4,76	0,517

The application is innovative	4,48	0,789
The application doesn't require medical knowledge or skill	4,76	0,431
The application can be used even if one doesn't have technical skills and doesn't know a programming language	4,84	0,37
The application stimulates the development of intellectual skills such as learning by doing	4,32	0,551
The application enables you to improve your interest and to reinforce your retention	4,16	0,584
The application enables you to acquire more rapidly the technical skills than in an equivalent training in the real environment	4,16	0,548
The application enables you to familiarize with medical equipment: it is a great help in understanding the sequence of tasks to be performed in order to use the medical equipment	4,18	0,523

As presented in Table 3, most of the respondents agreed that the applications were simple to use (Mean=4,76; SD=0,517), interactive (Mean=4,04; SD=0,669) and didn't require specific skills, ability or medical qualities (Mean=4,76; SD=0,431). This remarkable outcome encourages the use of these web-based applications in all the contexts of the health care (medical university, private or public healthcare settings, homes) independently by personal attitudinises, in particular medical experience. The participants found this web-based training extremely similar to real training (Mean=4,16; SD=0,618). Tested users agreed that the application allowed the learning by doing (Mean=4,32; SD=0,551) and to acquire more rapidly the technical skills than in an equivalent training in the real environment (Mean=4,16; SD=0,548). One explanation could be that with these Web-based applications, there is in theory infinite repetitive training sessions, which can be carried out in an unlimited timeframe. In other words, a trainee can choose his or her own pace, the number of repetitions, and at any time that suits him or her: reducing the time required to access to real instrumentation for the training practice. This is particular useful for the familiarization of the equipment and for the improving interest and retention (Mean=4,16; SD=0,548).

In order to check whether students' satisfaction with the medical applications differed according to age and computer skills and to investigate whether there was any interaction among these variables, a two-way analysis of variance (ANOVA) was conducted. Since the means of the results calculated for each question are almost similar (table 3), the median scores calculated for each interviewer have been used for the ANOVA (table 4).

Table 4 – Summary of course satisfaction (median scores) based on student's variables (Age and Computer skills)

		Computer skills		
		b	m	h
age	i	44	43	44
	ii	44	44	44
	iii	43.5	44	44

The table 5 shows the results of ANOVA. They indicate that students' satisfaction with the applications was not different in relation to age ($F= 0.5$, $Pr > 0.05$) and computer skills ($F=0.5$, $Pr> 0.05$). Therefore, no differences are found in satisfaction between younger and older students and among students with different computer skills. Thus, the hypotheses H1 and H2, proposed about the relationship between the level of satisfaction and age and computer skills, are not supported.

Table 5 - Two-way ANOVA for the course satisfaction based on student’s variables

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
age	2	0.16667	0.083333	0.5	0.64
computer skills	2	0.16667	0.083333	0.5	0.64
Residuals	4	0.66667	0.166667		

This is a very interesting result, because it could mean that the introduction of these applications in the community makes possible their use to people of all ages and with different computer experiences.

5. CONCLUSIONS

With the advent of 3D graphics and Virtual Reality technology, realistic models and simulations are becoming commonplace in both the teaching and practice of medicine.

In this work the authors describe the design and the implementation of Web-based interactive medical applications, aimed at the training of healthcare/not healthcare professionals on medical instruments such as sphygmomanometer, ECG and defibrillator.

The main reasons of the use of these applications are mainly justified by:

- growing employ of ICT in the context of medical education
- changes in health care delivery and academic environments that limit patient availability as educational opportunities

- worldwide attention focused on the problem of medical errors and the need to improve patient safety
- transfer of health care services from hospitals to the community and home settings, workplaces and public areas such as airports, airplanes, etc.

Cardiovascular disease is the leading cause of death in the world. Despite recent advances in resuscitation and cardiac life support, a lot of myocardial infarctions results in deaths annually.

A sphygmomanometer or blood pressure meter is a device used to measure blood pressure, exerted by circulating blood upon the walls of blood vessels. The physicians consider a patient's blood pressure when determining general health or diagnosing disease.

An electrocardiogram (ECG), usually obtained with a computerized recording device, is the most common diagnostic test for myocardial infarctions and other cardiovascular problems.

A defibrillator is a machine that can monitor heart rhythms. It can tell if the heart has stopped beating effectively. If required, the machine can then deliver an electric shock to the heart. Most of the time, this shock will restart the heart. Defibrillation improves survival rates by up to 30% if delivered in the first few minutes. With each passing minute, the probability of survival declines by 7 to 10%. For this reason it's essential to integrate early defibrillation into an effective emergency cardiovascular care system.

In the hands of someone (both hospital and non-hospital such as family members, police, fire-fighters, flight attendants, security guards, all first-responding emergency personnel, etc), who is trained, these devices are very effective in saving the lives of those experiencing cardiac arrest or cardiovascular problems.

These 3D medical applications imitate the real environments in which medical services are rendered, reproducing the patient, the anatomic regions and the clinical tasks necessary to the use of the instrumentations. The applications are highly interactive allowing users to perform the clinical tasks as if they used a actual device. Using interactive 3D modelling, the 3D model can be rotated around any axis, and panned or zoomed in any direction, enabling a better and more complete visualization and instigating an interactive learning process. 3D objects are presented on the Web and can be interactively navigated and it is beneficial for the students' conceptual understanding on the clinical tasks. These virtual medical devices are readily available at any time: there is in theory infinite repetitive training sessions, which can be carried out in an unlimited timeframe. This is particular useful for the familiarization of the device and the individual operations. It is possible manipulate these virtual models at the time when the students learn individually without the presence of the real device and the real patient.

In the paper a study was conducted to measure the students' perception of the 3D objects' effectiveness for learning. The result was very satisfactory indicating that these applications are interactive and easy to be used even without medical or technical experience. Their use is also possible to people of all ages and with different computer experiences. They are realistic and can positively assist students in learning how to operate a device but without actually handling a real device.

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