INTERACTIVE VIRTUAL REALITY SYSTEM FOR AUSCULTATION TRAINING

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Abstract

It is increasingly common to find virtual reality systems in any virtual field: education, industry, marketing and, of course, medicine. In this article, we will study a Virtual Reality system that allows medical professionals to practice in the auscultation process. We will analyze how we have created this system and the advantages that virtual reality systems have over traditional techniques.

Keywords: Innovation, immersive system, stereoscopic glasses, cardiac auscultation, virtual reality, medical training.

1 INTRODUCTION

The auscultation of the precordial area allows the identification of different noises in different foci of auscultation. The noises of these specific areas allow us to identify how your heart valves work and thus, to know the status of the heart.

[1] It has been two centuries since René Laenec, in 1816, used a rolled-up notebook to listen the heart of a patient with manifestations of heart disease (Barquin, 2007) (Fig. 1), creating the first ancestor of the stethoscope (of the Greek stethos=chest, heart skopeou=to observe), also correctly called stethoscope. Since then, there have been numerous instruments, increasingly accurate, to appreciate the different normal and pathological heart sounds. It was in 1960 when Dr. David Littmann, a professor at Harvard Medical School, a distinguished cardiologist and world-renowned authority on electrocardiography, patented a revolutionary new stethoscope with a vastly improved acoustic performance, which helped transforming a Simple listening device in a powerful diagnostic tool. Nowadays, electronic stethoscopes have a higher frequency response, a better sensitivity to sound and a higher accurate volume control to identify and appreciate the sound.

Learning how to accurately perform heart auscultation is an important skill for medical students, as this procedure can help in the diagnosis of many important heart problems. A cardiac auscultation must be done accurately; otherwise, the results will not be exact. Therefore, it is important to take the necessary time and carry out each step with confidence and precision.

Traditionally medical learning has been based on the observation and subsequent action of the student or medical resident, under the tutelage of the teacher or tutor. In this sense, the learning of medicine has taken place essentially at the bedside of patients, through direct contact with them. [2] However, without questioning the effectiveness of these traditional methods, there are now complementary resources that reinforce medical learning and training. It is therefore important to have technological resources that facilitate the training, required to acquire these clinical competencies. [3]
For this reason the realization of a virtual environment, immersive nature, for the learning of cardiac auscultation proves to be a favorable method in the process of medical training in this technique of exploration.

Our mission as medical professionals is to improve patient safety and make health care more effective by training students and medical residents using innovative, high-performance resources through clinical simulation technologies.

2 METHODOLOGY

We got the cardiac sounds using a Littmann® stethoscope (Model 3200), capable of recording sounds and later transferring them to a computer. The stethoscope has a sound amplification function of 24x and an environmental noise elimination system, which reduces this noise by an average factor of 85 percent and can interfere with auscultation (Fig. 2).

![Figure 2 Capturing heart sounds with stethoscope](image)

We have used the Unity 3D game engine to implement this immersive system. This tool is cross-platform, which allows us to use the same source code to create an executable for different platforms (with small adaptations), such as Android devices, iOS devices, WebGL... You can even use the development made for systems for game consoles, such as XBOX or Play Station, desktop systems for PC or Mac OSX, web pages ... It is therefore a very useful tool, since it also makes available for the programmer a set of tools which facilitate the creation of virtual environments.

We use the Unity3D programming methodology to create this system, according to which we divide the source code into different scripts, where each of them is related with a specific behavior. For the organization of all the scrips we use the software architectural pattern Model View Controller, which consists on organizing the source code (in this case the scripts) into three groups. In the first group, the Model, we have the scripts that save the information. In the second group, the View, we have the scripts related to the appearance of the application. In the last group, the Controller, we can find all the business logic of the application: the source code that controls all the application and interaction with the user, divided into different scripts or controllers [4].
We have used C# programming language, as this is one of the languages that Unity3D supports. Also it is a powerful language that allow us to implement all the source code using an Object Oriented language.

We also have to add different Game Objects (normally 3D models) to the scene. The most important ones are the human body, the stethoscope and the 3D points that indicate the different auscultation points. The stethoscope and the 3D points will have different components that control the interaction with the user. These components will be C# scripts. As an example, one script will control when the stethoscope is on an auscultation point, and what to do afterwards, in this case: play the corresponding audio.

Also there are some elements in the scene that are part of the View group, such us the buttons that allow the user to show or hide the skin of the human body or the auscultation points. To control the interaction between the user and these buttons, we will have an empty Game Object, that is an invisible Game Object. It will have a component attached that will control when a button is pressed or not, and what to do in that case. For example when the user press the button to hide the skin, the script will render or unrender the mesh of the 3D model related with the skin.

For the construction of this system, a room was created where each of the walls is decorated with a diagram or drawing with information about the different foci of auscultation in each wall (Fig. 4). Next, a stretcher with a human body in three dimensions was placed in the middle of the room. Then, four three-dimensional elements were placed, one at each of the auscultation points. The user can choose whether or not to see these listening points. The option of hiding and showing these points indicates the level of difficulty for the student when finding the points of auscultation (easier if they can see where to auscultate). The goal is that you can initially see them, but once they have practiced a number of times they should hide them to be able to identify them quickly.

We have also included a basic 3D model of a heart so that the student can also see his position in relation to each other of the foci. Therefore, it is also allowed to make the patient's skin translucent, so that they can see the interior of the patient.

One of the main features of this system is the following: the user is an active participant, which is one the best advantages of virtual reality simulations [5]. For the user's interaction with the immersive system, two different philosophies have been implemented. First, we implemented an alternative
application that turns any smartphone into a remote control, using the device's accelerometer and gyroscope, that are sensors that give us information about the orientation of the smartphone. Thanks to this system, we can detect and recognize the movements of the user's hand, and translate those movements to the virtual environment. This allows users to move the stethoscope with their own hands, making the experience more realistic.

Second, we implement other system where the user does not need any external device to interact with the virtual world, as he/she will be able to interact using the button of the glasses. Many Virtual Reality goggles feature one of these buttons, which allow the user to take the stethoscope and move it with the movement of his head to the desired auscultation point.

We implemented both interaction systems because many Virtual Reality glasses does not have any button to interact, so it was necessary to find another option, as we wanted all people to be able to use our system without spending money in specific glasses or virtual reality platforms.

Regarding the Virtual Reality technology used for the implementation of this project, we wanted the system to be available for the greatest number of devices. For this reason, two different technologies have been used: Cardboard and Samsung Gear VR. The first one allows virtually any current smartphone, for both Android and iOS, run the system and use a wide range of glasses available in the market. These glasses can be found from 2 euros, usually made of cardboard, up to more than 150 euros. This technology has been developed by Google, and although initially used with the glasses that they manufactured, there are currently countless manufacturers with glasses of many different qualities.

The system has also been created for Oculus devices and Samsung Gear VR (Fig 4). These devices have a slightly higher cost, and require certain smartphones to work with. In the case of Oculus Rift it is a pair of glasses that already incorporate a screen inside, reason why they do not need any smartphone to work, although they do require a connection to a computer of great power. However this last system is too expensive nowadays to be used for our auscultation system, available for everybody.

Both cardboard and Oculus glasses have different configurations available, as some people may need to adjust the interfocal distance, to avoid some inconveniences which may cause dizziness [6].

Once the stethoscope is placed on an auscultation point, a collision between them is detected and an audio associated with the auscultation point is released (Fig. 5). This audio may be different, depending on whether it is a healthy patient or one with a specific heart disease. The goal is, on the one hand, that the user quickly finds the point of auscultation, and on the other hand he should be able to recognize the sound and identify if it has any heart disease and what would be.
One of the greatest advantages of the virtual simulation of cardiac auscultation versus real auscultation is that the user will be able to practice as many times as he/she requires [7], without practicing with a real patient.

3 RESULTS

Cardiac auscultation requires an elementary knowledge of the anatomy and physiology of the heart. The blood that circulates in our body is a flow of liquid that, under normal conditions, does not sound because it flows in an orderly way. At rest, the heart normally beats between 60 and 100 times per minute. Each heartbeat is caused by an electrical impulse from the sinus node, made up of a group of cells in the right atrium that mark the heart rate under normal conditions. However, the moment something goes wrong (as a result of a stenosis, a regurgitation or anything that disrupts the normal course of blood molecules) the flow becomes turbulent, causing a noise that we call a murmur, which is what we try to detect with the stethoscope.

Our application is intended for training in the auscultation of the most basic heart noises. Aortic area: located in the second right intercostal space, right sternal border. Pulmonary area: located in the second left intercostal space, left sternal border. Tricuspid area: in the fourth left intercostal space, left sternal border. Mitral area: in the fifth left intercostal space, clavicular midline. When the user places the stethoscope on an auscultation point, he will see a small description of that area and listen the characteristic sound of the heart in that point (Fig. 6).
Medical simulation can be a good complement to practices in a real clinical environment. Our immersive interactive technological environment is a very useful tool in the learning process of cardiac auscultation. The integration of this new methodology of medical training also implies a change in the culture of university and hospital training with resident physicians and define the criteria that allow us to select the competences that best benefit from this type of training.

Our development therefore consists of a Virtual Reality software system that includes an artificial scenario with a virtual patient, in which the user has the impression of being with the patient and manipulating a stethoscope on the individual's thoracic surface. In this way we try to simulate the sensory perceptions so that the user takes them as real acting within the fictitious environment.

Through the use of stereoscopic vision glasses (or virtual reality glasses) we immerse ourselves in an environment where we visualize the patient for the cardiac exploration using the virtual stethoscope, which we can move on the surface of the patient to hear the different heart noises.

Among the most positive evaluations of our technological environment are the following: its high efficiency in the identification of the optimum auscultation point, the specific identification of cardiac noise, it facilitates the subsequent identification of the noises on a real patient and being a good method of medical training.

The final purpose using this technological application of clinical training has been the construction and simulation of an alternative and complementary clinical environment in medical training, which allows the professional to maintain virtual interaction with the patient, always seeking to achieve a sense of reality. These technological tools, with a proper use, can undoubtedly contribute to an improvement in medical training processes. The use of these technological systems with stereoscopic vision help us to improve the training in practical skills and the acquisition of medical knowledge, beyond the auscultation process.

4 CONCLUSIONS

[8] Simulation is not a technology, but a participant-centered learning technique or method based on our own experience, and in our opinion the key element is the training of instructors. Thus, the main limitation for their widespread application are the costs derived from their training in teaching methodology, and the time spent by them and the participants for each particular activity.

The results of simulation-based education depend on three factors: appropriate technical resources, enthusiastic teachers prepared to get the most out of them and integration into the curriculum. Only the intelligent combination, adapted to the circumstances of each institution, from highly realistic simulation activities to practices focused on more specific aspects (eg, task simulators for learning simple technical skills) and clinic experience will contribute to optimal learning outcomes.

The practical incorporation of these technologies into teaching-learning systems is becoming more frequent, however virtual reality is not widespread used yet [9]. Many universities around the world begin to use technological developments based on virtual simulations in their teaching practices [3], by using different devices such as stereoscopic vision glasses, gloves, motion sensors, etc.

Therefore, university environments are starting to make changes in education systems leading professional teachers to assume new responsibilities, based on the management and use of these emerging technologies.

The use of our simulator improves the skill in cardiac auscultation, being a useful and attractive alternative of training, that will help the users to recognize the cardiac noises on a virtual patient, and later on a real one. From the results of its assessment, it is clear that this system constitutes an excellent learning method.

This technological procedure of training in cardiac auscultation facilitates the training to acquire the clinical ability to differentiate the main cardiac noises. Our development shows the advantages of virtual reality techniques and immersive systems in the field of medical training.

The use of this simulator improved the skill in cardiac auscultation, being an attractive and useful training alternative, which helps to recognize the cardiac sounds on a real patient.
ACKNOWLEDGEMENTS

This project has been developed with the help of ARSOFT and Visual Med. ARSOFT is a Spanish company specialized in Augmented and Virtual Reality systems, and Visual Med is a research group of the University of Salamanca. Both organizations are located in Salamanca.

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