MEASUREMENT OF THE IMPROVEMENT IN ABILITY LAPAROSCOPY USING A VIRTUAL SIMULATOR

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Abstract. Laparoscopic surgery is a surgical technique which demands surgeon visuospatial and motor skills that seldom are exercised. The surgical instruments handling and laparoscopic camera navigation are complicated tasks in small spaces such as the abdominal cavity, where the visualized image is magnified and the size of the instruments reduces the skill, eliminates the tactile sensation and reduces kinesthetic force feedback to the surgeon. In addition, the surgeon must interpret a 3D space from images transmitted by video to a 2D monitor. LAPAROS is a developed tool thanks to the multidisciplinary work of the Computer Graphics Laboratory, the Bioengineering Center and the Experimental Surgery Institute at the Central University of Venezuela. This system for laparoscopic surgery training presents a dual platform: mechanical and virtual simulator. The mechanical simulator SIMULAP v.1 has been developed bearing in mind design aspects resembling to the human torso. The virtual simulator provides three training levels: basic, average and advanced, each one focused to develop specific abilities and skills in the surgeons. In this work we present the measurement of the effectiveness of the basic level of our system in the laparoscopic training process. The tests were applied to a group of seven expert surgeons in laparoscopy and to eleven medicine students without any knowledge in the area. These tests consisted in the accomplishment of seven training sessions in the virtual simulator and one in the mechanical simulator. The results were obtained through careful measurement of the movement precision, ability in handling of instruments and speed of execution of the exercises proposed in the mechanical simulator.

Keywords: Laparoscopy, Simulation, Virtual Reality, Surgical Training, Tests.
1 INTRODUCTION

Laparoscopic surgery, or Minimally Invasive Surgery (MIS) is a new surgery technique that reduces the risk of complications and the patient recovery is faster than with traditional surgery. In this procedure, a laparoscope is inserted through a 10 mm incision in the abdominal wall. A camera mounted on the laparoscope transmits the image to a monitor. The surgeons handle the camera and the instruments inside the abdominal cavity based on the visual feedback of the image displayed on the monitor [1].

Evidently, this technique presents some difficult situations to the surgeon. The surgeon should develop the ability of interpreting two-dimensional images out of a three-dimensional real environment, corresponding to the abdominal cavity of the patient. Additionally, the instruments reduce dexterity, eliminate tactile sensation, and reduce kinesthetic force feedback [2,3]. The lack of a stereoscopic image and limitation on resolution, contrast, and color inherent in video imaging increase moreover the difficulty of the procedure [3].

Laparoscopic training by the simulation allows the surgeon to develop and acquire the skills demanded for this surgery through practice, increasing surgeon’s experience and patient safety [4,5,6]. LAPAROS is a laparoscopic surgery training system that offers a mechanic [7] and virtual reality simulator using the same hardware. The virtual simulator is conformed by three training levels associated to specific abilities and skills.

In this paper we present the system LAPAROS and the tests [8] that were made to measure the effectiveness of the basic and intermediate level of the virtual simulator. The tests were applied to eighteen persons, seven expert surgeons in laparoscopy and eleven medicine students without any train in the area. After initial evaluation in the mechanic simulator, divided randomly to the persons in a group A trained in the virtual simulator during seven training sessions and a control group B no practice. Each group was reevaluated in the mechanical simulator. Finally, we compared and analyzed the performance scores for initial versus final test of both groups.

2 THE LAPAROS SYSTEM

LAPAROS is a laparoscopic surgery training system that offers a mechanic and virtual reality simulator using the same hardware. The hardware component is mainly conformed of a mechanical simulator and a tracking subsystem adhered to the laparoscopic instruments. The software component of the virtual simulator exploits current technology in virtual reality and 3D computer graphics. Hardware component were developed at the Bioengineering Center, UCV and software components were developed at the Computer Graphics Lab, UCV. The system was tested at Experimental Surgery Institute of our university.

2.1 The Mechanical Simulator

SIMULAP V-1 [7], as shown in figure 2, is a mechanical simulator that resembles the size and shape of a male abdomen. This allows accommodate the tracking subsystem when working as part of the virtual reality system, or a real camera when working as isolated mechanical simulator. In addition, the trainee can incorporate different laparoscopic instrument.

The top frame can be inclined or removed. It has several openings strategically located to simulate several surgery procedures. The openings have special rubber gums that simulate resistance of the body tissue to the insertion of the instruments.
Figure 1: Two views of the SIMULAP V-1 mechanical simulator, showing the top frame, the base, the openings and the removable camera holder.

2.2 Virtual Reality Simulator

Observation and analysis of the training sessions for medical students in laparoscopy surgery, conducted at the Experimental Surgery Institute (UCV), allowed us identify the main abilities that should be trained. These abilities were classified in three training levels: basic, intermediate and advanced. Table 1 summarizes the abilities associated with each level.

Table 1: Summary of laparoscopic abilities associated to each level.

<table>
<thead>
<tr>
<th>Basic</th>
<th>Intermediate</th>
<th>Advanced</th>
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<tbody>
<tr>
<td>Precision</td>
<td>Camera navigation</td>
<td>Dissecting</td>
</tr>
<tr>
<td>Spatial orientation and perception</td>
<td>Instruments handling</td>
<td>Suturing</td>
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<tr>
<td>Hand-eye coordination including</td>
<td>Grasping</td>
<td></td>
</tr>
<tr>
<td>dominant and non-dominant hand</td>
<td>Cutting</td>
<td></td>
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Each exercise in our virtual system is designed to improve abilities correspond to one of the training levels and their complexity can be configured. Additionally, the system measures the time performance and precision of the trainee. Figures 3, 4 and 5 show the LAPAROS’s workstation displaying some of the exercises incorporated by the system. Together each figure, we have included a review of the exercise.

Across the rings
Description: The trainee must go through different color rings using a needle, dominant and non-dominant hand can be used.
Evaluation: Starting from a maximum score, points are subtracted when the trainee touches the border of a ring. The trainee obtains a perfect score only when no borders are touched.

Figure 3: Exercise corresponds to basic level designed to increase the precision of the trainee during the movement of the instruments.
Putting the figures
Description: The trainee must take each figure and put it on the rectangle of the same color in the predetermined time, using his dominant and non-dominant hand.
Evaluation: The final score depends on the number of spheres placed correctly in the predetermined time and the times that the trainee touches other rectangles or exceeds the board.

Figure 4: Exercise of intermediate level designed to train the ability of grasping.

Cutting the threads
Description: The trainee must cut the section coloured of the thread in the predetermined time, using his dominant and non-dominant hand.
Evaluation: The final score depends on the number of sections cut correctly in the predetermined time and the times that the trainee touches or cuts outside this.

Figure 5: Exercise of intermediate level, designed to train the ability of cutting.

3 TESTS

These tests allowed evaluate the effectiveness of the basic and intermediate level of the virtual reality training system. Initially, the key test was applied to eighteen persons, seven expert surgeons in laparoscopy and eleven medicine students without any train in the area. After initial evaluation in the mechanic simulator, divided randomly to the people in a group A trained in the virtual simulator during seven training sessions and a control group B no practice. Each group was reevaluated with the key test in the mechanical simulator. Finally, we compared and analyzed the performance scores for initial versus final test of both groups and the performance (precision and time) in the virtual simulator during training sessions of the group A.

3.1 Key Test

The key test allowed us to measure the effectiveness of the system through the comparison of the results of both groups. This test was developed in the mechanical simulator and consisted in construct four towers of plastic beads of the same color in the smaller possible time and without fall down the tower. A restriction of the exercise was that the trainee should not loosen the bead once that has taken it to place it.
3.2 Training Session

The trainees belonging to the group A made seven training sessions before being reevaluated in the mechanical simulator. A training session consist in achieve three times all virtual exercises. The information thrown by the system in each training session was recorded and compared.

3.3 Results

The score thrown by the seven training sessions demonstrates that the continuous practices in the virtual simulator diminish the time of accomplishment and improve the precision of the trainee during the virtual exercises. The figure 6 shows the performance score average of the trainee in each exercise of the training sessions.

![Figure 6: Comparative graphic of the exercises in each training session.](image)

Improvement in the performance of all the exercises could be observed. The performance measured in the last session of training of exercise 1 showed an improvement of 13.63% with respect to the performance of the first session, the exercise 2 showed an improvement of 13.33%, the third exercise 23.07%, the exercise 4 showed an improvement of 5.48% and the fifth exercise 7.84%.

With respect to the key test, it was observed that the average of the score of the initial evaluation of each group was very similar. Nevertheless, the final evaluation showed a better performance for Group A. The performance of the Group A improved in a 22.43%, while that the Group B showed improve of 5.63%. This indicates that the training in the virtual simulator improves the laparoscopics abilities, specifically the precision and space coordination necessaries in the established key test.

The results demonstrated us that the virtual simulator of laparoscopic training is an excellent tool to train the laparoscopics abilities of the surgeons.
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REFERENCES


