VIDEO-BASED TRAINING FOR LAPAROSCOPIC SURGERY

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ABSTRACT

Current laparoscopic cholecystectomy surgical training programs lack the ability to accurately convey cognitive skills, an aspect which is essential to properly training skillful surgeons. Laparoscopic cholecystectomy is the noninvasive surgical removal of the gallbladder. Our Capstone group has developed a laparoscopic cholecystectomy surgical training program that conveys the cognitive skills necessary to identify varying anatomy, and the experience necessary to recognize and effectively make timely decisions regarding the anatomy.

Our program is computer-based to allow for interactive modules. Training sections combine real laparoscopic cholecystectomy videos with annotations to familiarize users with laparoscopic images. Surgical sections are viewed in repetition using various surgical videos, to enforce absorption, expose the user to varied anatomy, and stress crucial procedures. Experimental testing and evaluation of this program with medical students at the University of Virginia revealed an increase of 10 percent in cognitive skills as measured by pre-test/post-test sets of test questions. Various statistical tests verify the central conclusion of this study: video repetition is a significant method of training surgical cognitive skills. Once implemented this program could possibly reduce the chance of surgical mistakes during laparoscopic cholecystectomy, thereby increasing patient safety.

INTRODUCTION

Cholecystectomy, the surgical removal of the gallbladder, is one of the most prevalent surgeries in the United States (Ress 1993). Before the late 1980s, this surgery had to be "open," requiring surgeons to make a large incision across the abdomen to expose and remove the gallbladder. Thanks to a revolution in surgical technology, these surgeries are now almost exclusively performed using a minimally invasive surgical procedure called laparoscopic cholecystectomy (Stiegmann 1997). The laparoscopic procedure reduces the risks common to invasive cholecystectomy and provides the patient with a shorter hospital stay and recovery time. Laparoscopic cholecystectomy is performed by making four small incisions in the abdominal cavity. A laparoscope equipped with a camera is inserted into one of these small incisions, and the magnified view of the inside of the cavity is projected onto video monitors located on either side of the operating table. Two or more surgeons use the video image and manipulate specialized instruments through three other incisions to perform the actual surgery. Our Capstone group's software tutorial aims to provide medical students, interns and residents with increased exposure to the laparoscopic view, aiming to improve their recognition of the critical anatomical structures in a "safe", laboratory environment.

The present instructional methods for laparoscopic cholecystectomy are lacking. Currently, medical residents learn how to perform laparoscopic surgery as an apprentice to a senior surgeon. While this experience is valuable to the resident, laparoscopic surgery provides new challenges that are difficult to surmount using traditional training techniques. The adjustment to the new two-dimensional image of the patient's anatomy is one such challenge. Current training has fallen short of providing accurate depth perception and haptic feedback, resulting in errors such as bile duct injury, unplanned perforations, and bleeding (Cowan 1998). In a study by William A. See *et al.,* surgeons who performed laparoscopic procedures without additional training after completing an 18-day training seminar were 3.39 times more likely to have at least one complication compared with surgeons who sought additional training after the course (1993). Similar findings from a study done by Moore *et al.* found that the chances of a bile duct injury occurring during a procedure conducted by an experienced surgeon decreased from 1.7% during the first case to .17% after 50 cases . Ninety percent of bile duct injuries occurred within the first thirty cases performed by an individual surgeon (Moore 1995). Our project provides surgeons with significantly more exposure before they even arrive in the operating room, and we hope that such training will decrease the errors made during surgeons' initial cases.

Our Capstone group collaborated to produce and test a preliminary version of a laparoscopic cholecystectomy computer-based training tutorial. We edited images from actual laparoscopic surgeries to create the software. The product's major features include an introduction section highlighting the pertinent segments of laparoscopic cholecystectomy through narration by an expert surgeon, a training section capable of switching back and forth among videos, within a video, or among specific segments of the surgery, and a testing section with both objective and video-based questions that include graphical annotations. Once we had completed the software package, we then designed and conducted a study to evaluate the software's effectiveness.

EXPERIMENTAL DESIGN

A between-subjects experimental design was used to compare the effectiveness of two training methods: a "freeform", "view as you please" training section, where subjects could watch a set of laparoscopic cholecystectomy videos in any way that they chose (the Control Group), or a more structured training section that repetitively showed the same procedures from the set of surgery videos available (the Treatment Group). Performance was measured using two sets of question banks that were designed to be equivalent in difficulty and subject matter. One of the two question banks was administered to each subject as a pre-test, and then the other question bank was given as a post-test after the training section of the video. The order of the question banks was controlled and counter-balanced to offset any difference in question bank difficulty.

Subjects

Three general surgeons and three general surgery residents, all familiar with LC, participated as beta test subjects. Suggestions made by the beta testers allowed us to improve our question banks and correct minor usability issues in the program.

Forty University of Virginia medical students participated in the actual experiment. After the first 10 trials, a software recording error was discovered. Thus, the data from these subjects were not used. The data reported here include the final thirty subjects, 14 in the Control Group, 16 in the Experimental Group.

Procedure

Figure 1 illustrates the sequence of activities performed by subjects in our experiment. Subjects began by filling out a demographic sheet that asked for year in medical school, school attended, experience

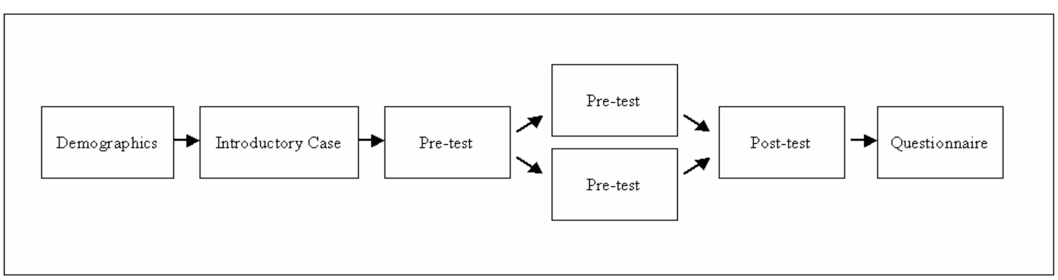

Figure 1: Program Architecture

with laparoscopic cholecystectomy (watched videos, read about procedure, used computer-based training, watched live surgeries, operated camera, or performed surgery), and native language. Subjects were then given short directions regarding the upcoming program segment. The directions were also accompanied by audio and the subject was not allowed to progress to the next step until the audio directions were completed. This ensured that the participant at least heard the directions once.

Subjects then watched and listened to a 15-minute introductory video. The introductory video briefly describes each pertinent segment of the surgery. This section of the program was designed and narrated by an expert laparoscopic cholecystectomy surgeon.

After the introductory video, subjects were given directions concerning the upcoming pre-test. The directions let the subject know they were about to take a 20-question test, and that each question was either an objective non video-based question or a subjective video-based question. The instructions also informed the subjects that they had 30 seconds to answer the objective questions and 45 seconds to answer the video-based questions. The administered pre-test would be one of two test banks, generated to be equivalent in difficulty and subject matter. During the test, subjects had the ability to answer a question as soon as it was asked and could replay the video if they desired. However, replaying the video did not give them any additional time to answer the question. Both their answers and the time it took them to answer were recorded and automatically placed in a Microsoft Excel spreadsheet by the software package.

Following the pre-test, was the training section of the software. The training section differed depending on whether the subject was in the experimental group or the control group, which was randomly decided by a coin flip when a subject entered the testing room (two subjects usually participated at a time, one in the Control Group, one in the Experimental Group). The training sections for both subject groups took exactly 27 minutes to complete. The experimental version of the Training Section breaks the surgery down into its key subdivisions. In chronological order, it traces through the surgery, showing three key instances of each surgery segment deemed critical. Again, the time-efficiency of our software tutorial is illustrated. A resident can spend over one hour in the operating room and only witness one case; with our training segment, a resident is exposed to all the key parts of the surgery for three separate cases in under half an hour.

The control version of the training section provides subjects with three entire case videos (the same ones used to generate the experimental video segments). The subjects have the ability to switch among the three videos as often as they like, and can fast-forward or rewind within a particular video. This set-up almost replicates the current available technology; residents can make the effort to find and retrieve entire case studies documented on VHS and use their own time to navigate through them in an attempt to learn. Control and experimental versions of the software training section were designed to test the impact of repetition; all other sections of the software were kept consistent between subject groups to limit confounding variables.

After the training section, subjects completed the 2nd test bank (the one not completed as the pre-test) as a post-test and the software once again recorded both their answers and answer times. Finally, the software played a thank you message and credits were shown referencing the design group, the medical consultants involved, the sponsoring organizations, and finally our technical advisor. The subjects were then directed to remove the headphones and fill out a brief subjective questionnaire

RESULTS

This section summarizes the data collected through subject testing and draws conclusions based on that data. Various aspects of the program were evaluated, including the equivalency and appropriateness of test banks and the significance of the control and experimental versions in conveying cognitive skills. We also verified the equivalency of the subject samples and the significance of the video repetition feature used in the experimental version. Various t-tests and stepwise linear regressions confirm or deny the significance of each aspect of the program.

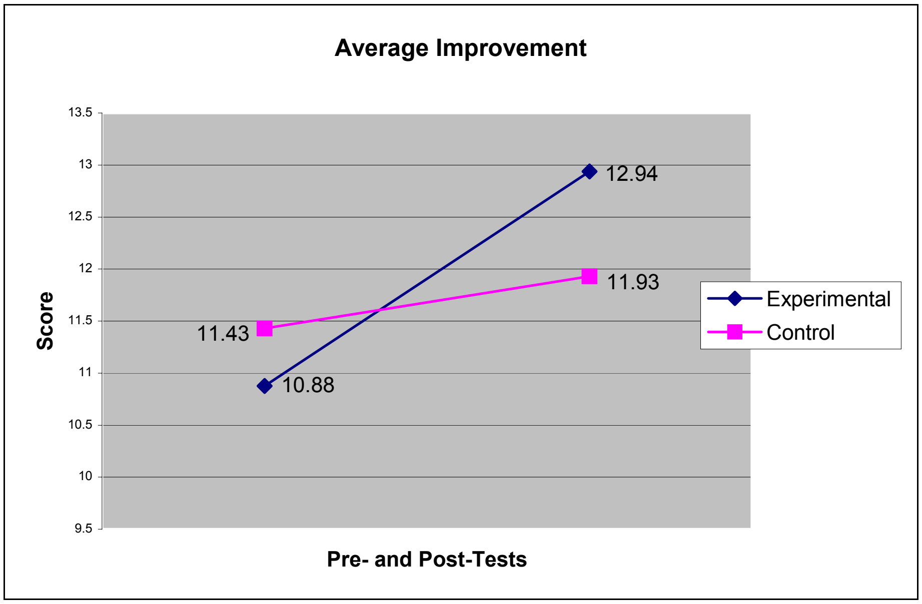

Figure 2: Experimental vs. Control Improvement

Summary of Results

Subject demographics are summarized in Table 1. No significant differences were found in any category between the two groups. Figure 2 shows the average pre-test and post-test scores for the two subject groups. Scores are calculated as the number of questions the user answered correctly, out of a possible twenty. The times are equal to the sum of seconds the user required to complete timed questions. Using the two-tailed t statistic, there is no statistically significant difference between the scores of the two groups on the pre-test or the post-test. Control subjects on average increased their score by 0.50 points, while experimental subjects on average increased by 2.06, (more than fourteen percent higher). Using a one-tailed t-test, this within-subjects difference in scores from pre-test to post-test is significant for the Experimental Group ($p < 0.05$), but not the Control Group ($p = .27$). The improvement value from pre-test to post-test for each group was also compared. Using a one-tailed t-test, the Experimental Group was found to have statistically improved more than the Control Group ($p = .023$). Box plots for improvement between the two groups is shown in Figure 3 on the next page.

Control subjects decreased their times by an average of 39.07 seconds, while experimental subjects decreased by 45.94 (a six percent greater reduction). Both within-subjects and between-subjects analyses show that these differences in times are not significant.

To test the equivalency of the two test banks, scores by all users who took test bank A as the pre-test and all those who took test bank B as the pre-test, regardless of program

	Background Information				Education			
Group	Age	Gender (M)	Lang	Med School (Uva)	1st Yr	2nd Yr	3rd Yr	4th Yr
Experimental	23.81	69.00%	100.00%	100.00%	43.75%	25.00%	25.00%	6.25%
Control	23.43	64.00%	86.00%	100.00%	71.43%	14.29%	0.00%	14.29%

	Experience with Lap Chole										
Group	None	Lectures	Books	Pictures	Videos	Comp	Sims	Obs(1-5)	Cam	Jr. Surg	Sr. Surg
Experimental	50.00%	12.50%	25.00%	25.00%	12.50%	0.00%	0.00%	37.50%	12.50%	0.00%	0.00%
Control	71.43%	14.29%	14.29%	14.29%	0.00%	0.00%	0.00%	21.40%	7.14%	7.14%	0.00%

	Experience with Training Methods						
Group	Lectures	Books	Pics	Vids	Comp	Sims	None
Experimental	43.75%	50.00%	50.00%	31.25%	31.25%	12.50%	62.50%
Control	37.50%	37.50%	25.00%	25.00%	12.50%	0.00%	71.43%

Table 1: Demographic Summary

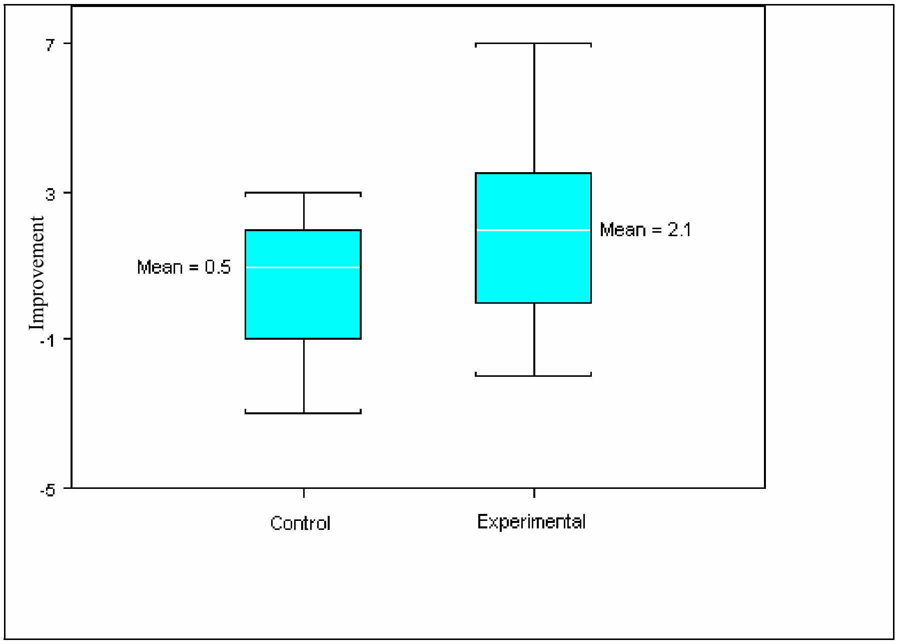

Figure 3: Improvement Box Plots

version, were compared. Using a two-tailed t-test, scores are not significantly different (Mean score for Test Bank A = 1.5; mean score for Test Bank B = 1.08; p = 0.62).

To gain a more complete understanding of all of the significant predictors that contribute to score improvement, and to once again verify the significance of video repetition, we ran a stepwise linear regression using *S-PLUS*. This analysis showed that educational level, previous LC experience, and training program version are the only significant predictors of improvement. Improvement increases with decreasing educational level, increasing LC experience, and the experimental version.

T-tests and a linear regression model reveal the significance of program aspects, especially the video repetition feature. Conclusions based on the data set are valid due to the equivalency of the test banks and subject samples. Although this is a pilot version of the program, testing has revealed the significance of the training methods used. This significance justifies further evaluation of the pilot program as well as development of enhanced iterations.

CONCLUSIONS

This study provides a solid foundation for future designs of medical computer-based training systems. Possible improvements to the knowledge transfer process outlined in this report can be made through the following modifications:

1) More Extensive Training Section. The training section in the current version of the software only lasts 27 minutes or about half of an entire laparoscopic cholecystectomy case. It would be useful to extend this time and compare the improvement shown by a subject that watches an entire case and one that watches clips for the same duration of time.

2) Additional Educational Enhancements. Audio could be added to the training section of the software as was done in the introductory case. Additionally, visual cues could be added to the videos to improve cognitive structure recognition. Multiple subject groups could use different versions of the software with these enhancements to determine their impact on the knowledge transfer process.

3) Validate with Actual Surgical Performance. The results from the software training should be validated with performance during actual laparoscopic cholecystectomies. Eubanks has developed a laparoscopic cholecystectomy scoring system that could be used for this purpose (566-574). Validation with surgical performance could not be done with the medical students who were subjects in this project because medical students do not perform surgeries. Surgery residents would be more appropriate subjects for this validation procedure.

Potential Impact

The laparoscopic cholecystectomy computer-based training program developed here has the potential to change medical education dramatically. Combined with the technical skill trainers already widely available, this program can teach the anatomical structure recognition skills that can only be gained through experience of watching actual surgeries. As laparoscopic surgery is done by watching a video while manipulating instruments, this cognitive skill trainer that we have developed is a highly realistic and now proven method for teaching required skills. Improved laboratory education in laparoscopic cholecystectomy could lead to a reduction of the serious common bile duct injuries that often occur during a surgeon's initial laparoscopic cholecystectomy cases. It is presumed that this technology could easily be expanded to teach cognitive perceptual cue recognition skills for other laparoscopic procedures. Perhaps with 3-D video technology, the same system could be used to teach open surgeries as well.

This part-task training methodology of using videos to selectively train practitioners on critical cues to be recognized has a theoretical basis in judgment and decision-making literature (Bisantz et al. 2000; Klein 1989). It has been demonstrated to be an effective technique for training football quarterbacks to recognize plays once the ball has been hiked (Walker et al. 1994) and to train pilots to recognize critical visual cues during visual landings (Kellman and Kaiser 1989). Our study has shown that this technique applies to surgery, and has demonstrated a much safer and more efficient method for training medical students and residents on what is considered to be the "training" case for laparoscopic surgery (cholecystectomy), than the current apprenticeship method used throughout the world.

REFERENCES

Biffl, Walter L. MD, FACS, et al. (2001). "Routine intraoperative laparoscopic ultrasonography with selective holangiography reduces bile duct complications during laparoscopic choecystectomy." *Journal of the American College of Surgeons* 193.3: 272-280.

Bisantz, A., Kirlik, A., Gay, P., Phipps, D., Walker, N., & Fisk, A. (2000). Modeling and analysis of a dynamic judment task using a lens model approach. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans, 30*(6), 605-616.

Cowan, Leticia, and Greg Smestad, (1998). "Cutting deeper into technology's role in medicine." *OE Reports* (January). 2 October 2001.<http://www.spie.org/web/oer/january/jan98/cowan.htm>.

Kellman, P., & Kaiser, M. (1994). *Perceptual learning modules in flight training.* Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, Santa Monica, CA:HFES 1183-1187

Klein, G. A. (1989). Recognition-primed decisions. In W. B. Rouse (Ed.), *Advances in Man-Machine Systems Research* (Vol. 5, pp. 47-92). Greenwich, CT: JAI Press.

Moore, Michael J. PhD, Charles L. Bennett MD PhD, (1995). "The Learning Curve for Laparoscopic Cholecystectomy." *The American Journal of Surgery* 170.1: 55-59.

Ress, Andrew M., Michael G. Sarr, David M. Nagorney, Michael B. Farnell, John H. Donohue, and Donald C. McIlrath, (1993). "Spectrum and Management of Major Complications of Laparoscopic Cholecystectomy." *American Journal of Surgery* Volume 165 (June): 655-662.

See, William A., Christopher S. Cooper, and Ronald J. Fisher, (1993). "Predictors of Laparoscopic Complications After Formal Training in Laparoscopic Surgery." *Journal of the American Medical Association* Volume 270 (December): 2689-2692.

Stiegmann, Gregory V., (1997). "Commentary: Advanced Laparoscopic Surgery." *American Journal of Surgery* Volume 173 (January): 19-20.

Walker, N., Fisk, A., Phipps, D., & Kirlik, A. (1994). *Training Perceptual-Rule Based Skills.* Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting. , Santa Monica, CA:HFES 1178-1182

Eubanks, T. R., Clements, R. H., Pohl, D., Williams, N., Schaad, D. C., Horgan, S., and Pellegrini, C. (1999). An Objective Scoring System for Laparoscopic Cholecystectomy. J Am Coll Surg, 189(6), 566-574.

BIOGRAPHIES

K. Brook Green is a fourth-year Systems and Information Engineering major from Denver, Colorado, concentrating in management systems. She concentrated on test design, administration, and analysis for this project. Post-graduation, she plans on relocating to New York City for a brief outing in the real world before pursuing graduate education in a field other than engineering.

Maranda S. Luniewski is a fourth-year Systems and Information Engineering major and Electrical Engineering minor from Palmyra, VA, concentrating in control systems. She concentrated on test design, administration, and analysis for this project. When not immersed in E-School work, she enjoys participating in the Society of Women Engineers, Alpha Phi, and the Order of Omega. She will begin work at Northrop Grumman in Baltimore, MD this September.

Todd C. Mersch is a fourth year Systems and Information Engineering student at the University of Virginia. He is graduating with a concentration in Management Systems and also demonstrates superior abilities in software design and development. He developed these skills while interning at Davenport & Co LLC, Virginia's oldest securities firm. Next year, he will be working for the Mission Systems division of the Lockheed Martin Corporation in the Engineering Leadership Development Program.

Brian A. Mitchell is a fourth year Systems and Information Engineering major and Biomedical Engineering minor from Columbus, Ohio. His major contribution to this project was working on the knowledge acquisition and transfer process. Next year, he will attend medical school.

G. Reed Poole is a fourth-year Systems and Information Engineering major from Virginia Beach, VA concentrating in management systems. His principal contribution to the project was knowledge acquisition and video editing. Next year, he will be applying to medical school.