SURGICAL LEARNING AID: REDUCING UNCERTAINTY FOR THE NOVICE DURING SIMULATED MINIMALLY INVASIVE SURGERY

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Can a procedural learning aid assist novice surgeons in reducing uncertainty and workload during critical points of minimally invasive surgery in an OR environment? Twenty Tufts University students performed a multi-step cutting task on a laparoscopic skills training simulator, with and without a multi-media procedural learning aid. A simple between subjects design was used. The results showed that those subjects who used a learning aid while completing the procedural cutting task were significantly faster ($p = 0.02$). However, subjects’ perceived workload with and without the learning aid were not significantly different. These results have implications for the teaching of residents and communication between experts and novices in the OR.

INTRODUCTION

Novice surgeons are held to very high standards even during their training. They are required to recognize symptoms, make diagnosis, assist in surgical and non-surgical tasks, and be proficient and attentive to details throughout the service (Bosk 1979). However, with the increased proliferation of medical information and new technology, compounded by the shortened work week (Accreditation Council for Graduate Medical Education 2002), there is a large physical and cognitive burden placed upon the novice. We observed that novices required a great deal of guidance and reassurance from more expert surgeons, a requisite part of the medical training cycle. But how does this learning model and other burdens affect their performance during safety critical tasks in the operating room (OR)? More specifically, can a procedural learning aid be useful in reducing this uncertainty and reducing mental workload, thereby increasing the overall safety in the OR? A learning aid could serve to promote procedural knowledge, reinforce proper procedure and remind surgeons about safety-critical aspects of surgery.

Preliminary research was conducted on communication techniques and decision making strategies employed in the OR at a local teaching hospital in Boston. Based on direct observation and video analysis of minimally invasive procedures, the OR environment observed was highly demanding of cognitive resources with a minimum reliance on communication technology, consistent with previous findings (e.g. Moss & Xiao 2004; Parker & Coiera 2000; Coiera & Tombs 1998). A majority of the procedures observed required an attending (expert) and two assisting surgeons (one more senior and one junior resident). The attending served as the primary decision maker and therefore directed the pace of the procedure. The senior resident (semi-novice) actually handled a laparoscopic tool while the junior resident (the complete novice) operated the camera. Therefore, most of the communication was done between the semi-novice and the expert. Although the novice did ask questions, he or she mostly held the camera still and observed the procedure.

Through studying several cases and subsequent interviews with the expert surgeon, it was also found that many procedures do not follow a strict linear sequence. With the help of the expert, a hierarchical task decomposition of laparoscopic inguinal hernia was created as a blueprint. The blueprint was then compared with actual observed laparoscopic inguinal hernia procedures. Although the actual procedures followed the general pattern of the blueprint, each had its own intricacies.

For novice surgeons who have only a general idea of how a procedure should progress, these
case-based variations could be difficult to map to the blueprint. The complete novice, playing the more passive role, may not be in a position to interrupt the flow of the procedure to ask questions about these variations. For the semi-novice, who is more intent on tool manipulation and details pertinent to the on-going procedure, these variations may not map to greater procedural knowledge. Furthermore, the OR is an environment within which work and communication is continually being interrupted, which could negatively impact memory and lead to errors (Parker & Coiera 2000). Therefore, learning is easily degraded by the nature of the OR environment and individual elements of a given procedure.

The goal for this study was to explore the potential benefit of a procedural learning aid to be used in the OR. A learning tool can aid the novice surgeon by reducing cognitive demands, reducing uncertainty and increasing confidence without forgoing the natural and needed communication between the surgeon and novice. This would also help in increasing overall patient safety in the OR. The design was meant to remind and inform novices at critical points of a procedure using a multimedia format. Previous research has shown that multimedia presentation of procedural information aided in the recall of sequential ordering of steps (Brunyé et al. 2004). Our learning aid was designed to exploit this cognitive model by providing redundant procedural information in various representations.

For an enabling technology, such as a procedural learning aid, to be embraced in the OR it must not increase cognitive workload and interruptions to workflow. Preferably, the technology would provide useful information and enhance group interactions. It must also be intuitive, and able to be integrated with existing technology, to be effective and usable. Ineffective ways of integrating technology have caused major problems with older generation surgeons (O’Cathain & Thomas 2004; Bekker et al. 2002). The new generation of surgeons is more open to the use of technology to aid their work, especially if it could be integrated into their education. Therefore, the new generation of surgeons is in a better position to benefit from new communication technology.

Of note is the fact that the purpose of this aid was not to take away from the usual learning models but to enhance them. The most frequently observed learning model centered upon the novice directly asking the expert various questions and asking for confirmation. This learning model is an invaluable process that is essential to learning. The proposed aid was purely to supplement that learning by facilitating discussion and decreasing the cognitive burdens on the novice. It was hypothesized that a procedural learning aid would help reduce workload and time to task completion in a complete novice. This would require a series of experiments, the first of which is presented in this paper, to show the aid’s potential value. The hypothesis was tested by complete laparoscopic novices using a simulated laparoscopic task. The task was adapted from one of the tasks in the Fundamental Laparoscopic Skills (FLS) test battery administered by the Society of American Gastroenterologists and Endoscopic Surgeons (SAGES).

**METHODS**

**Participants**

Twenty Tufts University undergraduate students (13 females and 7 males) participated in the study. None had experience in laparoscopic surgical tasks. Participants were randomly divided into two groups.

![FLS Training Simulator](image)
Apparatus

A Fundamental Laparoscopic Skills (FLS) training box was used to simulate the endoscopic environment. The box represented the human abdomen, with slits for two laparoscopic tools (scissors and grasper) and an endoscopic camera (see Figure 1).

Materials

Two square pieces of mesh, each with a different pattern drawn upon it, were used. One mesh featured a triangle outlined in black ink and was used to measure the baseline skill of subjects in cutting along the line. The test mesh was designed to be a multi-step cutting task (see Figure 2). Microsoft PowerPoint was used to create a tutorial for the participants to learn the six-step procedure. The learning aid, which comprised of a two-panel design featuring a textual and a pictorial representation of the procedural task, was provided to one group of subjects (see Figure 3).

Procedure

After a brief explanation of the apparatus and materials, the participants were allowed to handle the tools in the FLS without touching the mesh. Once they were comfortable, the experimenter began timing. Participants had five minutes to cut the baseline pattern. A NASA-TLX questionnaire was then administered to assess their perceived workload.

Afterwards they were shown a tutorial on PowerPoint consisting of six steps in a certain order. They were allowed as much time as needed to memorize the procedure as if they were novice surgeons using the tutorial to learn. Once the procedure was memorized they were told whether they received a learning aid or not. Even if they received an aid they were told to try to complete the procedure from memory. Again, the subjects were timed until they had completed the six-step process with no time limit. Another NASA-TLX questionnaire was administered to assess the perceived workload of the second task.

Design and Analysis

A simple (Learning Aid: Aid, No Aid) between subjects design was used. Each participant completed the same baseline and test task; half the participants received a learning aid in the test condition and half did not. The dependent measures were task completion time, in seconds, and subjective workload. A series of paired 2-tailed t-tests were used to compare the two different conditions (aid and no aid).

RESULTS

Task Completion Time

Results showed large variability in the data between the two conditions when comparing the
times directly (see Figure 4). After accounting for individual differences by subtracting the baseline time from the test time, analysis showed that subjects were significantly faster when using the procedural learning aid ($p = 0.02$).

![Figure 4. Average Time (in seconds) and the Time Difference (Test - Baseline) for Each Condition.](image)

**DISCUSSION**

Although the original hypothesis was not fully supported by examining the dependent variables, the learning aid did seem to help in task performance. Many of the participants who received the learning aid noted that the task would have been much harder to complete without an aid, even though the workload measure did not reflect that. Also, all those who received the aid reported using it for confirmation during the procedure, suggesting its usefulness.

The workload measurement used was a highly subjective one. Since this was a difficult task for novices to learn, especially after minimal training, it is not unusual for the highly variable workload scores. Some subjects rated the baseline task as being more demanding than the test task, perhaps due to the novelty with initial exposure. The individual differences in ability may also have had an effect on the overall perceived workload measurements. However because only ten subjects were allocated to each condition, it was difficult to assess the true nature of workload without comparing it to other measures, such as task completion time.

Looking at task completion time and workload together allows us to better understand overall performance. Since neither group made any procedural errors, time to task completion became an important metric. It is important in the OR to complete a task accurately and quickly. Therefore, the significant results in task completion time, after accounting for individual differences, showed that the learning aid did not negatively impact performance, nor was it a distraction for the user. It also implied that the learning aid can quicken decision making in procedural tasks. Research on dynamic decision making (Gonzalez 2004) indicated that repetition of a task under time constraints is not an effective way to learn. Gonzalez argues that learning depends on cognitive abilities. Therefore, a learning aid that supports and augments cognitive abilities allows for better dynamic decision making. Easing the burdens on recall, the subject focused on the individual parts without compromising time or accuracy. The demonstrated improvements to overall performance in a simulated environment bodes well for the benefit of this aid in the OR environment.

As was stated, this was a preliminary look into the use of learning aids in the OR. However, further research is needed to evaluate knowledge retention with such an aid, and how teaching and learning is affected by the presence of the aid in the OR. Kaplan et al. (2001) concluded that reliance on decision aids hinge on their design characteristics. They argue that decision aids should make inherent error less salient and allow decision makers to remain cognitively involved. Their conclusions are apt for OR technologies, as surgeons are already faced with a wide array of technology. There are many barriers to entry for such technology, most importantly that of user acceptance. There are many environmental factors that, coupled with cognitive
factors, will negatively affect the usage of such a device. However, understanding how the effort and strategy of the user interact with the tasks and the aid can be useful in overcoming bias and limitations inherent in decision aid technology (Todd & Benbasat 1994).

This experiment had several limitations. Since real novice surgeons were not recruited to test this hypothesis in actual OR conditions, some liberties were taken. However, it is a good starting place, supporting further experimentation in more realistic settings. Using college students to represent medical students was by no means an inaccurate representation of the skill level. Nevertheless, if the aid can benefit the complete novice with no other burdens than task completion, these benefits may also be assumed for those with experience and many other burdens, no matter how little.

The implications for a novice learning aid are clear. New technology is becoming omnipresent in OR environments; it is only natural that teaching and learning models would evolve to accompany them. Traditional methods are highly efficacious for passing knowledge between the expert and novice. However, as the technology increases in complexity and number, so does the amount of knowledge needed. Therefore, a learning aid system will be a highly efficient method of supplementing information transfer. Based on the results of the current experiment, it is expected that the medical community can benefit from such a system. Although this experiment is small and not wholly representative of the desired population, as a preliminary study, the results do encourage further research.

ACKNOWLEDGEMENTS

This work was supported by a grant from the NSF (#0238284). The authors thank Drs. Schwaitzberg and Connelly for providing domain expertise and surgical instrumentation.

REFERENCES


