The Effectiveness of Training Mental Rotation and Laparoscopic Surgical Skills in a Virtual Environment

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Abstract

Current research in the area of medical simulation is investigating the efficacy of using virtual reality surgical simulators as a means of training surgical skills. More recently, medical simulation has focused on the use of virtual reality to train laparoscopic skills. Several traditional methods of training laparoscopic skills exist (e.g., pelvic trainers, video trainers, animal trainers). However, the medical community is now shifting its attention toward higher fidelity simulations and virtual reality in particular for a number of reasons. Simulations provide a quicker, more cost-effective method for training and practicing surgical skills. In addition, simulators minimize the amount of physical space required for training. Nonetheless, it has been reported that the transfer of training rate from a medical simulator was only approximately 38%. Therefore, there has been a movement to refine medical simulations by focusing on improving design and haptic technology. Current simulators utilize high-level graphics to more realistically simulate deformable tissues in order to improve visualization of organ properties. In addition, they employ force feedback in order to give the simulation a more genuine haptic performance. Both visualization of organ properties and realistic haptic feedback are characteristics lacking in traditional mechanical trainers.

Many experimental comparisons of traditional training methods to medical simulators, including laparoscopic simulators, exist in the current literature though few account for spatial ability when evaluating successful skills training. Spatial ability has been shown to significantly affect training in virtual environments. More specifically, inferior mental rotation skills are correlated with poorer performance on surgical tasks in real world and virtual environments. As such, the current study investigated the effects of mental rotation skills on the ability to acquire and perform laparoscopic suturing skills. In addition, a subsequent study is proposed that will experimentally compare laparoscopic surgical skill levels attained from training with the Reachin Laparoscopic Trainer to those obtained from a traditional mechanical pelvic trainer. Prior to training on the simulators, participants will be evaluated on their mental rotation ability and subsequently trained to commensurate levels using an existing mental rotation training paradigm.
Introduction

Although abdominal cavity surgery has been practiced for the last 100 years, more advanced procedures such as cholecystectomy (gallstone removal) were only performed in last 20 years (Himal, 2002). Cholecystectomy is an example of laparoscopic surgery, which in turn falls into the category of endoscopic or minimally invasive abdominal surgical procedures. Minimally invasive surgery has the advantage of reducing damage to healthy tissue, recovery time, and infection rate. These advantages for the patient come as a challenge to the surgeon learning these new techniques.

During a laparoscopic surgery, the surgeon loses direct contact with the operation site. In the current procedure an endoscope, or tubing attached to an optical system, projects video images of the internal organs and tissue into a monocular viewing display. The surgeon manipulates surgical tools for suturing and tissue manipulation with a loss of visual feedback and tactile stimulation (Szekely, Haller, & Bajka, 2000). A current review of British and Australian laparoscopic procedures suggests that these surgeries are more difficult, time consuming, and harder to learn (Molloy, 2001). Molloy suggest that not all surgeons possess the visuo-spatial skills necessary to perform laparoscopic surgery. Most literature reviewed cited limited and ineffective training paradigms as the number one problem for surgeons performing these types of surgeries.

Typically, doctors learning endoscopic procedures attend a weekend seminar to learn the methods, and then practice using animals such as pigs (Durlach & Mavor, 1995). In some cases, this training does not allow the doctor to reach proficiency before proceeding to human patients. Mechanical simulators were introduced in the early 1990’s (Satava, 1998). Although still in use, these simulators are rigid and biologically unrealistic. Surgeons performing laparoscopy suffer from restricted vision and lack tactile perception. Current simulators, for example KISMET, utilize high-level graphics to more realistically simulate deformable tissues to improve visualization of organ properties. In addition, they use a “force feedback probe to give the simulation a more genuine haptic performance. However, problems of fidelity and realism still exist in designing medical trainers. Of more concern is ability to train surgical dexterity and decision-making. These skills might rely more on the surgeon’s ability to mentally rotate objects and their comfort in pressure scenarios (Wanzel, Hamstra, Anastakis, Matsumoto, & Cusimano, 2002).

Though many researchers have sought to compare or evaluate the effectiveness of various types of laparoscopic trainers to train laparoscopic skills, few have controlled for the individual’s ability to mentally rotate objects, such as organs. Tendick (2003) notes that high correlations have been observed between standardized spatial ability tests and performance ratings on open surgery tasks. However, Tendick proposes that laparoscopic surgery might be even more dependent on spatial ability due to the lack of available perceptual information leaving surgical actions dependent on internal representations of surgical information. Eyal and Tendick (2001) investigated the effects of spatial ability on learning the use of an angled laparoscope in a virtual environment and found support for their hypothesis that those who score higher on standardized spatial ability tests will perform better in the laparoscopic simulation. Related to spatial ability and its effects on laparoscopic skills is the gender of the surgeon performing the surgery.

Much of the research conducted to date has demonstrated a gender difference in spatial ability such that males perform at a higher level than females (Rizzo, Buckwalter, Neumann, Kesselmann, Thiebaux, Larson, & van Rooyen 1998; Peters, Laeng, Lathan, Jackson, Zaionua, & Richardson, 1995; Peters, Chisholm, & Laeng, 1995; Masters & Sanders, 1993) The current study seeks to replicate the gender difference findings of Rizzo et al regarding gender and spatial ability. In addition, the current study will evaluate the effects of mental rotation skills on the ability to acquire and perform laparoscopic suturing skills. In congruence with the previous findings in the literature, it is expected that females in both the control and experimental groups will perform worse in the paper and pencil version of a mental rotation test. Furthermore, it is expected that these gender differences will be eliminated after participants receive training with the virtual reality mental rotation task. With regard to performance in the surgical environment, it is expected that those participants who received mental rotation training will perform better on the suturing task exams.

Method

Participants

Twelve university students (6 males and 6 females, mean age = 22.67 years) were recruited to participate in the experiment. All participants were right handed.

Materials

To test initial mental rotation ability, The Mental Rotations Test (Peters et al., 1995), a paper-based mental rotation test was used. In addition, the University of Mississippi Mental Rotation Experiment was presented online. A computer based mental rotation task was constructed using 3D objects generated in 3D Studio Max. The 3D computer based task was used for the object rotation pre and posttest as well as for the training phase.
Procedure
Participants completed the informed consent form and demographics questionnaire upon arrival. Participants were then asked to complete the paper-based mental rotation test and the online mental rotation test. The presentation of these tests was counterbalanced to prevent order effects. Following these tests, the participants completed a 20 item pre-test in which they were to rotate a 3D object in 3D Studio Max to match a static 3D object (also generated in 3D Studio Max) presented in Microsoft PowerPoint on an adjacent computer. The objects generated were comparable to those found in the standardized paper-based mental rotation test. Those participants in the experimental condition followed the pre-test with 10 blocks of 10 trials each of the object rotation in 3D Studio Max. For this experimental phase, 10 screenshots of each of 10 original 3D stimuli were taken. Though each stimulus type was presented in the same order to each participant, the 10 static screenshots of each were presented in a randomized order for 30 seconds on the adjacent computer in PowerPoint. Participants were again required to rotate the original object in 3D Studio Max to match the object presented in PowerPoint. The experimental group then performed the same items on the 20 item pre test in the form of a post test. The total time required to rotate and orient the object for each trial of the pre, experimental, and post test was measured in seconds via a stopwatch.

After the mental rotation portion of the experiment, all participants were provided with suturing training by an endoscopic surgeon. More specifically, participants were shown the procedure for completing the endoloop suturing procedure, the extracorporeal curved needle procedure, then the intracorporeal knot-tying procedure. Participants were trained in accordance with the typical procedure the surgeon utilizes for student training. For each procedure, the participants were instructed orally then watched the surgeon perform the suture in a standard box trainer with a 2D monitor. Following the instruction by the surgeon, the participants practiced the procedure one time. After the instructional and practice sessions, each participant was required to perform the 3 procedures while being evaluated by one of 2 experienced surgeons. The participants were rated on technique and the time to complete each procedure was recorded.

Results
The demographic questionnaire revealed that participants represented several disciplines of educational study: 3 Engineering, 4 Computer Science, 1 Biology, and 4 Psychology. Only one participant had prior experience internal surgery, while four had experience with virtual environments. Over half of the participants played video games (67%). The average of video game play was 3.5 hours, SD = 6.07.

For the paper and pencil test, a significant difference was found between the females ($M = 7.0, SD = 0$) and males ($M = 14.67, SD = 2.52$) of the control group only, $t(4) = -5.77, p < .01, a = .05$. While the females of the experimental group outscored the males ($M = 13.33, SD = 5.03$ and $M = 9.33, SD = 7.09$, respectively), this difference was not significant.

Although the total time to perform the online mental rotation task was highly correlated with same or different stimuli, $r(6) = .988, p < .001$, the time was not correlated with scores on the paper and pencil version of the test. However, number of hours spent playing video games was positively correlated with the paper and pencil test scores, $r(6) = .818, p < .05$.

Neither gender showed significant differences in time (seconds) to rotate the 3D object after training. However, males ($M = 11.23, SD = .86$) performed better on the posttest after training than females ($M = 13.38, SD = 3.16$). These differences were not statistically significant.

One male participant from the experimental group could not participate in the surgical training aspect of the experiment. Although this data was analyzed for total time for each surgery and number of errors, there was not enough statistical power to show differences between the genders or the two testing conditions.

Discussion
The small sample size limited the conclusions of this study. However, there were two important outcomes that cannot be disregarded. First, females in the experimental group outscored the males by 4 points. Given the scoring procedure used for the Mental Rotation test, females in the experimental group answered 4 more questions correctly than their male counterparts.

Although the sample size was small, the fact that all three of the experimental group females played video games while none of the control group females did seems to suggest that females who play certain video games may achieve the same or higher metal rotation abilities than males. Moreover, only one male out of the 6 total did not play video games. Thus, females in the experimental group were possibly better matched to the males in whole sample population. This conclusion is supported by the positive correlation between female scores on the mental rotation test and number of hours playing video games. Given the unequal match between video game players and gender, we cannot replicate the results of Rizzo et al. until we attain a more balanced sample.

In addition, the initial hypothesis that females would perform worse than males in both the experimental and
A second important result is that all naïve participants learned all three surgical procedures in less than an hour. The mean total times (seconds) did not show an effect of mental rotation training, (M = 476.14, SD = 111 for females, and M = 412.83, SD= 87.45 for males). This result could be due to the confound of video game play. This conclusion is not supported in the literature. Another explanation could be that these surgical procedures relied more on depth perception than mental rotation. A future study will determine a more appropriate surgical task that utilizes mental rotation, such as determining the location of vital landmark before suturing.

Although the hypotheses were not supported for the surgical aspect of the experiment, the results do support that novice participants with no prior surgical training are adequate for studying this type of research question. Moreover, the participants were rated quite high on their surgical performance scores. Despite confounds of the small sample size and unmatched groups, the experimental paradigm is valid and can produce reliable results when implementing the full design.

The knowledge gained from the pilot study will help to guide the next phase of this experiment, which is to compare the Reachin virtual laparoscopic trainer to the pelvic box trainer. A sample size of at least 48 subjects is needed for this study. In addition, a second study on the effects of video game use, gender, and mental rotation is planned to eliminate video game experience as a confound in the experimental design.

References


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