Eye Trackers in a Virtual Laparoscopic Training Environment

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Abstract.
Virtual laparoscopic training systems have been shown to differentiate between the skills of experienced and novice laparoscopic surgeons. Measures such as total number of errors and completion time are used to assess skill, but these metrics do not give much insight into the processes behind skilled behavior in simulated laparoscopic part-tasks. The eye gaze of two groups of subjects, one experienced with laparoscopic surgery, and the other with no experience, was recorded while they performed an aiming task in a virtual laparoscopic trainer. Number of errors committed was much lower for the experienced subject than the novice group. Initial analysis of the eye data showed that the experienced group required less feedback than the novice groups.

1. Introduction

Laparoscopic surgery is unlike open surgery and requires adaptive skills to overcome the difficulties of working with an indirect view of the workspace through the endoscope camera and the remote manipulation of tools. Because experience is a key factor of proficiency at laparoscopy, surgical simulators have received attention as a learning device. One approach for continuing development of training simulators is examining surgeons' cognitive processes and visuomotor skills [1]. Identifying these skills can provide a basis of how to approach training. This paper is an initial investigation into the visuomotor skills required in a virtual training environment and the feasibility of using eye trackers with this application.

Eye trackers have been used to compare the eye patterns of skilled pilots [2] and experienced radiologists [3] over their inexperienced counterparts. Visuomotor skills are learned by creating a map between visual information and generated motor commands [4]. This gives a hypothesis that inexperienced subjects will tend to gaze on the tool more often than the experienced group because they are learning to correlate arm movements on the input interface with visual information.

2. Materials and Methods

2.1 Equipment

The subject is seated on a chair that does not swivel or roll. A 21" Sony Trinitron CRT monitor set at 1024x768 resolution with refresh rate of 100 Hz sits at eye height on a desk. The virtual training environment is implemented in Visual C++ 6.0 and runs on a Windows 2000 dual 933 MHz Pentium 3 workstation at about 50 frames per second. The VGA signal from the workstation is sent to the eye tracker control module via a TView Gold scan converter. The eye tracker is an Applied Science Laboratories (ASL) Model 504 with an update rate of 60 Hz. The simulation interface tool is an Immersion Laparoscopic Impulse Engine, but the program does not return force feedback.

2.2 Procedure

A total of 4 subjects were assigned to 2 groups based on their prior laparoscopic experience. The novice group included 2 graduate students and 1 faculty member from the Simon Fraser University School of Computing Science. The experienced group is represented by an experienced laparoscopic surgeon now retired from active practice.

Each subject performed 2 sets of 10 trials while eye gaze data was recorded. Subjects were given 1 practice trial before doing the 2 sets. Before eye gaze recording, calibration is done for each subject by fixating on a 9 point calibration pattern. After subjects finished a set, calibration drift is measured by fixating on the 9 point calibration pattern again. A break was provided in between sets.

Eye gaze data before and after training may show changes in scanning strategy. Therefore novices perform a training session before performing the second set. This training session, of which the eyes are not tracked, comprises of a total of 20 or 30 trials divided into 2 or 3 sets of 10 respectively. No special instructions were given for training. After training, the second set of trials are administered with the eye tracker on. After the trials, a questionnaire is completed.

2.3 Aiming Task

Each subject must maneuver the tool on the screen using the Immersion device so that its tip touches the target cube. Another larger cube positioned just behind the target cube records error. Error is defined as the total time the tool tip remains inside or on the surface of the error cube. The experimental instructions state that accuracy and speed are equally important. See Figure 1 of how the task appears to the subject.

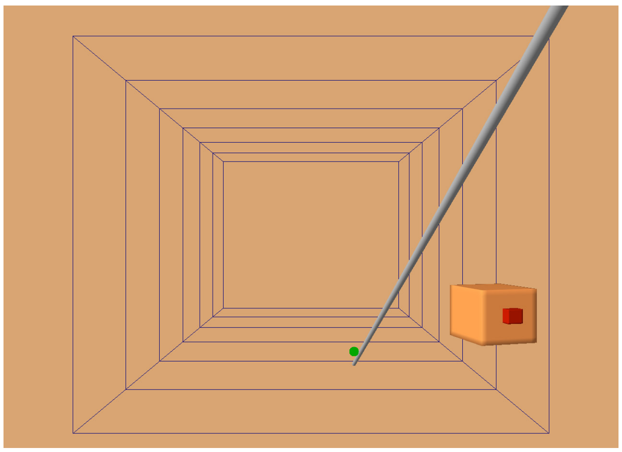

Figure 1. Screenshot of aiming task. The circle on the left of the tool is the current point of gaze.

3. Results and Discussion

The total time to complete 10 trials and the number of errors are shown in Table 1 for each group. Although the experienced subject was slower than some of the novices, the number of errors committed is much lower. The additional time is partially attributed to some confusion with the experimental instructions.

Table 1. Performance measures of aiming task. Novice (n=3) entries are means.

Set	Time (seconds)		Errors	
	Experienced	Novice	Experienced	Novice
1	327.05	304.60	113	640.33
2	231.46	242.39	11	530.33

One novice subject was given 30 training trials, but surprisingly, this subject did not improve in both time and errors in the second set of trials, but instead, increased by 22.7 s and 77 errors.

Qualitative observations show that when subjects were tracking the tool, they generally gazed at the tip, and not anywhere else on the tool. This result supports the hypothesis that end-effectors of a tool are information rich [5]. An example snapshot of a novice subject tracking the tip is found in Figure 1. In addition, novice subjects made proportionately more gazes on the tool than the experienced subject. Overlays of the eye position over the session show that these gazes on the tool are similar to cursor following and switching behaviours [6].

4. Conclusion

This pilot study shows that the aiming task differentiates experienced and novice subjects in terms of number of errors committed, although comparing total time does not yield a large difference. ??Better?? performance correlated with laparoscopic experience ? Explain.. Novice subjects were more likely to gaze on the tool than did the experienced subject, presumably to learn the mapping between hand motion on the input device and visual information. A follow-up study will include a larger subject pool and more quantitative analysis.

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References

[1] Payandeh, S., Lomax, A.J., Dill, J., MacKenzie, C.L., Cao, C.G.L. (2002) On Defining Metrics for Assessing Laparoscopic Surgical Skills in a Virtual Training Environment. In Proceedings of Medicine Meets Virtual Reality (MMVR:10).

[2] Kasarskis, P., Stehwien, J., Hickox, J., Aretz, A., Wickens, C. (2001) Comparison of Expert and Novice Scan Behaviors During VFR Flight. In Proceedings of the 11th International Symposium on Aviation Psychology.

[3] Wooding, D.S., Roberts, G.M., Phillips-Hughes, J. (1999) The Development of the Eye-movement Response in the Trainee Radiologist. In Proceedings of SPIE Medical Imaging (Image Perception and Performance). 3663: 136-145.

[4] Rosenbaum, D.A. (1991) Human Motor Control. San Diego, USA (Academic Press. Inc.).

[5] Mataric M.J., Pomplun, M. (1998) Fixation Behavior in Observation and Imitation of Human Movement. Cognitive Brain Research 7(2):191-202.

[6] Smith, B.A., Ho, J., Ark, W., Zhai, S. (2000) Hand Eye Coordination Patterns in Target Selection. In Proceedings of 2000 ACM Symposium of Eye Tracking Research and Applications, 117-122.