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Identifying Eye Gaze Mismatch during Laparoscopic Surgery

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Abstract. During a laparoscopic operation, the surgical team should have a common understanding of the action plan which can be aided by focusing on the same surgical site. We show how measuring the overlap between two spatially and temporally aligned gaze recordings can be used to identify periods during which the primary operator and assistant were focused on different areas of the surgical display.

Keywords. Eye tracking, Laparoscopic surgery

Introduction

In laparoscopic surgery, often a primary surgeon operates using surgical instruments while an assistant controls the laparoscopic camera and other secondary instruments. As a result it is important for the surgical team to focus on the same surgical target [2,5] for the operation to proceed efficiently. Where the points of gaze of the surgeon and assistant diverge could potentially indicate a mismatch in the common team focus. As the point of gaze often reflects the minds of surgeons, investigating gaze mismatches may potentially shed light on studies of team cognition between surgeons in a team [1].

Using a remote eye tracker to record the eye movements of the surgeon in the operating room and a resident watching the surgical video afterwards, we present a method of identifying periods of gaze divergence and discuss events possibly leading to such disconnection.

With current technology, we cannot record two eye gaze records simultaneously from surgeons while they both operate on a case together. This is because our eye trackers determine the point of gaze from video-based calculation of infrared reflections on the eye and face, and each eye tracker produces its own infrared emissions which interfere with the other's internal video processing. However, using a single eye tracker we can record one surgeon's eye motions while he performs a surgery, then later record his gaze while he is watching the surgical video. Comparing gaze points between the operating

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Figure 1. Tobii x50 on a stand under the surgical display. Infrared emissions from the eye tracker are captured in visible light photography as bright dots.

surgeon himself and by another while watching the videos will give us a chance to examine the mental connection to the task and give a cue to their sense of team cooperation.

We understand that how a surgeon gazes will be affected by the task requirement. In performing tasks requiring a high level of attention, a surgeon exhibits different eye behavior than he does when performing an easier task [7]. We would like to know whether the task requirement will also affect the connection of two surgeons' points of gaze when working together on the same operation.

1. Method

1.1. Recording Eye Gaze in Live Surgical Setting

Eye tracking data were recorded during eight laparoscopic cholecystectomy cases at UBC Hospital, The University of British Columbia. A Tobii x50 remote eye tracker was placed on an adjustable stand covered with a sterile drape and connected to a Windows PC, providing sampled point of gaze coordinates on the main surgical display at 50 Hz. The video from the laparoscope and eye tracking data were saved to the eye tracking PC by Tobii Clearview 2.7.0 software. Full operating room eye tracker setup and calibration details can be found in Atkins et al. [3]. Figure 1 illustrates the live OR setup with the x50 eye tracker below the surgical display.

1.2. Recording Eye Gaze in Video Watching

At least 3 months after the recorded cases, the operating surgeons and trainee residents were invited to have their gaze tracked while watching the captured laparoscopic video feed from the cases performed previously. Video watching was done while seated in a quiet, closed room, although the viewer could still potentially become distracted by traffic into and out of the room or pager calls. The videos for each case were edited into two parts: the first part consisted of the procedure from the completed establishment of all necessary laparoscopic ports in the patient to the cutting of the isolated cystic duct and cystic artery, and the second part consisted of the procedure from having cut the duct and artery to complete separation of the gall bladder from the liver bed.

In addition to being reviewed by the operating surgeon, one of the recorded cases was also viewed by three surgical residents.

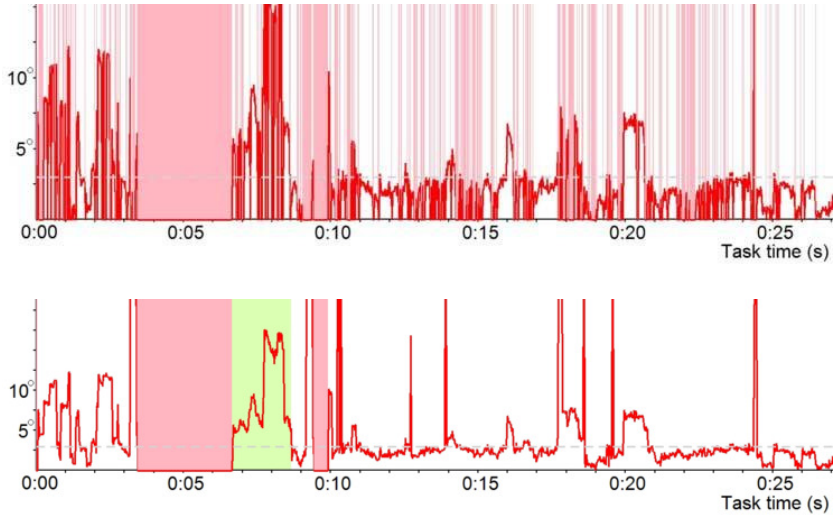

Figure 2. A plot of Euclidean distance between two gaze recordings with task time on the X-axis and visual angle on the Y-axis (Top) before interpolation of short missing segments, and (Bottom) after interpolation. Highlighted bars represent segments where overlap is not available due to missing data from one or both gaze recordings. The period between 6.5 seconds and 8.5 seconds represents an interval satisfying the mismatch criteria which became available after interpolation.

1.3. Data Processing

Due to the dynamic nature of OR conditions, the surgeons tended to make many large body or head movements which led to temporary periods of eye tracking loss. In some cases, the surgeon was focused on the same part of the surgical display as he drifted temporarily out of the eye tracker's range. Thus we performed a linear interpolation on the recorded data to fill in short gaps of missing data lasting up to 200 milliseconds during which large shifts in attention are unlikely to occur. A visualization of the detected mismatch for a small example task interval before and after interpolation is shown in Figure 2. Without interpolation, no intervals satisfying the mismatch criteria were found.

Comparisons were made between the operator's gaze during performance and his gaze while reviewing the cases. Where available, the gaze of the reviewing residents were compared to the operator's gaze. After temporally aligning two gaze recordings, the Euclidean distance between each sample pair's points of gaze was calculated, as detailed in Tien et al. [6]. Periods of gaze mismatch were defined as intervals where the two gaze recordings were continuously separated by a visual angle of at least 3 degrees for a minimum of 1000 milliseconds. However, overlap data are only available during the surgical video where both the operator's and viewer's gaze are both present and valid. Examples of overlapping and mismatched gaze pairs in a surgical scene are described in Khan et al. [4] and shown here in Figure 3, captured as screenshots from a surgical video overlaid with the operator's and viewer's points of gaze.

2. Results

One surgical case with multiple viewers will be explored here. The first part of the procedure had a duration of 598 seconds and the second part lasted 121 seconds. A count of the number of mismatched intervals for four viewers is reported in Table 1. The surgeon

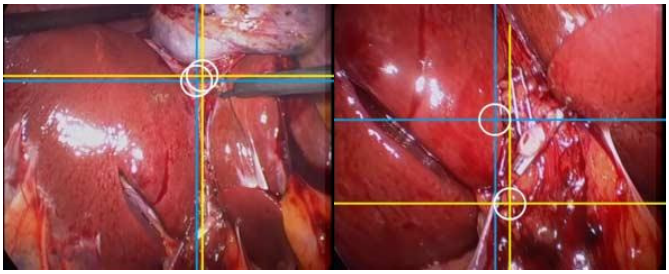

Figure 3. Screenshots of dual gaze overlaid videos with the operator's OR gaze and post-review gaze. The circles indicate 3 degrees of visual angle. (Left) Highly overlapping gaze, (Right) mismatched gaze.

Table 1. Mismatched intervals when comparing operator's gaze to viewer's gaze

Component of surgical procedure	Viewer	# mismatched intervals	Mean interval duration (s)	% task time mismatched
Isolation and cutting of cystic duct & cystic artery, 598 seconds	Operator	20	1.47	4.9
	Viewer 1	49	1.48	12.1
	Viewer 2	25	1.42	5.9
	Viewer 3	30	1.52	7.6
	Mean	31	1.47	7.6
Dissection of gall bladder from liver bed, 121 seconds	Operator	5	1.58	6.5
	Viewer 1	14	1.58	18.3
	Viewer 2	7	2.09	12.1
	Viewer 3	9	1.75	13.0
	Mean	9	1.73	12.5

produced the fewest number of mismatches out of all viewers. The mean interval length of the mismatched periods for all viewers ranged between 1.4 seconds and 2.1 seconds. A period of mismatched gaze is highlighted from 6.5 to 8.5 seconds in Figure 2(Bottom).

From Table 1, in the first part of the procedure where precision was required in dissecting the cystic duct and artery, the operator's and the watcher's gaze recordings were mismatched 7.6% of the time on average, and the gaze recordings were on average mismatched 12.5% of the time for the straightforward gall bladder removal in the second part of the operation.

Aligning the mismatched intervals for all viewers allowed us to identify two intervals across the entire case where all viewers' points of gaze diverged from the operator's point of gaze at the same time, and four intervals where three viewers gazed at different places.

3. Discussion

This preliminary report includes only one surgeon's data. It is impossible for us to run statistical analysis between self-review and video watching by residents, and between two different parts of surgical procedures. However, results support our prediction. Watching his own case, the operating surgeon had fewer mismatches than when the case was watched by residents. Mismatches dropped in frequency more during precision surgical tasks such as isolation and severance of the cystic duct and artery, compared to relatively easy surgical procedures like the routine separation of the gall bladder from the liver.

Having identified the mismatched intervals common to most viewers, we revisited the surgical video to postulate the reasons for this group gaze divergence. Common events in these intervals were observed - either the laparoscopic grasper had released its site and was seeking a new grasping location, or there was a shift in camera position or the grasper was used to move some patient anatomy for inspection. With knowledge of these events, the instructional value of these mismatched intervals is revealed, for example to teach residents how to choose the best location to grip with the grasper.

4. Conclusion

Deploying multiple eye trackers simultaneously in a live surgical environment is currently logistically difficult so as yet we are unable to study the real-time gaze dynamics of a surgical team. However, we have developed a new technique for measuring overlap between gaze recordings for viewers obtained offline, to aid in visually identifying intervals of gaze mismatch, and applied this to a recorded laparoscopic operation. These visualizations may have particular instructional value for drawing visual attention to different parts of the surgical scene depending on the role of the viewer.

In the future with a compatible hardware setup the gaze overlaps could be visualized with simultaneous recording of both the primary operating surgeon and the surgical assistant to capture the real-time dynamics of gaze synchronization that may arise from the team-oriented task.

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