Revealing Team Cognition from Dual Eye-tracking in the Surgical Setting

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Abstract

Surgery is a team effort. In this video, we display how we record two surgeons' eye motions during a simulated surgical operation, then performed Cross Recurrence Analysis (CRA) on the dual eye-tracking data to develop a valid technology to assess shared cognition. Twenty-two dyad teams were recruited to perform object transportation task using laparoscopic techniques. Outputs from CRA, including overlapping, recurrence rate and phase delay were correlated with team performance measured by the task time, errors made, and movement de-synchronization. Gaze behaviors between the two team members recorded in the surgical videos correlated positively with team performance. Elite teams were overlapping gaze more with higher recurrence rate than the poor teams. Dual eye-tracking analysis can be a useful tool for assessing team cognition and evaluating the team training.

• Human-centered computing ~ Interaction design – Systems and tools for interaction

Keywords: dual eye-tracking, cross recurrence analysis, team cognition, image-guided surgery

1 Introduction

By analyzing where an individual surgeon is looking during a surgical procedure, scientists have successfully assessed the behavior of the surgeon through visual cues for guiding movements of hands[Law et al. 2004; Atkins et al. 2008] and for monitoring environmental inputs while the surgeon is concentrating on the main surgical tasks on patients[Tien et al. 2010; Zheng et al. 2011]. Over the last few years in studying eye behaviors in the individual surgeon, eye metric evidence has been successfully used for identifying surgical expertise [Richstone et al. 2010] and for designing a novel training protocol for surgeons-in-training [Wilson et al. 2011; Vine et al. 2013; Tien et al. 2014]. However, surgery is a team effort [Cassera et al. 2009; Zheng et al. 2012]; team collaboration between surgeons is critical to the success of any surgical procedure.

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When it comes to the assessment of team quality, we believe it is important to assess the shared cognition among the team members. The *shared cognition* within a team refers to collective mental activities regarding the team members, team tasks, team resources, and team goals[Cooke et al. 2000; Salas et al. 2008]. Sailer et al. use multiple choice questions to examine the similarity amongst the team members when facing team challenges [Sailer et al. 2005]. The fidelity of this indirect and subjective measure on team cognition is questionable [Stout et al. 1999; Salas et al. 2008]. There is a need to develop a valid and objective method to assess team cognition.

2 In the Video

In this video we used dual eye-tracking technology to explore the possibility of assessing shared cognition between two surgeons in performing laparoscopic surgery, a type of image-guided surgical procedure inside the abdominal cavity[Atkins et al. 2012; Khan et al. 2012; Atkins et al. 2013; Tien et al. 2013]. The overlapping gaze provides a basic measure of the similarity between two sets of eye-tracking data. However, it is not entirely appropriate, as each team member may scan over the same surgical spot at a different point in time.

In this video, we introduce cross recurrence analysis (CRA) [Richardson and Dale 2005; Dale et al. 2011] technology to the dual eye-tracking data to compare the spatiotemporal similarity between two surgeons while performing a laparoscopic surgery. We display the task performed in the Surgical Simulation Research Lab at the University of Alberta. Participants included 14 university students, formed 22 dyad teams to perform a simple object transportation task under the simulated surgical environment. Methods used in this experiment were reviewed and approved by the Health Research Ethics Board of the University of Alberta. Consent was obtained from each participant before entering the study.

We show how we capture two team members' eye motions during the trial using two high-resolution remote eye-trackers (Tobii 1750 and X50, Tobii Technology, Stockholm, Sweden). Each team member watched one of two 17' monitors that were set in an orthogonal arrangement. Eye-tracking data from two Tobii systems fed into the Labview software on a third computer to synchronize the gazes on top of the surgical video streams.

In this project, when operators' fixations fell within the *Euclidean* distance of 60 pixels, we recorded this as a moment of dual gaze *overlapping*. Within this range of viewing difference, both team members were believed to look at the same surgical spot. We also performed the *cross recurrence analysis* (CRA) on the dual eye-tracking data to analyze both spatial and temporal features[Coco and Dale 2014]. Simply put, the CRA allows us to quantify whether a particular surgical spot has been visited by two team members at a different time frame.

Besides gaze, we also display task performance of each team. We report the *task completion* (in seconds), number of *errors* (drops of the object or making the adjustment on the grasping during the trial by releasing and re-grasping the object on the box floor), and number of episodes when *de-synchronization*, when the object or the tool was out of the camera view at any time during the trial

3 Results

Pearson Correlation tests were performed between task time, recurrence rate, phase delay, overlapping, number of drops, and number of de-synchronization periods.

Table 1: *Correlation matrix between dual gaze features and team task performance*

	Task time (sec)	Recurrence Rate (%)	Phase delay (sec)	Overlap (%)	Drops (#)	De-sync (#)
Task time (sec)	1	-.415*	0.316	-0.291	0.133	.559**
Recurrence Rate (%)		1	-0.228	0.112	-0.07	0.035
Phase delay (sec)			1	-0.207	.479*	0.226
Overlap (%)				1	-0.093	-0.27
Drops (#)					1	-0.038
De-sync (#)						1

The task time was negatively correlated with recurrence rate but positively correlated with the number of de-synchronization periods; this means that for the teams with the shorter task times, we recorded increasing numbers of gaze recurrences on the surgical spot and decreasing numbers of movement de-synchronization between the two team members. There was clear evidence that the spatial and temporal features of gaze in scanning over the surgical spots displayed significant higher recurrence rates with less phase delay as the team performance improved.

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