Perceived Usefulness and Acceptance of Telestration in Laparoscopic Training

Yuanyuan Feng, MS, Jatin Chhikara, MS, Jordan Ramsey, BS, Helena M. Mentis, MS PHD
University of Maryland Baltimore County, Baltimore, MD, USA

Abstract

In laparoscopic training, trainers take great effort to gesture over video for trainees to develop a mutual understanding of the complex operative field. To facilitate the conveyance of expert knowledge, we designed a telestration system that enables trainers to point or draw free hand sketches over a video for a trainee to see. The perceived usefulness and acceptance of the telestration system was evaluated by 18 surgeons fulfilling the role of trainer or trainee in a simulated laparoscopic surgical task. The post-task questionnaire responses suggest that the telestration system is useful in enhancing the trainees' learning performance. In addition, we identify barriers that hinder the acceptance of the telestration system in surgical training and provide insights in improving the system design.

Introduction

Minimally invasive surgery (MIS), where surgeons rely on video to see the patient's anatomy, has prompted a significant paradigm shift in the advancement of surgery. Learning to perform laparoscopic surgeries is extremely challenging, as it relies not only on the trainee's proficiency in laparoscopic skills, which are often taught in classes and labs, but also on the communication between the trainer and trainee in conveying non-formalized knowledge, such as the situated actions and professional vision, in the operating rooms (OR)[1, 2].

Communication becomes more efficient as common ground – the mutual knowledge, beliefs, and assumptions – increases between the trainer and trainee[3]. Gestures and actions facilitate the development of common ground[4, 5]. In surgery, gestures are often used to clarify the referred anatomical structure[6], negotiate about the trajectory of the operation[7, 8], and demonstrate the technical skills[9]. For instance, a surgeon may draw on the skin to indicate the path of the incision and to mark the major landmarks of the anatomy[7]. The drawing ensures that the team is on the same page at the beginning of the operation. Or a surgeon may use gestures to clarify the relative location of a tumor after a verbal description[6].

In laparoscopic training, where the indirect view of the operative field limits the ability to directly gesture on the anatomical structures, trainers take great effort to work with the video for trainees to develop a mutual understanding of the complex operative field[1, 2, 10]. Trainers often guide trainees' hands to maneuver the laparoscopic camera, accompanied by a series of verbal explanations and gestures over the monitor to reveal the subtle changes in the structure in order to translate what they are seeing into the abstract anatomy in the textbook[1, 2]. The surgical instruments are used to point at the target or draw imaginary lines to elucidate the structures embedded in the tissues. These efforts, however, are not efficient. For instance, in some cases, the orientation of the display may require the trainers to turn away from the operative table and point at the display behind them. The trainees need to parse, envision and make sense of the trainers' gestures to perceive the location and direction given by the instructions. This often engenders a series of checking, clarifying, aligning of the information that is already presented[10].

To overcome these problems, we hypothesized that conveying the gestures directly onto the video is beneficial. Previous research has shown that communication becomes more effective when annotation and gesturing tools are provided for shared view of the workspace[4, 11]. For instance, Fussell et al. found that the pointing and representational gestures added on a shared view of a robot assembly task effectively facilitated task communication and reduced performance time[4]. Tang et al. provided direct views of the hands on the shared view and these natural gestures allowed the collaborators to be more engaged in the communication and the tasks[11].

We designed a telestration system, which enables a trainer to point or draw a free hand sketch over a video for a trainee to see. For our system to have a real influence on laparoscopic training, users need to be able and willing to use it. Thus, we conducted a study to evaluate the perceived usefulness and acceptance of the system among trainers and trainees in laparoscopic training. The perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance."[12] In surgical training, the job performance refers to trainees' learning performance, i.e. the knowledge they gained, the skills and abilities they developed, and the effort they expended in training, as well as the trainers' ability in conveying the knowledge. The user acceptance is the degree to which a person is willing to use the system in their work practice. In surgical training, the user acceptance refers to the trainers' willingness to use the telestration system in conveying knowledge to the trainees, as well as the trainees' willingness to gain knowledge through the annotation or reference on the video provided by the trainers using telestration. The user acceptance is influenced not only by the user experience and perceived usefulness, but also by the users' attitudes and intentions in using the system[12].

System Design

The telestration system aims to facilitate the conveyance of expert knowledge by enabling trainers to point or draw on the laparoscopic video for the trainees to see. The program works by using a combination of audio key words and hand movements to trigger different functionality. The Microsoft Kinect is used as the gesture and voice control sensor.

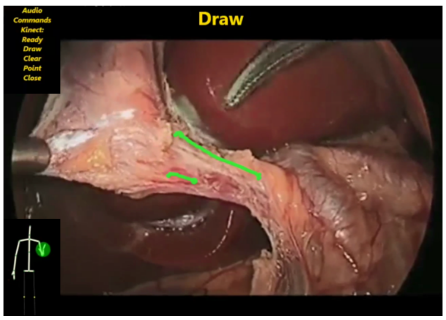

Figure 1. The interface of the Telestration program.

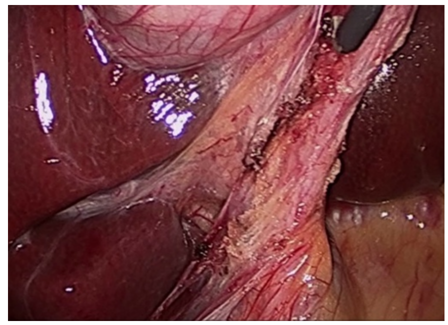

Figure 2. The simulated task.

Figure 1 shows the interface of the system. The collection of the verbal commands is shown in the upper left corner. The current mode is presented in the center above the laparoscopic view. The lower left corner shows the user's skeleton to provide timely feedback of the user's movement. To awaken the Kinect, the first command is verbally saying "Kinect ready". When this is said the Kinect starts detecting other verbal cues and gestures. There are two verbal cues the Kinect is looking for, either "Kinect draw" or "Kinect point", to switch between the drawing mode and the pointing mode. In the pointing mode, the user moves the hand to control a small green circle, which acts as a pointer. In the drawing mode, the user closes their hand to draw over the video. The position of the pointer and the drawing responds to the position of the user's hand. To clear the screen of all annotations, there is the verbal command "Kinect clear". When the program is finished being used, the voice command "Kinect close" can be used at any time to set the program to sleep and stop the Kinect from detecting.

Experiment Design

A questionnaire was designed to collect the perceived usefulness and acceptance of the telestration system in laparoscopic training. The trainers and trainees were asked first to participate in a simulated laparoscopic task using the telestration system and then to complete a questionnaire on their experience, outcomes expectations, attitudes and intentions of using the system. The questionnaire was adapted from previous research in educational technologies[13, 14, 15], including 21-item 7-point Likert scale and open-ended questions. The participants were assigned into two groups based on their experience levels – the trainer group (attending surgeons and fellows) or the trainee group (surgical residents). The trainees performed the laparoscopic task with the telestration guidance from the researchers, while the trainers provided guidance using the telestration for the researcher to perform the task.

The Simulated Task

The simulated task in the experiment was to separate the cystic duct and cystic artery on a paper model. It is an important step in achieving the "critical view of safety" in laparoscopic cholecystectomy. This task requires the trainees not only to correctly identify the cystic duct and cystic artery that are embedded in the peritoneum, but also envision the imaginary line of safety over the two structure to avoid dissecting into the common bile duct. Thus, this task involves the effort of both referring to task objects or locations and managing the process of dissection.

Study Settings

The telestration system was connected to a Fundamentals of Laparoscopic Surgery (FLS) Box Trainer System. The Microsoft Kinect sensor was oriented towards the trainer. The trainee stood in front of the FLS Box with the dominant hand controlling the scissors and the other hand manipulating the Maryland dissector. The telestration system provided an overlay of the reference and annotation from the Trainer to the laparoscopic video for the Trainee to see. As the transfer of the video created a 2-second lag, we presented the telestration on a secondary display.

Recruitment

Attendees of the Telestration-Guided Laparoscopic Visual Skills Practice Station at the Learning Center during the 2017 Society of American Gastrointestinal Endoscopic Surgeons (SAGES) Annual Meeting in Houston, Texas, were invited for participation. A total of 18 trainers (10) and trainees (8) participated in the study, including four female surgeons and 14 males. Experience levels ranged from novice medical student to senior surgeons with more than 20 years in practice. Among the 18 post-task questionnaires collected, 3 were identified to contain inconsistent answers and were removed from the analysis.

Results

Responses from the Trainees

Figure 3 shows the responses from trainees (n = 6). Overall, 66.7% trainees were satisfied with the support of telestration in completing the task. 83.3% trainees agreed that the telestration made it easy for them in identifying the target referred by the trainer. Trainee #3 commented, “it was ease of use and clear”. However, two out of six trainees thought that the telestration distracted them from the task. Trainee #3 suggested, “having the telestration on the same screen with their laparoscopic video would be a plus.”

In learning performance, 83.3% trainees agreed that telestration increased their knowledge gained from the training, especially for the procedural knowledge (Figure 3). 33.3% trainees were neutral about the anatomical knowledge and laparoscopic skills conveyed through the telestration. Trainee #5 doubted the usefulness of telestration in minimizing the effort spent on learning, as well as on performing the task. The justification was as follows, “it is difficult to draw accurate lines and unreliable to follow voice commands and manual gestures”. Trainee #6, who strongly agreed that it minimized the effort on learning and performing the task, justified that “it saves time for attendings to explain things to medical students and observers”. 83.3% trainees indicated that it is easy for them to apply the knowledge they gained from the telestration-supplemented training into practices. 66.7% trainees agreed that telestration increased their desire to learn more during the training.

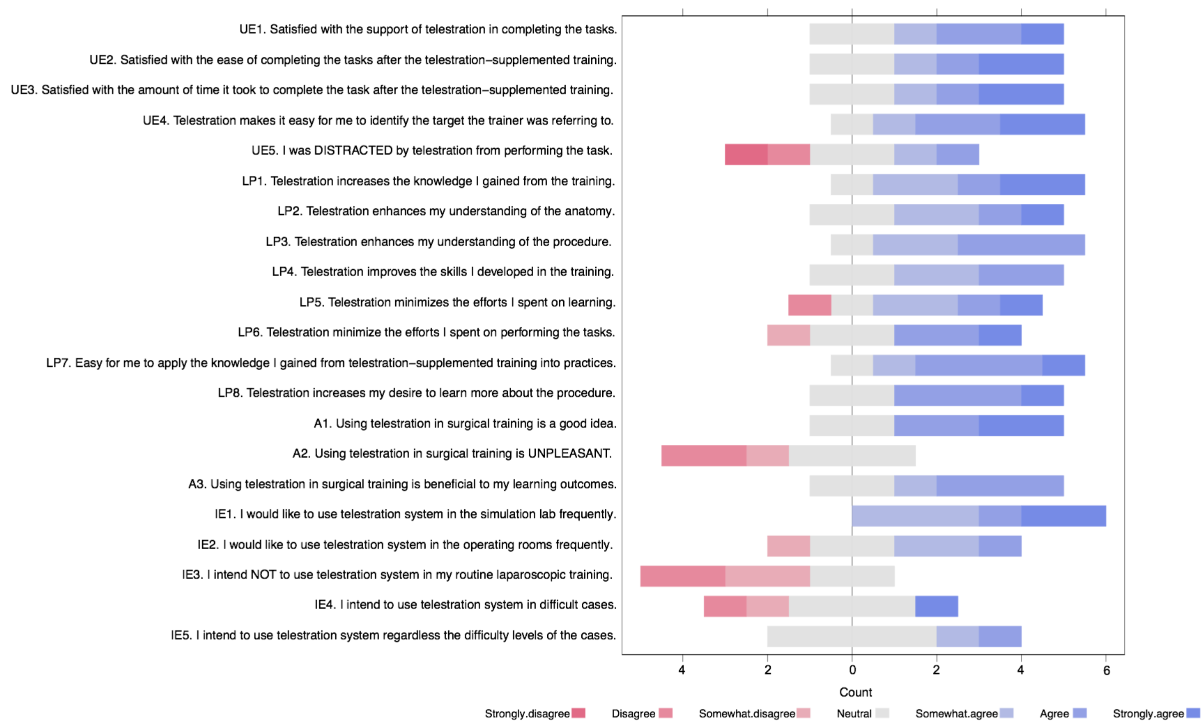

Figure 3. Responses from trainees (n = 6). (UE = user experience, LP = learning performance, A = attitude, IE = intention to use)

66.7% trainees were positive about using telestration in their trainings and thought the telestration would be beneficial to their learning outcomes. The intention to use the telestration is varied in different settings. All trainees indicated that they would like to use the telestration in the simulation lab, while there were only a half of the trainees would like to use it in the operating rooms. Case difficulty levels have limited effect on the intention to use, as 50% trainees were neutral about using the telestration in difficult cases and 66.7% trainees were neutral about use the telestration regardless of the difficulty levels.

Responses from the Trainers

Figure 4 shows the responses from the trainers (n = 9). Overall, 66.7% trainers were satisfied with system. Trainer #1 favored the "immediate user feedback" on the screen, while identified that the "sensivity of capture" was an issue. 75% trainers were satisfied with the support of telestration in conveying the knowledge. 55.6% trainers were satisfied with the amount of time in conveying knowledge via telestration. Trainer #5, who was not satisfied with the use of telestration in completing the task and conveying the knowledge, commented, "it requires I not use the instrument at hand while telestrating". 62.5% of trainers found the system easy to use, while 66.7% trainers thought that they would need the support of a technical person.

With regards to learning performance, 77.8% trainers agreed that telestration might increase their trainees' knowledge gained from the training, especially the knowledge of anatomy and procedure. However, 66.7% trainers regarded telestration as less useful in improving laparoscopic skills. Most trainers found telestration could minimize the efforts of both guiding (87.5%) and learning (75%), and thought it would be easier for their trainees to apply the knowledge into practices (77.8%). Compared to the trainees' increased desire to learn (66.7% trainees agreed that telestration would increase their desire to learn), 55.6% trainers agreed that telestration increased their desire to teach.

All trainers were positive on using telestration in surgical training and 77.8% agreed that telestration would be beneficial to their trainees' learning outcomes. For the intention to use the system, the trainers would like to use it in both the simulation lab (75%) and the OR (62.5%) for routine laparoscopic trainings. It is noteworthy that there were two trainers against the adoption in the lab or the OR, including Trainer #5, who indicated that he had to stop using tools at hand while telestrating, and Trainer #6, who found the system difficult to use. For using the system in varied difficulty levels, the approximate balance between 'agree' and 'disagree' indicates that case difficulty is not a decisive point for trainers to use the telestration.

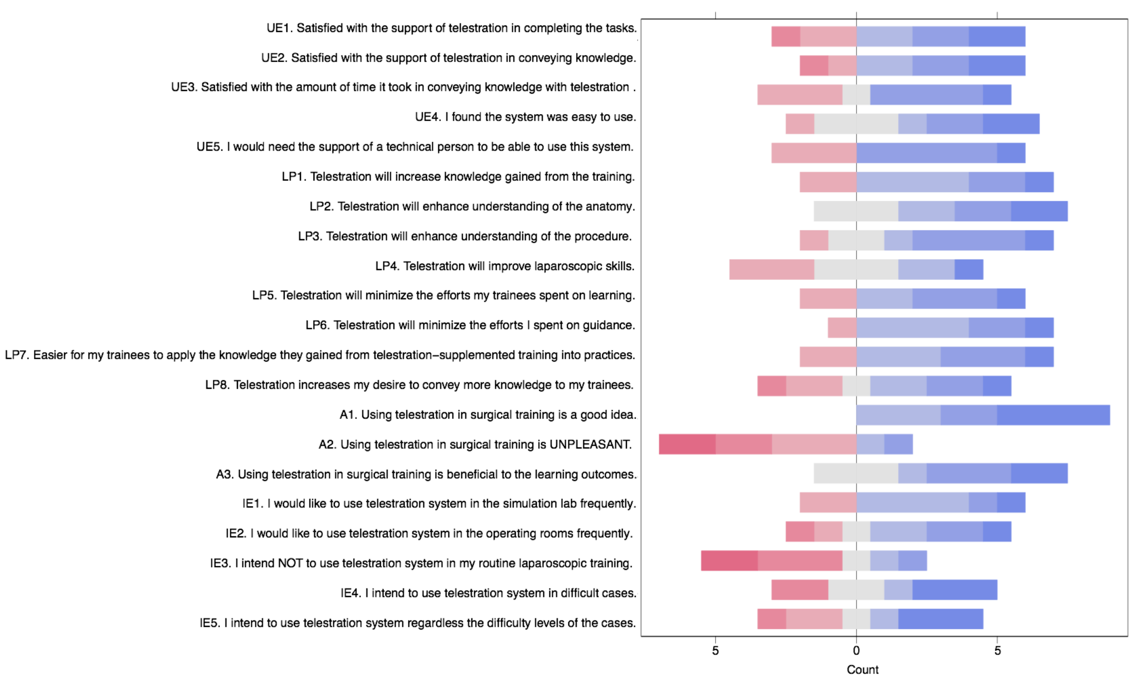

Figure 4. Responses from the trainers (n = 9). (UE = user experience, LP = learning performance, A = attitude, IE = intention to use)

Correlation between Questions

The correlation analysis between the questions allows us to investigate the factors associated with the acceptance of the telestration system in surgical training. Since the difference of the responses between the trainers and trainees is insignificant, we combined these two groups together for the responses of the same questions to increase the power of the correlation analysis (Table 1).

Table 1. Correlation between questions.

					Correlations														
		N	*Mean*	*Std. Err.*	*UE1*	*LP1*	*LP2*	*LP3*	*LP4*	*LP5*	*LP7*	*A1*	*A2 #*	*A3*	*IE1*	*IE2*	*IE3#*	*IE4*	*IE5*
UE1	Satisfied with the system	15	5.111	0.408	1.000														
LP1	Increase knowledge	15	5.333	0.330	.764**	1.000													
LP2	Enhance understanding of the anatomy	15	5.250	0.300	.538*	.801**	1.000												
LP3	Enhance understanding of the procedure	15	5.278	0.284	.618*	.810**	.739**	1.000											
LP4	Improve laparoscopic skills	15	4.611	0.307	.286	.456	.196	.511	1.000										
LP5	Minimize efforts in learning	14	5.042	0.406	.458	.704**	.813**	.758**	.313	1.000									
LP7	Apply knowledge to practice	15	5.389	0.319	.598*	.870**	.760**	.765**	.315	.806**	1.000								
A1	Using telestration is a good idea	15	5.889	0.284	.483	.477	.513	.457	.052	.387	.529*	1.000							
A2#	Using telestration is UNPLEASANT	15	4.972	0.365	.015	-.007	-.162	.140	-.008	-.109	-.012	-.041	1.000						
A3	Beneficial to the learning outcomes	15	5.306	0.287	.125	.423	.428	.384	.292	.530	.604*	.367	-.160	1.000					
IE1	Use in the simulation lab	14	5.354	0.339	.570*	.851**	.700**	.714**	.564*	.490	.719**	.255	-.041	.612*	1.000				
IE2	Use in the operarting rooms	14	4.625	0.372	.808**	.737**	.641*	.788**	.378	.638*	.649*	.285	-.005	.502	.699**	1.000			
IE3#	NOT to use in routine training	14	5.063	0.399	.606*	.540*	.406	.485	.255	.679*	.465	.046	.001	.394	.365	.645*	1.000		
IE4	Use in difficult cases	14	4.375	0.510	.699**	.569*	.449	.558*	.353	.433	.530	.415	.044	.471	.431	.808**	.552*	1.000	
IE5	Use regardless of case difficulties	14	4.625	0.427	.599*	.462	.356	.721**	.232	.331	.501	.287	.336	.132	.435	.712**	.147	.596*	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

#. The scale is reversed.

As shown in Table 1, the responses on user experience are significantly correlated with gaining and applying knowledge in learning performance, as well as intention to use. Interestingly, the rating of user experience is highly correlated with the use in the OR ($\rho = 0.808$), while has moderate association with the use in the simulation lab ($\rho = 0.570$). This reflects that users' satisfaction of the system requires much more attention for the system to be implemented in a more critical environment.

Unsurprisingly, increasing overall knowledge is correlated with the increase of anatomical and the procedural knowledge, and the ability to apply the knowledge into practice. It is worth noting that the increase in knowledge is positively associated with minimizing learning effort ($\rho = 0.704$), which reflects that telestration effectively improves learning outcomes and smoothly enhances the learning process. In addition, knowledge gained is significantly correlated with the intention to use, especially in the simulation lab ($\rho = 0.851$), which indicates that the simulation lab is a main place for trainees to accumulate the knowledge that could be telestrated on the screen.

The insignificant correlation between the laparoscopic skills improvement and all other responses indicates that laparoscopic skills are not the main focus of telestration supplemented guidance and suggests that telestration would not be the proper choice for laparoscopic skill training.

Applying knowledge is highly correlated with minimizing learning effort, which can be explained by attention allocation – as trainees easily apply knowledge into practices, more attention will be allocated to gaining knowledge. The significant correlation between applying knowledge with positive attitudes towards using the telestration indicates that the benefits of easy knowledge application enhance surgeons' acceptance of the system. Except for knowledge application, the attitudes towards using the system were insignificant with all other responses.

The use of telestration in difficult cases is moderately correlated with procedural knowledge ($\rho = 0.558$), compared to the high correlation for the use of telestration regardless of case difficulties ($\rho = 0.721$). This indicates that telestration can be used in a variety of cases to effectively assist in enhancing procedural knowledge.

Discussion

Our study suggests that the telestration system can be used to implement gestures on the laparoscopic video in order to efficiently facilitate the conveyance of expert knowledge and improve the trainees' learning performance in surgical training. Specifically, both the trainers and trainees thought the telestration was useful in improving learning performance, especially in accumulating anatomical and procedural knowledge, as well as transferring the knowledge into the OR. The correlation revealed that with the increase in knowledge gained, the effort in learning was minimized.

In addition, our study reveals some barriers in acceptance of the system in laparoscopic training that highlights the need for future effort in the design of the telestration system. As indicated in our correlation analysis, user experience is a key factor for the success of the system adoption. However, there are several user experience issues detected from our study. First, the telestration system on a secondary display distracted trainees from their work – the trainees have to switch their attention between the work field and the telestration representation. This barrier highlights that the lag should be solved and the telestration should be integrated in the trainees' monitor. Secondly, the interaction with the system may be a source of interruption in the trainers' workflow – the trainer imagined that he had to pause the procedure and put down the instruments, waving in the air to draw any annotation. To address this issue, new interaction mechanisms that do not depend on arm movements can be designed to control the system. In addition, precision is another barrier. The trainees must spend extra effort to identify inaccurate annotations on the monitor, discuss them with the trainer, and make judgments on how to proceed. This suggests the algorithm to be improved to accurately relate the hand position to the pointer.

Accordingly, there are two major goals in our future works – understanding the mechanisms in which telestration supports the conveyance of expert knowledge and identifying new interaction mechanisms for the telestration system to integrate unobtrusively into the trainer's workflow.

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