Towards Sterile Interaction with Medical Devices in the Operating Room using Extended Reality

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Abstract

In the OR, indirect device control via circulating nurses increases workload and delays, thus potentially compromising patient safety. Therefore, the SISOPS project develops a contactless system using gesture recognition and distortion-free projection onto sterile drapes, enabling surgeons to control devices and view data in the sterile field without HMDs. A pilot study with 24 novices compared two conditions: self-operating a tablet nearby vs. instructing another person while performing a primary task (surgical simulation). Eye movements were tracked, and workload and feasibility assessed. Perfomance for the surgical task was better when instructing others, suggesting self-managing secondary tasks increases distraction. Participants performed better on secondary tasks when using the tablet themselves but looked away from the surgical task more often, indicating a trade-off beween autonomy and attention. However, ceiling effects and novice participants limit generalizability. Future work will use the fully operational SISOPS demonstrator with gesture control, which may alter outcomes.

Index terms: XR, OR, workload, Human–Computer Interaction, Surgical Workflow, Ergonomics, Contactless Interaction

1 Introduction

In the perioperative environment, various potential risk areas affecting patient safety are well known. In particular, indirect intraoperative device control from outside the sterile field through verbal communication with dedicated operating room (OR) personnel (so called "circulating nurses") poses significant challenges. These circulating OR nurses are currently needed to pass items to the sterile surgical team and to operate medical devices that are not sterile and therefore cannot be handled by the surgical team. On the one hand, this leads to prolonged waiting times, increased frequency of incorrect settings, and causes the surgical team to divert their attention away from the operative site, resulting in negative consequences for patient safety [1,2]. On the other hand, it significantly restricts the autonomy of the surgical team and often leads to frustration among them. Furthermore, errors in device operation of less experienced circulating nurses may compromise sterility, prolong surgery duration, or lead to intraoperative complications [3–7]. Finally, surgical procedures represent one of the most cost-intensive work environments in hospitals. Therefore, technical solutions that reduce operating time are economically necessary and entirely justified—especially when patient safety is simultaneously enhanced. Moreover, the shortage of specialized medical personnel means that systems helping to reduce reliance on non-essential staff will be urgently needed in the future.

For these reasons, the third-party funded collaborative SISOPS project aims to develop a demonstrator that enables a contactless interaction and visualization system using modern camera technology and distortion-free visualization on curved surfaces. To optimize device control, the sterile drapes covering the patients will be utilized as projection surfaces. The system will allow direct control of relevant medical equipment—such as surgical lighting or intraoperative neuromonitoring (IOM) systems—within the sterile operating field via standardized interfaces. Moreover, CT/MRI data, procedural workflows, checklists, and critical surgical parameters can be visualized within direct view of the sterile surgical team. This represents a novel application of Extended Reality (XR) in the OR, potentially leading to shorter anesthesia times, reduced risk exposure for patients, and a decrease in workload of the surgical team, thereby significantly improving patient safety [8,9]. A key advantage of this concept is that no additional equipment—especially no AR/VR headsets—is required for the surgical team.

The technical approach combines a camera system (multiple RGBD cameras—color and depth cameras combined—mounted on the ceiling) with a projection system [10]. The camera system continuously and automatically captures the operating table, including all sterile drapes, as well as personnel standing around the table. Additionally, the head position and gaze direction of the surgical team at the operating table are tracked to determine the optimal projection surface. To detect the operating table, methods for implicit surface reconstruction from point clouds will be further developed or combined with machine learning techniques (neural implicit representations). For head and gaze detection, pose estimation methods will be employed. To project controls and visualizations without distortion onto the curved drapes, optimization algorithms and target functions will be investigated. To prevent shadowing, coordinated projections from multiple projectors will be used.

For interaction, hand and gesture recognition will be developed using the RGBD cameras. The gesture recognition will build upon existing software and machine learning models. Efficient and error-free interaction—such as pointing at control elements on a curved projection surface—will be achieved through intuitive interaction metaphors. As an example, an IOM device and OR light control

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will be integrated into the SISOPS system. A dedicated user interface will be developed, featuring control elements and visualizations optimized for projection. Special attention will be paid to safety aspects. Furthermore, the accurate acquisition, processing, and display of measurement data will be critically analyzed to ensure a user-friendly visualization for the surgical team. For more detailed information on the actual SISOPS setup, we refer to the publication by Muehlenbrock et al. [10].

To measure general feasibility of giving the surgeons more autonomy during surgery, we employed a tablet instead of the SISOPS system during a simulated surgical task. The aim of this pilot study was to establish a viable and informative study design for future evaluations with the SISOPS demonstrator and to evaluate the effect of handling a secondary task in addition to a simulated surgical task on workload, as well as task performance of the primary (surgical simulation) task and secondary problem-solving tasks, where the secondary task was either handled by the participants themselves or by instructing another person to do so. This should give an indication with regards to the trade-off between autonomy and attention in the OR.

2 Methods

All participants (9 male; 15 female) were students of the Carl von Ossietzky University Oldenburg and novices with regards to laparoscopic tasks. Participants received a patient information sheet and signed an informed consent form, if they were willing to participate. Afterwards, they completed a questionnaire about their medical history. Then, they put on a pair of eye-tracking glasses (Core, Pupil Labs) to measure eye movements during the measurement phase. These glasses then adjusted and calibrated.

Each participant completed a brief training session. During this time, they became familiar with all logic tasks and the task they had to perform on the laparoscopy simulator (LAPSIM; Surgical Science).

The actual measurement consisted of two tasks which had to be executed simultaneously: The primary task required participants to perform a laparoscopic simulation on the LAPSIM system, where they alternately retrieved small needles from the left and right sides of the simulated surgical field. This task served to simulate a realistic laparoscopic procedure.

The secondary task consisted of a series of problem-solving exercises designed to simulate typical cognitive demands in a surgical setting (see also Figure 1). Tasks included 3D spatial reasoning (e.g., determining viewing angles), simple manipulation tasks such as adjusting the position of a table by a specified distance, completing logical number sequences, graph and chart interpretation, and basic arithmetic problems. Many tasks were adapted from the German medical school admission test (TMS). Participants either completed the tasks themselves on a tablet ("tablet" condition) or instructed another person—comparable to the current situation in the OR—to carry out the task and enter the solution ("other person" condition). All participants completed both conditions in randomized order, and each session lasted approximately 15 to 20 minutes. This setup allowed us to evaluate how direct versus delegated handling of secondary tasks affects performance and attention in the simulated surgical environment.

Throughout the entire procedure, eye movements were recorded. After each of the two conditions, participants were asked to complete two short questionnaires: one assessing the perceived workload during the task (SURG-TLX) and another evaluating the usability of the respective situation.

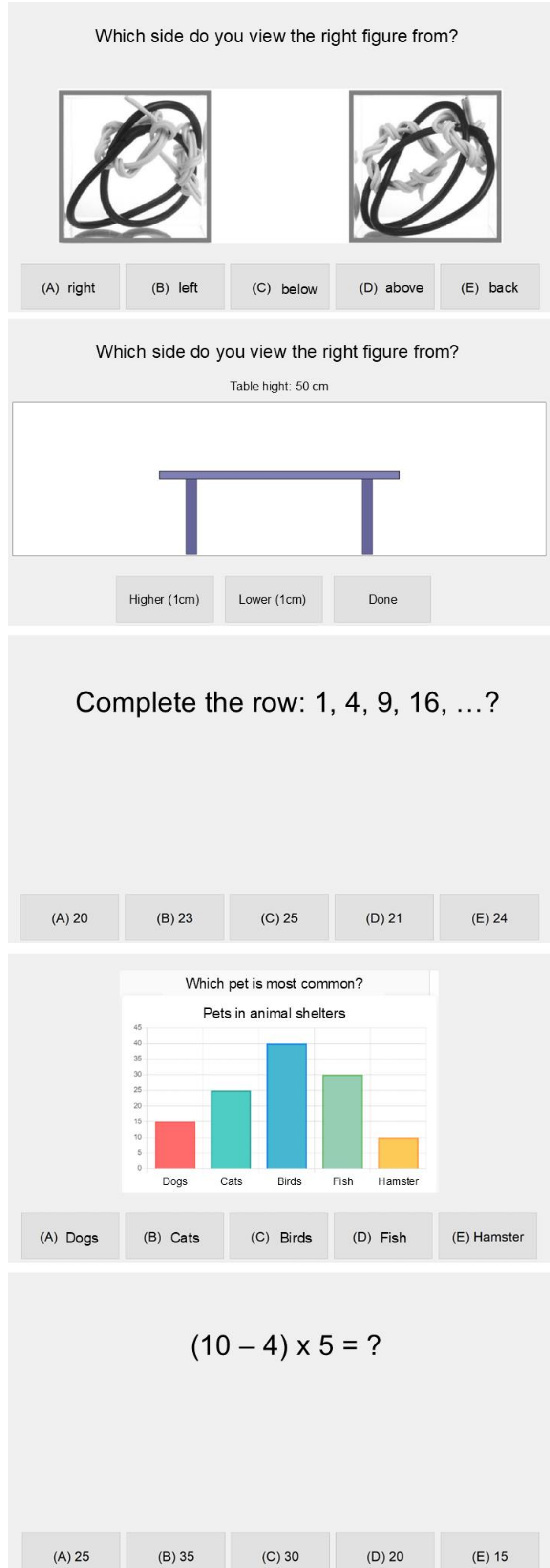

Figure 1: Examples for the five types of problem-solving tasks (secondary task) provided on a tablet; The responses were either provided directly by the participants on the tablet, or participants had to instruct another person to enter the correct answer.

Currently, we analysed the data connected to the logic tasks, i.e., number of correct answers and mean reaction time for the 20 logic task per condition (as surrogate parameters for the completion of the secondary task), as well as the percentage of time participants spent looking at the monitor of the LAPSIM (surrogate parameter for the attentiveness to the simulated surgical task), and the amount of needles retrieved during the laparoscopy simulator task (surrogate parameter for the performance in the primary task). Means and 95% confidence intervals (95% CI) were calculated for each outcome per condition and t-tests were performed, with p-values < 0.05 indicating significant differences between conditions for the respective outcomes.

3 First Results

Significant differences between the tablet and the "other person" condition were found for the number of correct answers (tablet (mean [95% CI]): 16.0 [15.3 – 16.8]; other person: 17.8 [17.0 – 18.5]; see also Figure 2, upper left panel), the mean reaction time (tablet: 12.8 sec [11.4 – 14.2]; other person: 13.9 sec [12.9 – 14.8]; Figure 2, lower left panel), and the percentage of time spent looking at the monitor (tablet: 73.3% [70.8 – 75-8]; other person: 76.1% [73.1 – 79.0]; Figure 2, lower right panel). The number of needles retrieved did not differ significantly between the tablet and "other person" condition (tablet: 67.6 [59.6 – 75.5]; other person: 71.3 [64.0 – 78.5]; Figure 2, upper right panel).

4 First Conclusions

Based on this first study within the scope of the SISOPS project, it has some benefits for the surgeons to be able to handle some tasks themselves, as well as some drawbacks.

It seems like the secondary task can be handled slightly faster when self-managing. However, accuracy for secondary tasks seems to go down.

Participants had to look away from the primary task more often, when handling the tablet themselves, indicating that participants could better concentrate on the surgical procedure, when just instructing another person instead of handling the logic tasks themselves, as evidenced by the slightly larger number of needles retrieved in the tablet condition, and the percentage of time spent looking at the monitor of the laparoscopy simulator.

However, overall differences are not as great as anticipated, thus leading us to speculate that enabling surgeons to handle tasks in addition to the actual surgery does not increase distraction of the surgeons to a point where it might impact patient safety or the performance of the surgery.

Differences between logic tasks, as well as subjective workload as measured with the SURG-TLX questionnaire are not analysed currently, but are needed to get the full picture. Also, the SISOPS demonstrator, once fully operational, will work with gesture control

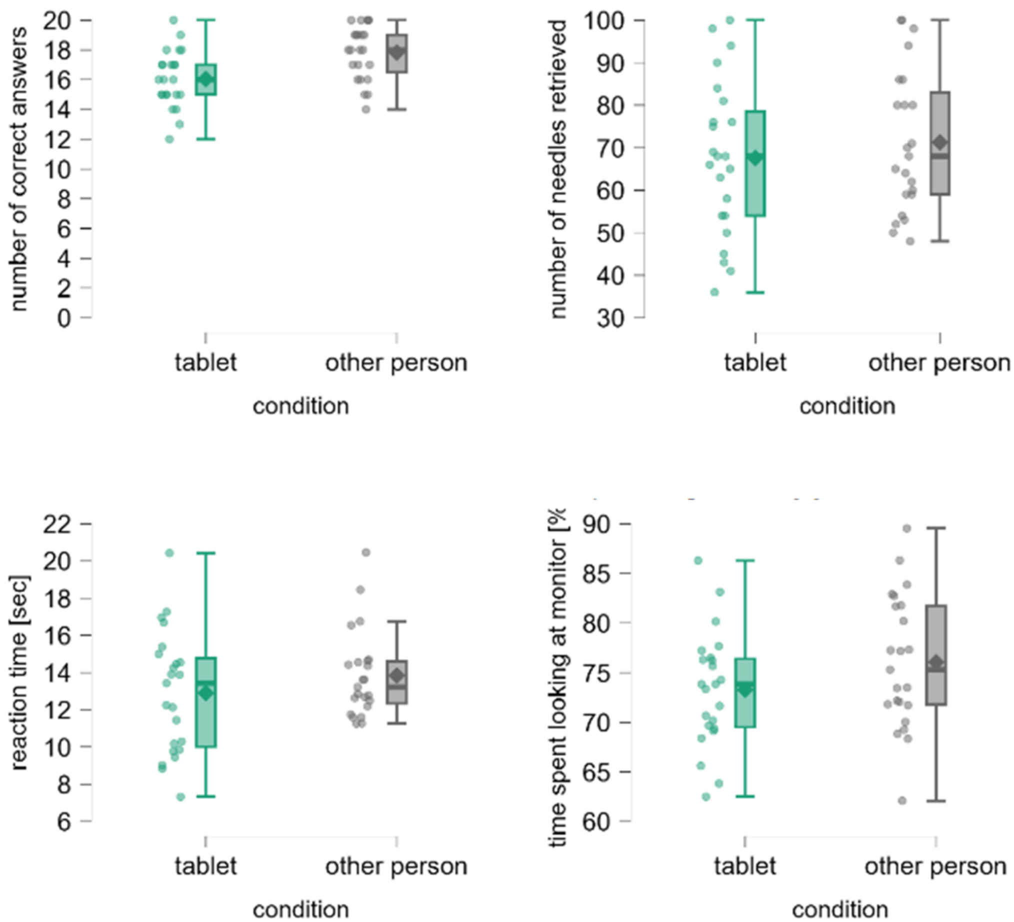

Figure 2: for each condition (participants handling the tablet themselves vs. giving another person the instructions) number of correctly answered logic tasks (upper left), mean reaction time for each participant over all 20 logic tasks (lower left), number of needles retrieved (upper right), and percentage of time spent looking at the monitor (lower right) are depicted

instead of the interaction with a tablet, which might influence the results as well.

The fact, that only laparoscopic novices took part in this study might limit the generalisability of the results. However, limited experience with the surgical simulator led to high attention to the task, which might not have been the case with experienced laparoscopic surgeons, which might have been to bored by the primary task to show any differences in the secondary task. The observed ceiling effects for accuracy of the secondary task and the performance of the primary task (needle gathering) seem to indicate that both primary and secondary task might have been too easy, even with our group of novices.

Overall, this study gave valuable insights into how to conduct further evaluations employing the fully operational SISOPS demonstrator in the future. Based on this new found knowledge, we are now able to adapt the current study design to gather further insight into sterile interaction with medical devices in the OR using XR, especially with regard to the potential trade-off between autonomy and attention in surgical staff.

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