Assessment of a Cognitive Workload-Adaptive Aid for Surgical Training

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Introduction

- High-risk surgical procedures often have avoidable errors, with over half attributed to extreme cognitive stress that care teams undergo [1,2]
- Workload management is not included in current training, especially for inexperienced surgeons [3]
- Laparoscopic surgery involves operations completed in the abdomen or pelvis using tiny incisions with the use of a camera and special tools (Figure 1).
- Augmented reality (AR) combined with physiological sensors can be used as a workload-management training aid
- A novel cognitive workload-adaptive tool for laparoscopic surgery training was developed (Figure 2) [4]
- The goal of this study is to test the effectiveness of an AR training guide for laparoscopic surgery

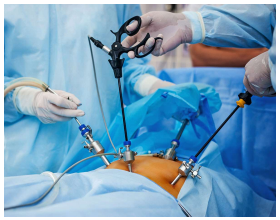


Figure 1 :Laparoscopic tools in surgical use

Figure 2: Participant using laparoscopic tools for peg task

Methods

Study Overview:

- Twenty-two participants completed 4 Fundamentals of Laparoscopic Surgery (FLS) adapted tasks
- Participants equipped with Tobii Glasses and Emotiv EEG headset (Figures 3 and 4) to measure eye and brain activity for workload monitoring [5]
- Participants filled out a System Usability Scale (SUS) to evaluate the usability of the overlay

Cognitive Workload: Gaze entropy and mean power frequencies, and engagement index were measured and calculated [5, 6, 7, 9]

- Calibration tasks were completed for personalized neural network models

AR Overlay:

- During the task, if the neural network detected high workload, overlay would modify guidance (Figure 5A)
- Participants received constant input from the overlay, which adjusted in real-time to workload changes (Figure 5B)

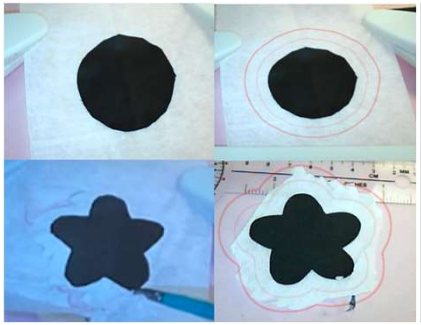
Cutting Tasks:

Participants cut two shapes (circle and star) and for each shape, there was a control version (no overlay) and an intervention version (with overlay) .

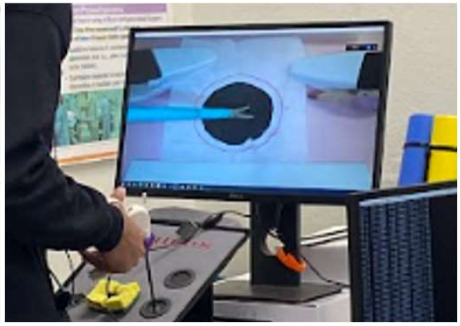
Figure 3: Emotiv EEG Headset

Figure 4: Tobii Eye-Tracking Glasses

Figure 5: AR Overlay Cutting Tasks

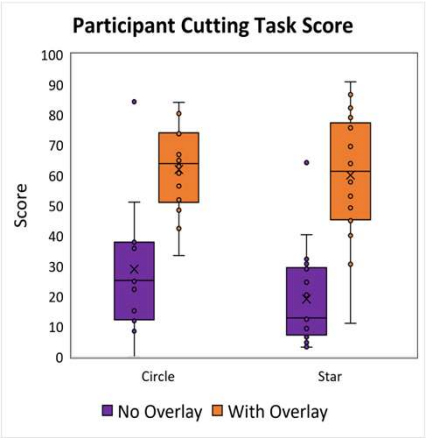


A. Overlay On/Off for both shapes

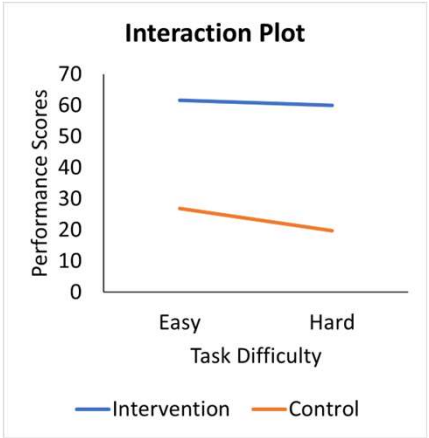


B. Participant cutting the AR Overlay Circle Task

Figure 6: Task Performance Scores



A. Participant Performance Scores with and without overlay



B. Performance Scores interaction plot

Preliminary Results

- Performance was calculated as the proportion of correctly cutting perimeter around the given shape (out of 100)
- Overall performance with overlay greatly improved with the cutting of both shapes (easy & hard), as seen in Figure 6A. Task difficulty had a minor effect on performance for both Intervention and Control; Intervention has a major effect on the score for both easy and hard cases as seen in Figure 6B.
- The average scores for the easy tasks (circle) significantly increased by 195% ($p < 0.05$) while the average scores for the hard tasks (star) increased by 280% ($p < 0.05$).
- AR-overlay intervention seems to affect performance score in both easy and hard tasks
- Average usability score of 68.6 with a standard deviation of 17.25.

Discussion

- Participants showed performance improvements during both easy and hard tasks when using the AR overlay
- Increase in performance with overlay suggests that the workload-adaptive aid enhanced participants' abilities to complete the cutting tasks
- The usability rating of the system shows the overlay met the standard for user interfaces but there is room for improvement
- Overall, the use of the AR overlay positively affected performance during the laparoscopic tasks, leading to greater performance

Next Steps / Future Work

- Increase participant size
- Create a delay protocol where the system will delay or lag on the participant during their trials or tasks for anomaly detection

Acknowledgement

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References

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