The Effect of Latency on Digital Vitreoretinal Surgery

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Summary

- Latency found in current versions of digital vitreoretinal surgery platforms are below the thresholds found to negative affecting performance for the majority of users

Background

- Three-dimensional heads-up display (3D HUD) surgical platforms have been and continue to be developed for a variety of surgical fields such as ophthalmology, general surgery, and urology[1-3]
- Potential advantages[1,4-7]
  - Ergonomics
  - Surgical teaching
  - Stereopsis
  - Lateral resolution
  - Digital manipulation of images in real time
- Potential disadvantages[8,9]
  - Learning curve
  - Cost
  - **Latency between what the surgeon does and what the surgeon sees**

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Background

- To the best of our knowledge, there have been no publications on different levels of latency in digital vitreoretinal surgery
- The effect of latency on surgery has been studied in the laparoscopy literature[10-18]
  - Different tasks
  - Looked at latencies of 200 - 1000 ms (current 3D HUD platforms for VR are at 70 ms or even less)

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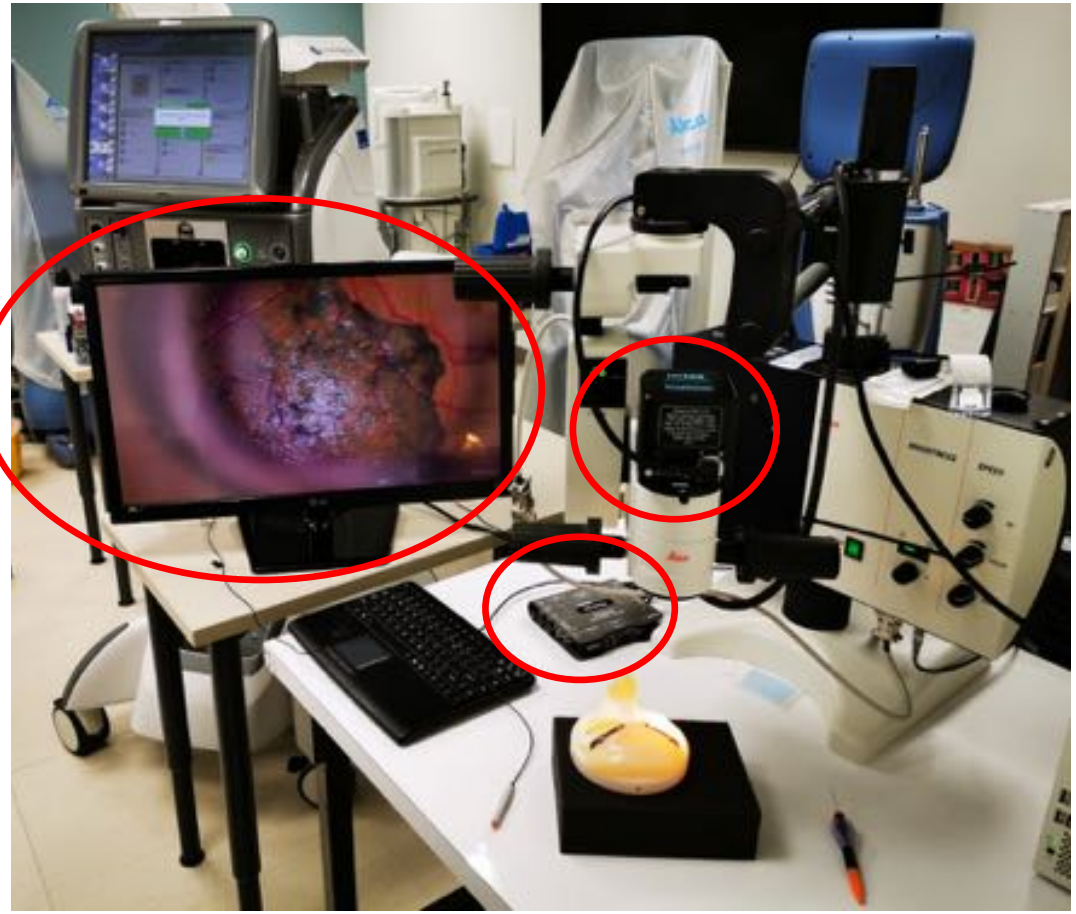
Objectives

- What is the effect of latency on surgical performance using a three-dimensional heads-up display (3D HUD) visualization system for vitreoretinal surgery

Methods

- Equipment
  - 3D camera mounted on a microscope
  - 27-inch 1080p 3D monitor
  - Video latency generator connected between the camera



Methods

1. Suturing task:
   - Place a suture through plastic foam using 7-0 Prolene ass a suturing needle throw plastic foam and then to tie a surgeon's knot.
2. Peeling task:
   - Peel off a coat of film simulating ILM in a model eye using 23G ILM forceps

Methods

- 4 levels of latency
  - 50 ms
    - Inherent level of latency of the camera-monitor system
  - 66 ms
  - 90 ms
  - 122 ms
    - Maximum added latency using the video latency generator
- The order of the level of latency was randomized and blinded to the participant

Methods

- Outcomes
  - Task completion time (objective)
  - "Usability" with a questionnaire used in a previous latency study in the laparoscopy literature[18] (subjective)

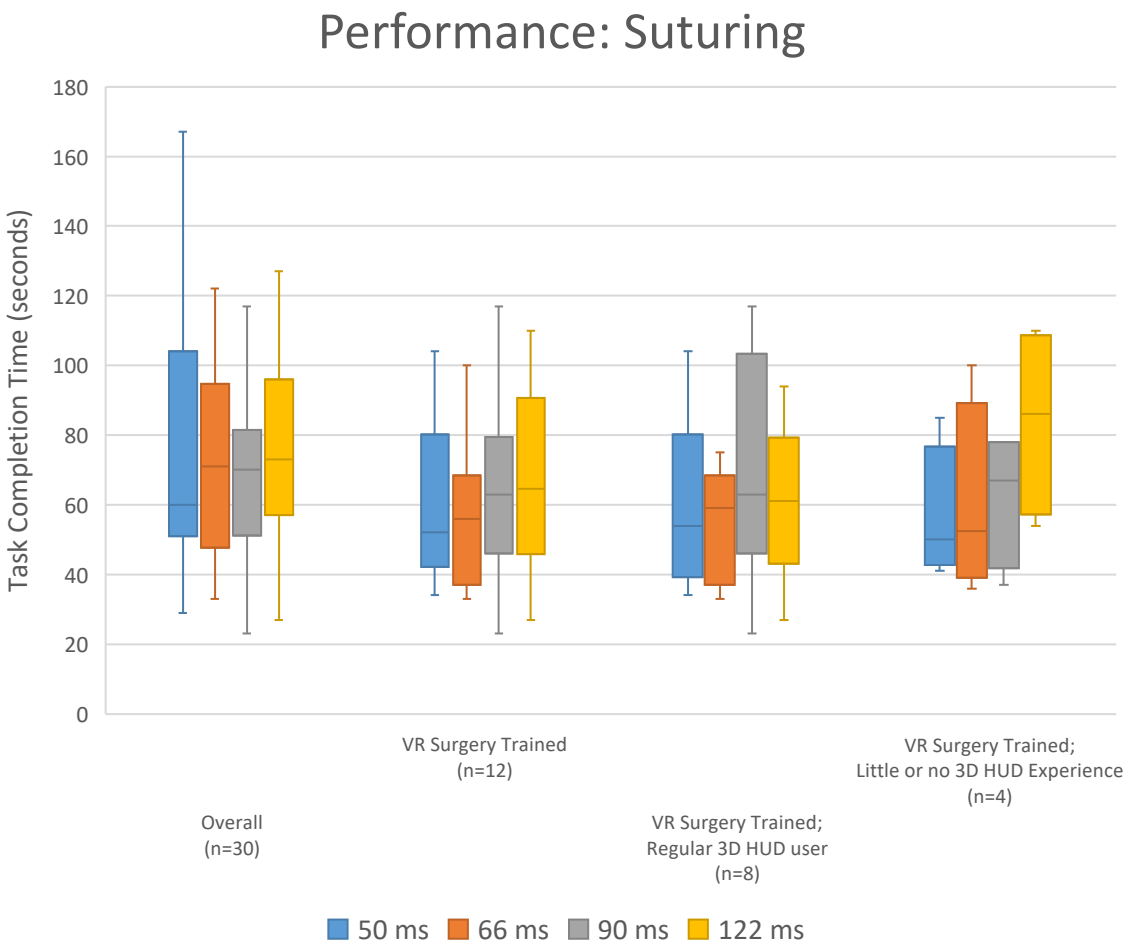
Awareness					
Indicate how large the delay was between what you did and what you saw					
None	Small	Somewhat Small Inefficiency	Somewhat Large	Large	Very Large
Inefficiency					
Indicate how efficiently you could execute the task					
Very Efficient	Efficient	Somewhat Efficient	Somewhat Inefficient	Inefficient	Very inefficient
Disturbance					
Indicate how disturbing you found the latency					
Not At All Disturbing	Not Disturbing	Somewhat Not Disturbing	Somewhat Disturbing	Disturbing	Very Disturbing
Inadaptability					
Indicate to what degree you could adapt to the delay					
Very Easily	Easily	Somewhat Easily	Somewhat Difficult	Difficult	Danger
Danger					
Indicate how dangerous this delay would be for the patient					
Not Dangerous At All	Not Dangerous	Somewhat Not Dangerous	Somewhat Dangerous	Dangerous	Very Dangerous

[18] Kumcu A, Vermeulen L, Elprama SA, Duysburgh P, Platiša L, Nieuwenhove YV, et al. Effect of video lag on laparoscopic surgery: correlation between performance and usability at low latencies. Int J Med Robot 2017;13:e1758. https://doi.org/10.1002/rcs.1758.

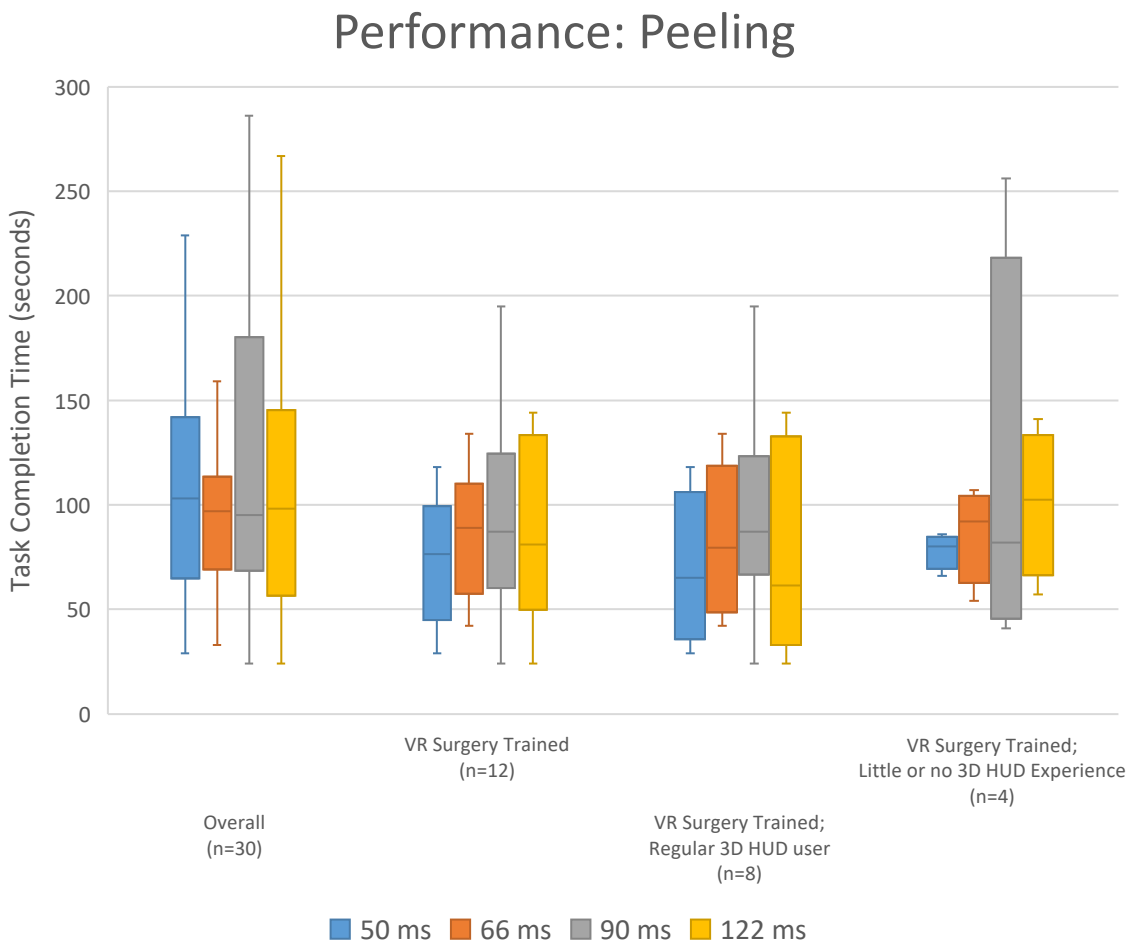
Results

Baseline Demographics of Participants	
Gender	
Female	7
Male	23
Background	
Vitreoretinal surgeons	5
Vitreoretinal surgery fellows	7
Ophthalmologists	3
Ophthalmology residents	11
Non-ophthalmology residents	4
Medical Student	1
With VR experience	12
With Heads-Up 3D Visualization experience	8
Without Heads-Up 3D Visualization	4
Without VR experience	18
Total Participants	30

Results (Task Completion Time)

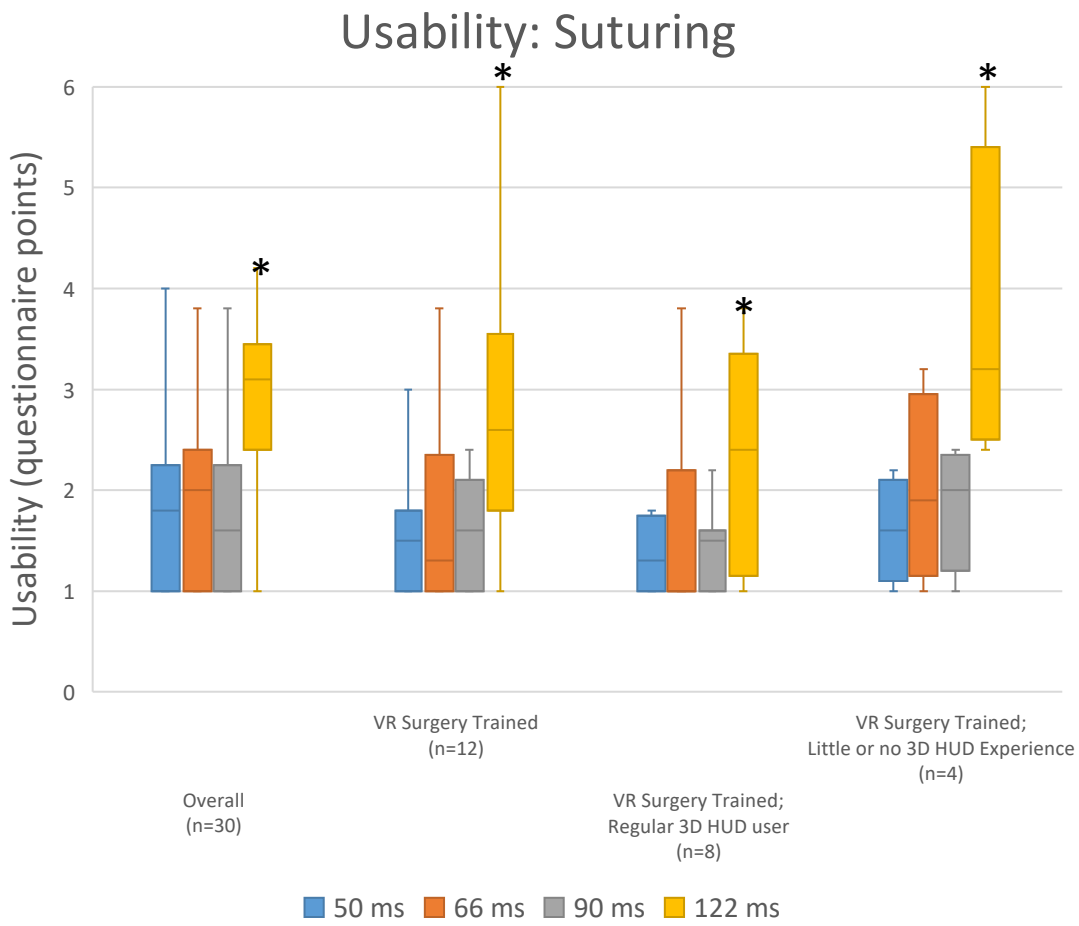


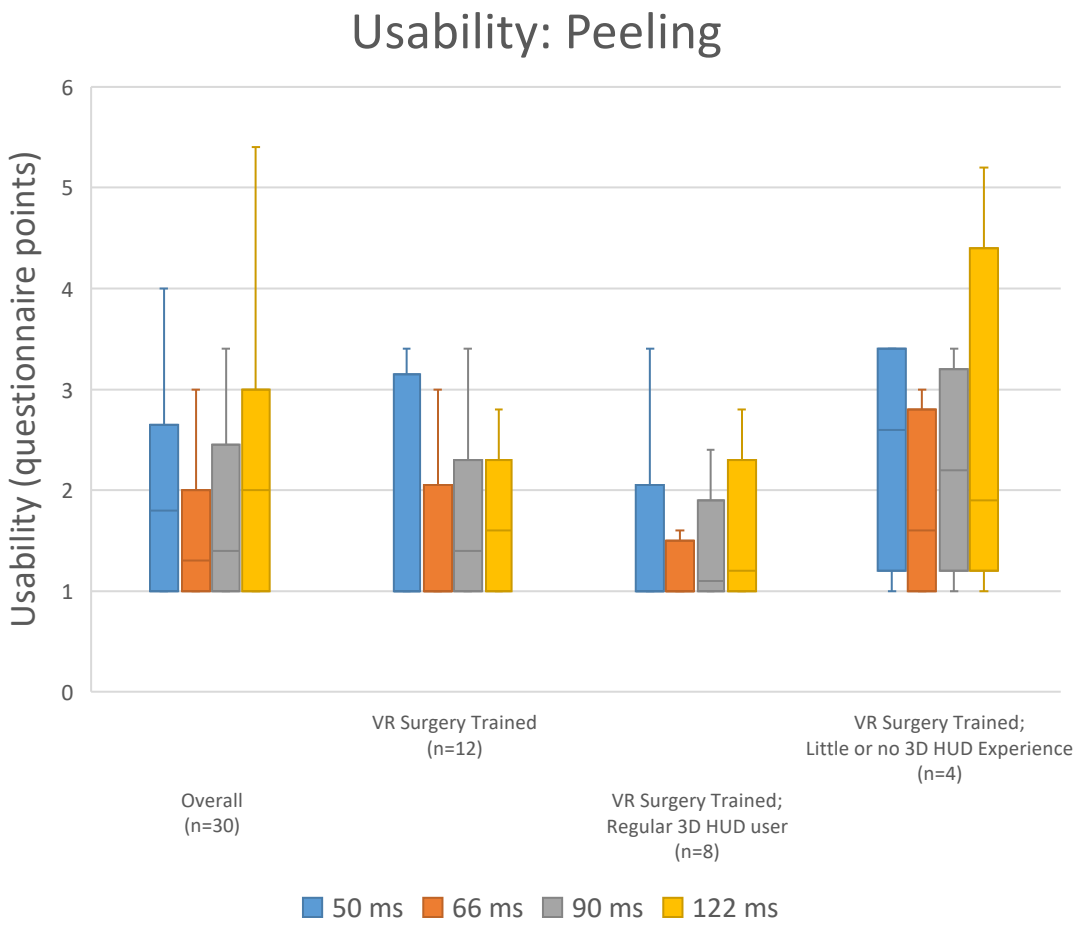
For suturing, no statistical difference between completion times at 66, 90, and 122 ms of latency when compared to 50 ms.



For peeling, no statistical difference between completion times at 66, 90, and 122 ms of latency when compared to 50 ms.

Results (“Usability”)





For suturing, usability at 122 ms statistically different compared to 50 ms (overall and all subgroups). No difference at 66 and 90 when compared to 50 ms.

For peeling, no statistically significant difference in usability at 66, 90, and 122 ms of latency when compared to 50 ms.

Results

- Suturing more affected by latency than peeling
  - Suturing: fast jerky movement?
  - Peeling: slow and study movement?
- Experience with a task seemed to lessen the effect of latency
  - Participants with VR training were less affected by latency than those without VR training
  - Furthermore, among those with VR training, those who were regular users of a 3D HUD were even less affected.
    - Due to being used to performing surgery with a certain level of latency?
    - Neuroadaptation?

Results

- The level of latency that adversely affects performance and usability for suturing is somewhere between 90 ms and 122 ms while for peeling is somewhere above 122 ms
- Both of these thresholds are higher than the latency seen in both the current platforms for Digital Vitreoretinal Surgery, which have approximately 70 ms of latency or less[19]

[19] Digital 3D microscopy. EuroTimes 2020. https://www.eurotimes.org/digital-3d-microscopy/ (accessed June 14, 2020).

Conclusion

- Latency found in current versions of digital vitreoretinal surgery platforms are below the thresholds found to negative affecting performance for the majority of users