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The effect of visualization method on the performance of simulated microsurgery tasks

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Abstract: The operating microscopes may be a significant cause of fatigue and discomfort in surgeons. The need for the microscope to be placed over the operating field forces surgeons to remain at the microscope's eyepieces at an uncomfortable posture for the entirety of the surgery. This study compared the effects on microsurgical task performance for four visualization methods: a monocular microscope, a binocular microscope, a three-dimensional (3D) flat-panel television display and a two-dimensional (2D) flat-panel television display. Eleven subjects each performed two microsurgical tasks and their performance was documented by video camera. The statistical analysis performed indicated utilization of the microscope as a visualization method increased subject performance. No significant difference in performance between the 2D and stereoscopic visualization methods.

Keywords: microsurgery, heads-up displays, task performance, fatigue

1. Introduction

Despite improvements in the field of microsurgery, the operating with microscope may still continue to cause fatigue and injuries in surgeons [2, 3]. The need for the microscope to be placed over the operating field forces surgeons to remain at the microscope's eyepieces at an uncomfortable posture for the entirety of the procedure [1].

This study compared the effects of four visualization methods: a monocular microscope, a binocular microscope, a three dimensional (3D) flat-panel television display and a two dimensional (2D) flat-panel television display on subject performance of microsurgical tasks. The study aimed at finding differences between visualization with a microscope and a flat-panel display, as well as, the effect of altering depth perception by switching from 2D to 3D.

Two hypotheses were tested. The first hypothesis was that the use of flat-panel displays would not impair subject performance and the second was that the use of 3D technology would improve subject performance.

2. Methods

2.1 Participants

Eleven university students with no prior surgical experience, six women and five men, consented to participate in this study and were compensated approximately $75 for five hours of participation. This study was approved by the University of Michigan Human Subjects Review Board.

2.2 Testing Stimuli and Tasks

The experiment included two microsurgical tasks, each with three trials, tested on each of the four visualization methods in randomized orders.

Task one involved transferring eight silicone tube segments to and from wire posts arranged on a fixture. The inside diameter of the tube segment was 0.645mm and the diameter of the wire was 0.38mm. Forceps were used by both hands; the dominant hand transferred while the non-dominant hand stabilized the fixture. The fixture consisted of 16 wire posts installed in a 4 x 4 matrix with 2.5mm spacing in between. The wire posts had randomized heights (1.5mm or 3mm) and orientations (perpendicular or 75º with respect to the fixture in one of four directions).

For trials one and two, subjects were given three minutes to transfer eight tube segments (initially occupying the left half of the 4 x 4 fixture) across to the right half and then return them to their initial positions. For trial three, subjects were instructed to transfer as many tube segments as possible in six minutes.

Task two involved threading tube segments (identical to above tube segments) onto a monofilament fishing line with a diameter of 0.2mm. The non-dominant hand forceps were used to hold the line while dominant hand forceps were used to thread tube segments.

For trials one and two, subjects were instructed to thread eight tubes in three minutes and for trial three, to thread as many tubes as possible in six minutes.

All trials were performed under 5X magnification using a binocular lab-scope (Sciencescope). One of the eyepieces was covered for the monocular trials. For the flat-panel trials, the same microscope was outfitted with two commercially available synchronized video cameras with resolutions of 640x480 pixels (Premiere MA87N). For the 3D flat-panel trials, the two video eyepiece signals were combined by a custom interface and displayed on a 3D television monitor (Samsung UN40C7000WF). For visualizing the 3D effect, subjects wore 3D active-shutter glasses. For the 2D flat-panel trials, live feed from a video camera installed overhead (Sony DCR-SX83) was streamed to the same television monitor with the 3D visualization disabled.

To observe subject performance, video of the subjects' hands and the work area was recorded with a video camera (Sony DCR-SX83).

3. Results

Trials one and two were used as training periods while the data from trial three was analyzed. The mean completion times, time to get and put one tube segment are given in Table 1. A pairwise comparison using the Tukey method at a 95% confidence showed performance was significantly faster using the microscope when compared to the flat-panel displays. No significant differences, however, were found between 2D and 3D visualizations for the microscope or for the flat-panel displays.

Table 1

Mean completion times (in seconds) with standard deviations in parenthesis for tasks one and two.

Visualization Methods	Task One	Task Two
Monocular (2D)	5.25 (3.43)	21.96 (19.37)
Binocular (3D)	4.97 (2.23)	26.17 (36.51)
Flat-panel (2D)	9.64 (4.73)	44.49 (33.73)
Flat-panel (3D)	8.88 (3.63)	42,75 (15.32)

Table 2 lists the mean error-rates (e.g. drops or movement errors per successful tube transfer) for both tasks. Again, a pairwise comparison did not show significant difference between 2D and 3D visualizations however, task two did show a significant increase in error-rates using the flat-panel displays.

Table 2

Average error per attempt for tasks one and two. Standard deviations are in parenthesis.

Visualization Methods	Task One	Task Two
Monocular (2D)	0.89 (0.55)	3.26 (2.60)
Binocular (3D)	0.76 (0.38)	3.35 (3.47)
Flat-panel (2D)	0.76 (0.72)	5.24 (4.71)
Flat-panel (3D)	0.89 (0.54)	5.02 (2.41)

4. Discussion

Based on the results, subject performance was slower using flat-panel displays. This may be due to the poor resolution and response rate of the flat-panel visualization compared to the optical microscope. In a future study, a high resolution camera will be utilized.

Unexpectedly, the results also showed an insignificant difference in performance between 2D and 3D visualizations. This may be due to subjects who have difficulty using a binocular microscope or viewing a 3D image on a flat-panel display. Some subjects performed better with 3D visualizations while others did worse.

Future studies should include more subjects, especially those with surgical experience, and a flat-panel display with enhanced resolution and improved response rate.

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