IPCAI 2016 manuscript No.
(will be inserted by the editor)

A Wearable Navigation Display can Improve Attentiveness to the Surgical Field

Abstract Purpose: Surgical navigation is typically shown on a computer display that is distant from the patient, making it difficult for the surgeon to watch the patient while performing a guided task. We investigate whether a light-weight, untracked, wearable display (such as Google Glass, which has the same size and weight as corrective glasses) can improve attentiveness to the surgical field in a simulated surgical task.

Methods: Three displays were tested: a computer monitor; a peripheral display above the eye; and a through-the-lens display in front of the eye. Twelve subjects performed a task to position and orient a tracked tool on a plastic femur. Both wearable displays were tested on the dominant and non-dominant eyes of each subject. Attentiveness during the task was measured by the time taken to respond to randomly illuminated LEDs on the femur.

Results: Attentiveness was significantly improved with the wearable displays, but with a small increase in task completion time and a small decrease in accuracy. The through-the-lens display performed better than the peripheral display. The peripheral display performed better when on the dominant eye, while the through-the-lens display performed better when on the non-dominant eye.

Conclusions: Attentiveness to the surgical field can be improved with the use of a light-weight, untracked, wearable display. A through-the-lens display performs better than a peripheral display, and both perform better than a computer monitor. Eye dominance should be considered when positioning the display.

Keywords surgical navigation interface, wearable display, divided attention, increased attentiveness, reaction time improvement

1 Introduction

Computer-assisted surgery is a “divided attention task” in which the attention of the surgeon is often split between the navigation display and the surgical site on the patient. Divided attention may result in impaired performance, such as reduced responsiveness to an adverse event in the surgical field, or malpositioning of a surgical tool due to reduced awareness of the physical patient when following the navigation display. Divided attention tasks are also present in other medical fields, such as anesthesiology and ultrasound.

This study investigates whether the surgeon's attentiveness to the patient can be increased with the use of a wearable, untracked navigation display. Such displays include Google Glass (a peripheral display slightly above the right eye), Brother AirScouter (a monocular display positioned in front of either eye), and Epson Moverio (a binocular display positioned in front of both eyes). These are all "optical see-through" displays which superimpose the computer image on the real world.

We consider only *untracked* wearable displays, as external tracking introduces the difficulties of calibration, registration, and line-of-sight interruptions. Although the wearable displays listed above may have inbuilt accelerometers which provide rudimentary motion tracking, the tracking is not yet sufficiently accurate to superimpose patient-registered navigation information.

We consider only *monocular* wearable displays, which are lighter and less obtrusive than binocular displays. However, most people have a dominant eye that has higher priority in visual processing. This raises the question of whether a monocular wearable display is better suited for one eye or the other.

This study compared a wearable display to a computer monitor in a simulated surgical task of positioning and orienting a tool on a plastic distal femur. The wearable display was considered both in a peripheral position (above and slightly lateral of the eye) and in a "through-the-lens" position (directly in front of the eye) on both the dominant eye and the non-dominant eye. Peripheral vision was considered because peripheral display devices are becoming more common and might find easier acceptance in the operating room than a more obtrusive through-the-lens display.

To measure attentiveness to the surgical site, several LEDs were embedded in the plastic distal femur and were illuminated at random intervals during the task. Subjects were asked to press a button as soon as they saw the illuminated LEDs. Response time was used as a proxy for attentiveness. Task completion time and accuracy of tool position and orientation were also measured.

2 Related Work

The closest work to ours is a study that compares an optical see-through head-mounted display (HMD) to a computer monitor in simulated tumour excision [12]. The HMD showed an inset view of the tracked tool with respect to the virtual tumour. As with our experiment, the HMD view was not tracked, so did not change with the user's gaze. Two subjects were tested but the results were equivocal: one subject achieved better accuracy but slower speed with the HMD, while the other subject did the opposite.

Our study and the one above use the HMD as the *primary* focus of the surgeon, since the HMD is used to guide the surgical tool. Other studies (discussed below) use the HMD as a *secondary* focus to, for example, monitor patient status for adverse events.

A study of a simulated coronary bypass compared placement of the electrocardiogram display on a remote monitor to its placement on a Sony Glasstron heads-up display worn by the surgeon [1]. Task completion times were similar in both conditions, but the heads-up display was associated with about a 50% reduction in reaction time to adverse events. This mirrors our own study results.

The anesthesia community is quite interested in untracked head-mounted displays, as the anesthesiologist's attention is divided between the physical patient and the display showing the patient's vital signs, sometimes while the anesthesiologist is performing critical procedures. In a study on an anesthesia mannequin, a head-mounted display showing patient vital signs was found to substantially increase the anesthesiologist's focus on the patient and to decrease the number of times the focus of attention was shifted, as compared to a display on the anesthesia workstation [11]. A clinical study by a different group [7,8] found that anesthesiologists equipped with a head-mounted display increased the amount of time looking at the patient.

In the endoscopic community, a study on display placement tested different display positions around the patient during an endoscopic task [2]. Performance was significantly better when the display was at hand level in front of the surgeon. The suggests that a wearable display, with its image always in front of the surgeon, may yield better performance than a distant monitor. In another study of a simulated endoscopic task, subjects had to manipulate a menu shown on the display of the surgical field or on a separate screen, and were later asked to recall the surgical field. No significant difference in recall was found, suggesting that brief attention to the separate screen did not affect the subject's memory of the surgical field [14].

Heads-up displays, in which information is projected directly on the user's field of vision, are well researched in the fields of aviation and surface transportation. One particular driving study considered a situation similar to our own: the effect of a heads-up display on driving performance in comparison to a separate display positioned off to the side [4]. Response times for questions about the displayed information were faster for the heads-up display. However, drivers using a heads-up display had significantly higher cognitive workloads than those using the adjacent display, so heads-up display should be used with caution. Simultaneous performance of two tasks is known to potentially worsen performance on one or both tasks [6].

Our study also considers the effect of the dominant eye with monocular head-mounted displays, since the dominant eye has higher priority in visual processing and has faster feature recognition [13]. Reaction time is also faster with the dominant eye [10].

3 Apparatus

The experiment simulated the task of positioning and orienting a surgical tool on a bone according to a navigation display. At the same time as guiding the tool, the subject had to watch LEDs on the bone and to press a button immediately upon seeing the LEDs illuminated.

A left distal femur from Sawbones knee model 1517-29-2 (Pacific Research Laboratories, USA) was modified to incorporate three red 5mm diameter LEDs (Figure 1). Each LED was placed in a hole such that it projected 4mm above the bone surface; the LED wires emerged on the other side of the femur. The LEDs were placed such that all three would be visible by the experimental subject: on the anterior aspect of the medial and lateral epicondyles, and at the anterior edge

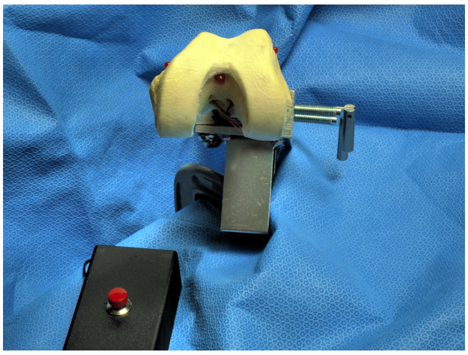


Fig. 1 The knee with three LEDs. The experimental subject positioned a tool on the knee according to the navigation display while simultaneously watching the LEDs. The subject pressed the red pushbutton as soon as the subject saw that the LEDs were illuminated.

Fig. 2 The Phantom Omni, which served as the tool to be posed on the knee. The experimental subject pressed the button on the pen of the Omni when the pen was deemed to be in the correct pose.

of the intercondylar fossa. The knee was clamped to a table and a red pushbutton in a box was affixed to the table beside the knee.

The pen of a Phantom Omni (Sensable, USA) served as the surgical tool (Figure 2). The haptic feedback of the Omni was disabled and the pen's pose was continuously reported by the Omni, along with the status of the button on the pen. During the experiment, the subject moved the pen into the correct pose on the femur, then pressed the pen's button to indicate completion. All experimental subjects were right handed, so they manipulated the pen in their right hands and responded to illuminated LEDs by pressing the red pushbutton with their left hands.

A Brother AirScouter WD-100G (Brother Industries, Japan) served as the monocular wearable display. The display of the AirScouter is easily moved from one eye to the other (Figure 3). We adapted the AirScouter by adding two mounting brackets, one on each side, which put the display in a peripheral position approximately 10mm above and 5mm lateral of the line of sight (each subject would bend the brackets slightly to fine-tune the position). In the different trials

Fig. 3 The Brother AirScouter monocular wearable display. The screen could be positioned in front of either eye. We added a bracket on each side (not shown here) to mount the display higher and slightly outside, converting the through-the-lens display in to a peripheral display. *(Unfortunately, our equipment was repurposed for another experiment and the brackets lost before we thought to photograph the entire apparatus together. Here we provide stock images from the Brother website, to be replaced by our own photographs in a published version.)*

of the experiment, the display was moved among four positions: through-the-lens left and right, and peripheral left and right.

A Dell 3007WFP monitor served as the conventional navigation display. The monitor was positioned 1.5m from the femur at approximately head height. The navigation display shown on the monitor was scaled so that it occupied the same visual field at a distance of 1.5m as it occupied on the AirScouter display. Both displays were set to the same resolution of 800×600 pixels.

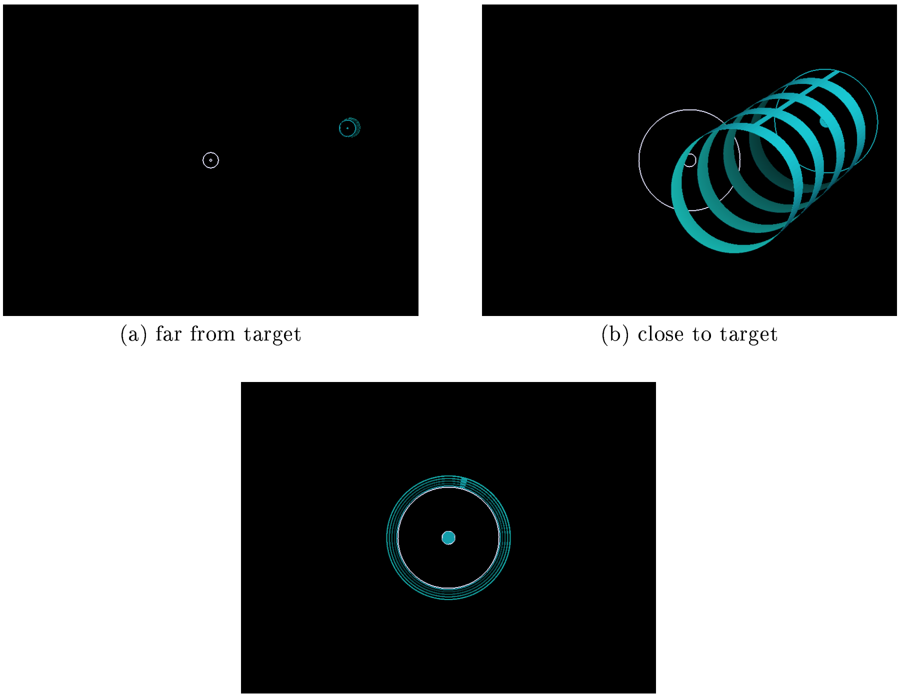
An Arduino Uno board controlled the femur LEDs and monitored the red pushbutton. During the experiment, the computer communicated with the Arduino to initiate LED illumination and to determine when the pushbutton was pressed. After the pushbutton was pressed, the time, ΔT, to the next illumination was chosen randomly according to an exponential distribution with a mean of three seconds, plus one second: $\Delta T = -3\ \ln(\text{random}(0,1)) + 1$.

The Arduino illuminated the three LEDs simultaneously and gradually, taking three seconds to go from zero to full illumination. During that time, the voltage of the LEDs was increased nonlinearly to achieve a linear change in luminosity (otherwise, the LEDs would become bright very suddenly). A gradual linear change was chosen so that the subject would not be notified by a sudden luminosity change in their peripheral vision: We wanted to know that the subject was attentive to the surgical site, not that the subject could detect sudden changes in their peripheral vision. (On the same note, red LEDs were chosen because they are less easy to perceive in the periphery than other colours [5].)

A Hewlett-Packard workstation computer controlled the overall experiment. While the subject was positioning the Omni pen, the computer read the pose of the pen from the Omni and showed it on the navigation display, which was either the computer monitor or an off-screen window that was mirrored on the AirScouter wearable display. The computer logged all activity for later analysis.

On the navigation display, the pose of the Omni pen was rendered as a set of stacked cyan rings with a smaller circle at the bottom of the stack, while the target was rendered as a white circle with a smaller circle in its centre (Figure 4(b)). The black background appeared transparent on the wearable display.

When the pen was distant from the target position on the femur, a wide-angle view was shown to provide the subject with coarse positioning guidance



(a) far from target

(b) close to target

(c) aligned with target

Fig. 4 The navigation display showing the pen pose as a stack of cyan rings and the target as a white circle. On the wearable display, the black background appears transparent. The experimental subject moved and oriented the pen on the femur surface until the stacked rings appeared concentric with the target circle.

(Figure 4(a)). Once the pen came close to the target position, a narrow-angle view was shown to provide fine guidance (Figure 4(b,c)). View hysteresis was provided so that the two views did not quickly alternate when the pen moved near the distance threshold.

The subject's task was to position the tip of the pen on the femur surface such that the stacked rings were concentric with the target circle. The pen *position* was achieved to within 0.5mm when the small cyan circle at the bottom of the stack of rings touched the small white circle in the middle of the goal circle. The pen *orientation* was achieved to within 1 degree when the outside of the stacked rings was no longer visible (Figure 4(c)). Subjects were told to pose the pen to within 0.5mm and 1 degree.

4 Method

A user study was conducted to determine simulated surgical performance under three navigation **conditions**: computer monitor, wearable peripheral display, and wearable through-the-lens display. The wearable displays were tested in two **sub-conditions**: on the dominant eye and on the non-dominant eye.

Each task in the study consisted of positioning and orienting the pen of the Phantom Omni on the surface of the femur according to the navigation display, while simultaneously responding as quickly as possible to illuminated LEDs. The LEDs were usually illuminated several times with each task.

Ten different tasks were selected in a wide range of positions and orientations. For each of the three conditions and two subconditions, the same ten tasks were performed by a subject, but in randomized order. In all, each subject performed 50 tasks.

Twelve subjects performed the experiment. We used a uniform, strongly balanced crossover design on the three conditions. Those three conditions could be presented in six different orders, so two of the subjects saw the conditions in each order. For the peripheral and through-the-lens conditions, the order of the subconditions (dominant-eye and non-dominant-eye) was randomized.

Each subject was provided with a letter of information and signed a consent form. The subject's dominant eye was determined using the Miles test [9], in which the subject holds the hands at arms length, palms facing outward with a gap between the hands, then moves the hands toward the face while focusing on a distant object between the hands. The gap naturally moves to the dominant eye as the hands approach the face. The subject was trained on each condition until they were comfortable with their performance (typically 10 minutes). The subjects answered an initial questionnaire, performed the 50 tasks, and answered a final questionnaire. Subjects took 45 to 75 minutes to complete the experiment.

All subjects were right-handed males between the ages of 18 and 50 (average 28.4). None had surgical experience, but all had substantial experience with video games (average 11.2 years), 3D user interfaces (average 5.4 years), and augmented reality devices (3.6 years). Eight were right-eye dominant and four were left-eye dominant, in the same proportion as the general population. All had experience with head-mounted displays (2.5 displays, on average).

We made the following hypotheses:

H1: Response time and task time are worst with the computer monitor and best with the through-the-lens display.

H2: No display has more than 0.5mm position error than any other display, and no display has more than 1 degree orientation error than any other display.

H3: For wearable displays, response time is better when the display is on the non-dominant eye.

H4: Response time and task time are better for the peripheral display *on the right side* (similar to Google Glass) than for the computer monitor.

H5: Response time increases with task difficulty.

H6: All performance measures improve as more tasks are performed.

Table 1 The effect of display type. Measures are shown as *mean* ± *standard deviation*.

Display	Response time (sec)	Task time (sec)	Position error (mm)	Orientation error (degrees)
through	2.24 ± 2.70	20.6 ± 9.5	0.40 ± 0.78	2.07 ± 1.68
peripheral	2.63 ± 2.02	22.3 ± 11.2	0.43 ± 1.27	2.08 ± 3.43
monitor	3.78 ± 1.80	20.0 ± 9.8	0.30 ± 0.25	1.61 ± 1.12

5 Results

For each trial, the computer logged start and end times, pose desired and pose achieved, LED illumination times, and pushbutton press times. From these we derived the average LED **response time**, total **task time**, **position error**, **orientation error**.

The wearable displays had two trials (one for each eye) for each pose, so we averaged the measures of the two trials when comparing them with the computer monitor.

5.1 Response Time and Task Time (H1)

A within-subjects ANOVA showed that the display had a significant effect on response time. No significant effect was found on task completion time. See Table 1.

The through-the-lens response time was better than peripheral response time ($p = 0.039$) and better than monitor response time ($p < 0.001$). Peripheral response time was better than monitor response time ($p < 0.001$).

Task time with the peripheral display was about 10% or 2 seconds longer than for the other displays, although this was not statistically significant as the variances were quite large.

5.2 Position and Orientation Error (H2)

We used the "two one-sided t-tests" method of equivalence testing to determine whether the position and orientation errors were equivalent between displays. The equivalence test determines, for an effect size ϵ, whether a measure (in this case, the difference between two errors) is significantly greater than $-\epsilon$ *and* significantly less than $+\epsilon$. The larger of the two p-values is reported.

For position error, the difference between any two of the three displays was less than 0.5mm ($p < 0.0001$). For orientation error, the difference between any two of the three displays was less than 1 degree ($p < 0.0001$).

Even though the errors were equivalent to within 0.5mm and 1 degree, a within-subjects ANOVA showed that the display had a significant effect on both position and orientation error.

The monitor position error was about 0.1mm less than that of the two wearable displays. This difference was statistically significant for the through-the-lens display ($p = 0.036$), but not for the peripheral display, perhaps due to that display's larger variance.

Table 2 The effect of the choice of eye on a monocular wearable display. The dominant (dom) and non-dominant (non-dom) eyes are compared in the two wearable displays. The right peripheral eye is compared to the monitor as it may indicate whether a Google Glass-like display would improve attentiveness in the operating room.

Display	Eye	Response time (sec)	Task time (sec)	Position error (mm)	Orientation error (degrees)
through	dom	2.56 ± 3.44	20.7 ± 9.4	0.47 ± 1.07	2.02 ± 1.88
through	non-dom	1.92 ± 1.62	20.4 ± 9.7	0.34 ± 0.29	2.12 ± 1.46
peripheral	dom	2.53 ± 1.47	21.2 ± 9.7	0.47 ± 1.53	2.04 ± 3.75
peripheral	non-dom	2.72 ± 2.45	23.4 ± 12.5	0.39 ± 0.93	2.13 ± 3.11
peripheral	*right*	2.81 ± 2.42	23.4 ± 12.0	0.41 ± 0.93	2.13 ± 3.10
monitor		3.78 ± 1.80	20.0 ± 9.8	0.30 ± 0.25	1.61 ± 1.12

The monitor orientation error was about 0.5 degrees less than that of the two wearable displays. This difference was statistically significant ($p = 0.041$ for peripheral and $p = 0.002$ for through-the-lens).

Despite these significant differences, no display was better than any other by more than 0.5mm position error or 1 degree orientation error.

5.3 Effect of Eye Choice on Response Time (H3 and H4)

For the through-the-lens display, response time was significantly better when the display was in front of the non-dominant eye ($p = 0.028$). See Table 2.

For the peripheral display, no significant difference in response time was found between the two eyes. On a side note, however, the task time was increased by 10% (2.2 seconds) when the peripheral display was on the non-dominant eye ($p = 0.022$).

For the peripheral display located on the *right* eye (regardless of whether that eye was dominant), response time was significantly better than with the computer monitor ($p < 0.0002$).

5.4 Relation Between Response Time and Task Difficulty (H5)

Correlation between response time and task time was negligible (Pearson's $r = 0.10$, 95% C.I. [0.007,0.183]) for all conditions together, and within each condition. If task time is taken as a proxy for difficulty, there appears to be no significant correlation between response time and task difficulty.

5.5 Effects of Task Repetition (H6)

A Theil-Sun robust median estimator was used to determine a linear fit for each measure under each condition over the time course of the experiment.

Response time *increased* at 0.008 seconds per trial for the monitor, at 0.17 seconds per trial for the peripheral display, and *decreased* at 0.015 seconds per trial for the through-the-lens display. All were statistically significant.

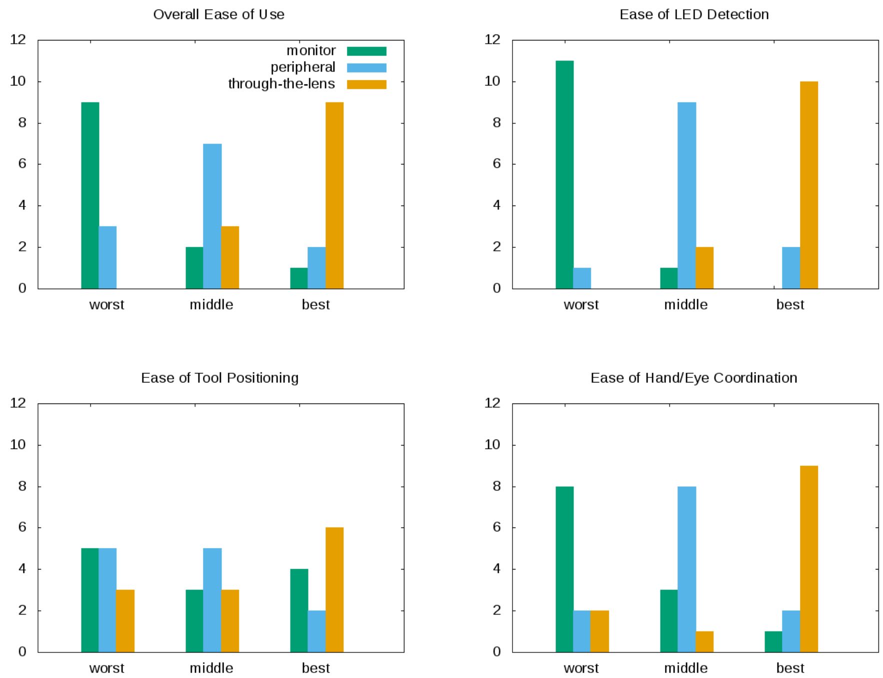


Fig. 5 Results from the post-experiment questionnaire asking subjects to rank the three displays according to four criteria. Each bar shows the number of subjects making that response.

Task time decreased at 0.31 seconds per trial for the monitor, at 0.15 seconds per trial for the peripheral display, and increased negligibly at 0.02 seconds per trial for the through-the-lens display. All were statistically significant.

Position error did not change significantly over the time course of the experiment. Orientation error decreased at 0.014 degrees per trial for the two wearable displays, and not at all for the monitor.

5.6 Questionnaire Responses

The results of the post-experiment questionnaire are shown in Figure 5. Subjects overwhelmingly preferred the through-the-lens display for ease of use, ease of LED detection, and ease of hand/eye coordination. For those measures, the peripheral display was consistently ranked second, with the monitor consistently ranked last. For ease of tool positioning, there was no clear favourite.

6 Discussion

The main goal of the study is to determine whether a wearable display could improve attentiveness to the surgical site, where attentiveness is measured in the simulated surgery by response time to illuminated LEDs.

The wearable displays increase attentiveness substantially at a small cost in task completion time. Both wearable displays were associated with faster responses: 40% faster (by 1.5 seconds) for the through-the-lens display and 30% faster (by 1.2 seconds) for the peripheral display, as compared to the 3.8 seconds for the computer monitor. Task time seemed to increase slightly (10%), but could not be verified statistically.

Position and orientation accuracy are equivalent among the three displays to within 0.5mm position accuracy and 1 degree orientation accuracy. Nonetheless, there was a statistically significant difference in favour of the computer monitor, but this was small (0.1mm better position accuracy and 0.5 degrees better orientation accuracy). Perhaps the monitor, being farther away from the surgical site, caused subjects to concentrate on the pose of the instrument at the cost of attentiveness.

Very interestingly, eye dominance had important effects. Response time was 29% faster when the through-the-lens display was placed on the non-dominant eye. When the display is on the dominant eye, more visual processing may be devoted to the display and less to the surgical field, even though both eyes see the surgical field.

Task time was 10% faster when the peripheral display was placed on the dominant eye, with no difference in response time. More visual processing may be given to the display when on the dominant eye (for lower task time), while attention to the surgical site is unaffected (for unchanged response time) because the gaze must be averted from the peripheral display to look at the site.

Surprisingly, no correlation between response time and task completion time was found, although we expected task time to act as a proxy for task difficulty. Either the two activities are independent, or we should have chosen a better measure of task difficulty (such as the NASA TLX questionnaire [3]).

Performance often increases with repetition, but the through-the-lens display did not have a significant change in task completion time over 50 trials, although response time improved somewhat. Nine of the 12 subjects considered this the easiest display to use for the overall task. Perhaps this display is immediately understandable, while the other displays take some effort to learn because of the required visual context changes (which is supported by the fact that the task completion time decreased substantially over the 50 trails for the monitor and the peripheral display).

Subjects overwhelmingly preferred the through-the-lens display for ease of LED detection, for ease of hand/eye coordination, and for ease of the overall task. The monitor ranked worst in all of these measures. The lack of a favourite display for tool positioning, despite the clear preference of the through-the-lens display for hand/eye coordination, suggests that the subjects found the tool positioning task difficult, regardless of display.

7 Conclusions

An untracked wearable display can improve attentiveness in a simulated surgical task without a substantial effect on accuracy or on task completion time. Whether this translates to clinical practice remains to be seen, but a clinical study in another domain [8] suggests that it may.

Eye dominance should be considered when locating a monocular wearable display, with a through-the-lens display being positioned on the non-dominant eye, and a peripheral display being positioned (if possible) above the dominant eye.

A through-the-lens display may not be as readily welcomed in the operating room as a lighter, more discreet peripheral display like Google Glass. Such a display – even if located above the right eye without regard to eye dominance – substantially outperforms the conventional computer monitor for attentiveness, although not quite as well as a through-the-lens display.

References

1. Beuchat, A., Taub, S., Saby, J.D., Dierick, V., Codeluppi, G., Corno, A.F., von Segesser, L.K.: Cybertools improve reaction time in open heart surgery. European Journal of Cardiothoracic Surgery **27**, 266–269 (2005)
2. Hanna, G.B., Shimi, S.M., Cuschieri, A.: Task performance in endoscopic surgery is influenced by location of the image display. Annals of Surgery **227**(4), 481–484 (1998)
3. Hart, S.G., Staveland, L.E.: Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In: P.A. Hancock, N. Meshkati (eds.) Human Mental Workload. North Holland Press, Amsterdam (1988)
4. Horrey, W.J., Wickens, C.D., Alexander, A.L.: The effects of head-up display clutter and in-vehicle display separation on concurrent driving performance. In: Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting (2003)
5. Ima, C., Mann, D.: Lightbar design: The effect of light color, lightbar size and auxiliary indicators on tracking and monitoring performance. Agricultural Engineering International: The CIGR E-Journal of Scientific Research and Development **3** (2003)
6. Karatekin, J.W., Couperus, C., Marcus, D.J.: Attention allocation in the dual-task paradigm as measured through behavioral and psychophysiological responses. Psychophysiology **41**(2), 175–185 (2004)
7. Liu, D., Jenkins, S.A., Sanderson, P.M.: Clinical implementation of a head-mounted display of patient vital signs. In: International Symposium on Wearable Computers, pp. 47–54 (2009)
8. Liu, D., Jenkins, S.A., Sanderson, P.M., Fabian, P., Russell, W.J.: Monitoring with head-mounted displays in general anesthesia: a clinical evaluation in the operating room. Anesth Analg **110**(4), 1032–1038 (2010)
9. Miles, W.R.: Ocular dominance in human adults. Journal of General Psychology **3**, 412–430 (1930)
10. Minucci, P.K., Connors, M.M.: Reaction time under three viewing conditions: Binocular, dominant eye, and nondominant eye. Journal of Experimental Psychology **67**(3), 268–275 (1964)
11. Ormerod, D.F., Ross, B., Naluai-Cecchini, A.: Use of a see-through head-worn display of patient monitoring data to enhance anesthesiologists' response to abnormal clinical events. In: International Symposium on Wearable Computers, pp. 131–132 (2002)
12. Sadda, P., Azimi, E., Jallo, G., Doswell, J., Kazanzides, P.: Surgical navigation with a head-mounted tracking system and display. Studies in health technology and informatics **184**, 363–369 (2013)
13. Shneor, E., Hochstein, S.: Eye dominance effects in feature search. Vision Research **46**(25), 4258–4269 (2006)
14. Webster, J.L., Cao, C.G.L.: Divided attention in using robotic surgical systems. In: Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting, pp. 1751–1754 (2004)