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Technical Report

The Perspective Effect of Wide-Angle Lenses in Laparoscopes

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ABSTRACT

Purpose: **To evaluate the effect of perspective distortion of wide-angle lenses in laparoscopes on hand-eye coordination during endoscopic manipulation.**

Methods: **Sixteen subjects repeatedly performed a standardized positioning task in a pelvi-trainer under two conditions. The subjects had no prior experience with endoscopic manipulation. In one condition, a wide-angle lens with considerable perspective distortion was used; in the other, a telephoto lens without perspective distortion was used. Task time and number of errors were measured.**

Results: **Task time and the number of errors did not significantly increase in the condition with a wide-angle lens.**

Conclusions: **The perspective effect did not influence task performance in endoscopic manipulation in this experiment. Subjects indicated that they even preferred the wide-angle lens because its extreme perspective improved their perception of depth.**

INTRODUCTION

In minimally invasive surgery (MIS), the use of small incisions to provide access and the use of an endoscope for visualization result in some limitations for the surgeon.[1,2] For example, instrument motion is mirrored because the incision acts as a pivoting point. Furthermore, in comparison with natural vision, endoscopic vision is monocular and usually presents the operating area from an unnatural viewpoint. In the literature, these effects are known to disturb the surgeon's spatial perception[1,3] and hand-eye coordination.[4–6] This study reports an additional effect that disturbs the visual information from the operating area: the *perspective effect*, which results from the use of wide-angle lenses in laparoscopes. Its possible consequences on hand-eye coordination during endoscopic manipulation are evaluated.

Perspective effect defined

To provide a large field-of-view inside the abdomen, laparoscopes are equipped with a wide-angle lens. Typically, the angle of view (α in Fig. 1) is about 70 degrees. An inherent characteristic of wide-angle lenses is that they show extreme perspective; in comparison with objects farther away, objects close to the lens appear much larger than would be expected from the difference in distance. As a result, movements of an instrument in a plane not parallel to the endoscope lens ($\beta < 90$ degrees in Fig. 1) appear distorted on the monitor. Rotations of the instrument around the incision can appear as translations perpendicular to the shaft on the monitor. This effect is visualized in Figures 1 and 2 and is what we define as the *perspective effect.* The effect increases when the angle β decreases and when the distance between the lens

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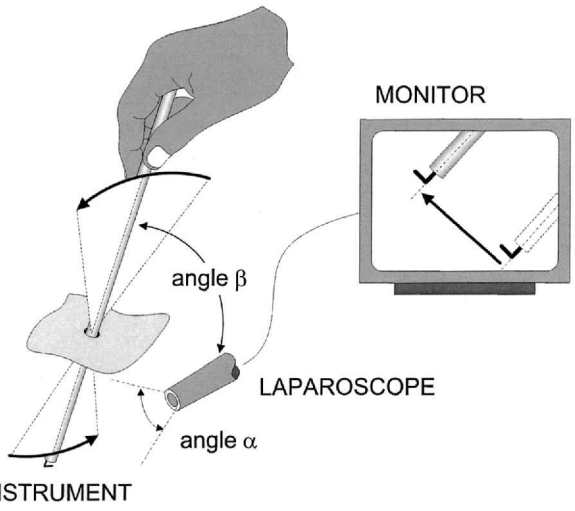

FIG. 1. Effect of perspective on pivoting movements of the instrument. The instrument tip on the monitor translates perpendicular to the shaft.

and the instrument tip decreases. Endoscopic surgeons can observe the perspective effect during daily practice by looking carefully at the movements of the instrument tip on the monitor while pivoting the instrument around the incision. If the angle β is smaller than 90 degrees, then the instrument tip does not make the anticipated pivoting motion around the incision.

Perspective effect during laparoscopic cholecystectomy

During a standard laparoscopic cholecystectomy, surgeons can observe that pivoting motions of the instrument handle (as large as 30–45 degrees) appear as translations perpendicular to the shaft on the monitor (Fig. 2). This observation was confirmed by a video analysis of a standard laparoscopic cholecystectomy. It was found that during most phases of the procedure, the instrument tip translated perpendicular to the instrument shaft, as depicted in Figure 2. When the angle β was small ($\beta < 60$ degrees in Fig. 1), the perspective effect was so strong that the instrument tip even appeared to be rotating around a pivoting point opposite to the incision.

Goal of this study

Although the perspective effect significantly distorts movements of the instrument tip on the monitor, the effect and its influence on hand-eye coordination are not well-known. Furthermore, surgeons have probably never noticed the effect during daily practice.

In this study, the effect of perspective distortion on hand-eye coordination during endoscopic manipulation was investigated. The goal of the study was to determine whether this intriguing phenomenon has a negative influence on manipulation performance.

For this purpose, the execution of a task in a pelvitrainer experiment with two types of lenses was evaluated. A telephoto lens was used to create a condition without perspective distortion. Although such a lens is not used clinically, it was used here to compare its effect on hand-eye coordination with that of a clinically used wide-angle lens that distorts perspective. If the perspective effect impairs hand-eye coordination, then insights derived from this experiment may provide clues to facilitate endoscopic procedures.

In the experiments, task time and the number of errors served as the measure of performance.

MATERIALS AND METHODS

Subjects

Sixteen students (aged 20–25, ten male and six female) from the Department of Mechanical Engineering of the Delft University of Technology participated as subjects in the experiment. None of the subjects had prior experience with endoscopic manipulation.

Experimental task

Subjects had to complete a trajectory of seven targets by touching each of the targets with the tip of a laparo-

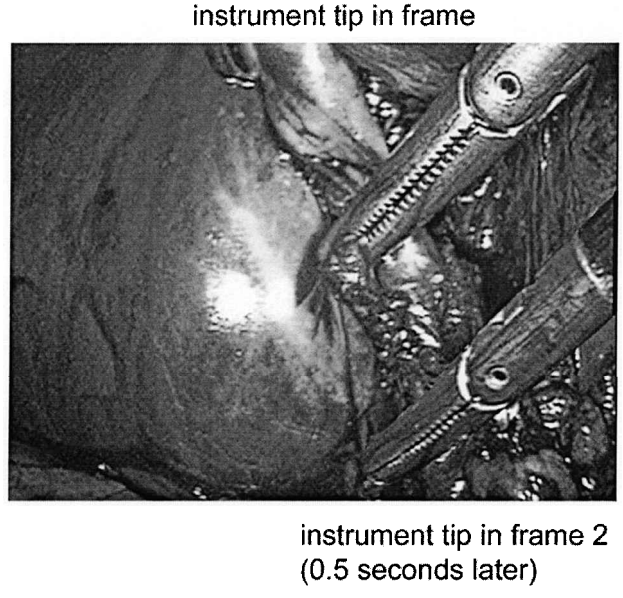

FIG. 2. Perspective effect in laparoscopic cholecystectomy. Two frames were pasted over each other to capture the movement of the instrument tip. Note that the tip on the monitor does not pivot around the incision; instead, it translates perpendicular to the shaft.

scopic grasper (Karl Storz, Tuttlingen, Germany) under endoscopic conditions in a pelvi-trainer (Fig. 3). A laptop computer positioned right below the monitor screen showed the randomized order in which the targets had to be touched. In addition, the laptop computer indicated when a target was hit and registered the task time needed to complete one trajectory. The targets consisted of small spherical disks ($\phi = 4$ mm). If the subjects missed the target and touched the outer disk, then the laptop computer registered an error. Subjects were instructed to complete the trajectories as fast as possible with a minimum number of errors. So that the subjects would have unambiguous feedback about the task time and the number of errors simultaneously, they were shown a cumulative task time (time + 3 seconds for every error).

Experiment design

Two conditions were tested. In condition 1, a miniature camera with a wide-angle lens (Panasonic wv-KS152, 80-degree field-of-view) filmed the task area from a distance of 7 cm. In condition 2, a miniature camera with a telephoto lens (Panasonic wv-KS152, 30-degree field-of-view) was used. To compensate for the larger magnification of the telephoto lens, the camera was positioned farther away from the task (21 cm) so that the view of the task area that was presented on the monitor was exactly the same in both conditions. Furthermore, the image size, resolution, and quality were equal in both conditions. In the condition with the wide-angle lens, the perspective effect resulted in translations of the instrument tip perpendicular to the shaft, whereas in the telephoto lens condition, the instrument tip made clear rotations around a point outside the monitor image (the incision).

Each of the two conditions was tested in four trials of eight repeated tests. This resulted in an experiment design of 2 conditions × 4 trials × 8 repeated tests. To compensate for a learning effect between conditions, half of the subjects started with condition 1 and then performed the task in condition 2, while the other half started with condition 2.

After the experiment, subjects were asked which condition they preferred.

Statistical analysis

The minimum and maximum task times of the eight repeated tests within a trial were removed from the data

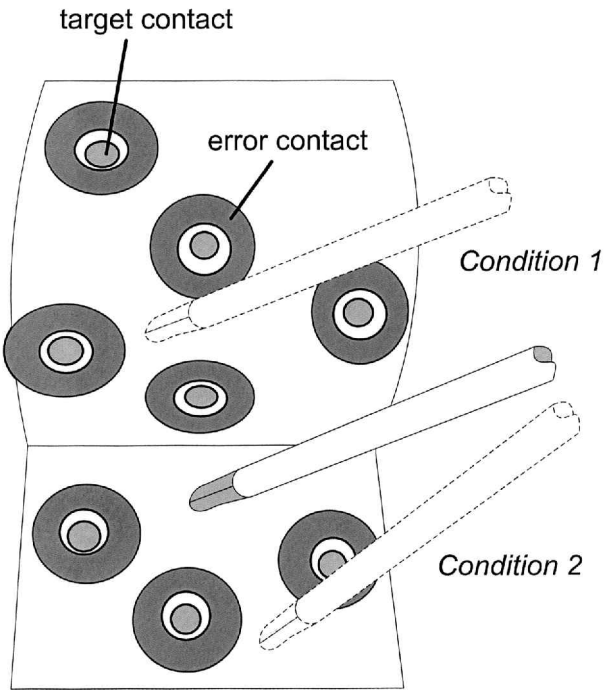

FIG. 3. The experimental task. Typical instrument movements in conditions 1 and 2 are shown.

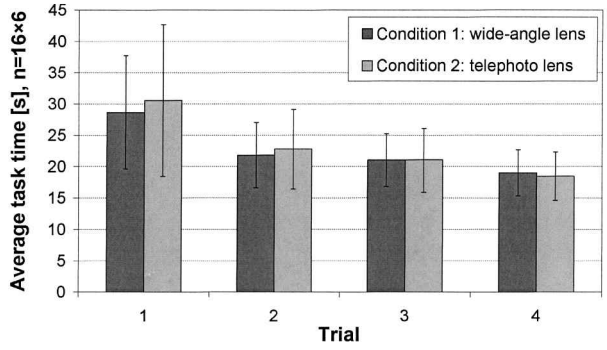

FIG. 4. Comparison of average task times in conditions 1 and 2 in four trials; standard deviations are plotted as well. Each column represents 96 (16 subjects × 6 repeated tests in each trial) data points.

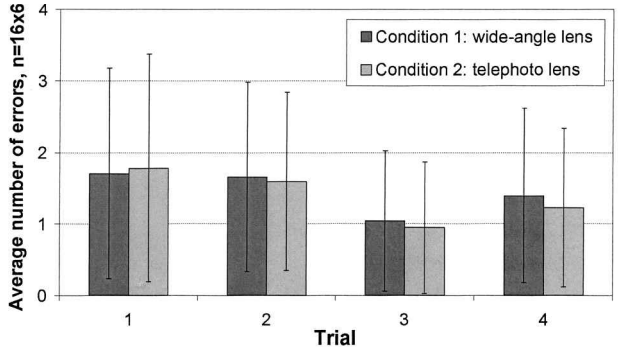

FIG. 5. Comparison of average number of errors made in conditions 1 and 2 in four trials; standard deviations are plotted as well. Each column represents 96 (16 subjects × 6 repeated tests in each trial) data points.

to reduce the number of outliers (yield of six repeated tests for analysis). The results were statistically tested with a repeated measures analysis of variance.[7] The significance level was set at $P = .05$.

RESULTS

Figure 4 shows the average task times for both conditions in the four trials. Figure 5 shows the average number of errors made. The type of lens had no significant effect on task time. Although the wide-angle lens distorted perspective, task performance did not decrease with this lens. Also, the type of lens had no significant effect on the number of errors made. Ten subjects (62.5%) indicated that they preferred the condition with the wide-angle lens to the telephoto lens condition, four subjects (25%) preferred the telephoto lens, and two subjects (12.5%) had no preference for either of the two conditions.

DISCUSSION

In this study, the task time and the number of errors were measured to evaluate the effect of perspective on hand-eye coordination during a basic positioning task. It was assumed that a disturbed hand-eye coordination would increase the time taken to complete the task and would also increase the number of errors made.

Although the perspective effect results in considerable distortion of the visual movement information perceived by the surgeon, the results of this study suggest that it does not influence performance in basic manipulation tasks. Furthermore, subjects indicated verbally that they did not consciously notice a difference in instrument movements on the monitor between the two conditions. This is a striking result, as in reality a significant visual difference existed. The wide-angle lens in condition 1 changed pivoting movements of the instrument handle into translations of the tip perpendicular to the shaft on the monitor. In contrast, the telephoto lens in condition 2 presented pivoting movements correctly as a clearly pivoting instrument tip on the monitor.

A possible explanation for the results found in this study comes from articles by Worringham and Beringer[8] and Holden et al.[9] Worringham and Beringer investigated the effect of different visual-motor mappings on hand-eye coordination. They defined a visual-motor mapping as the kinematic relation between hand movements and consequently observed movements of the instrument on a display. In MIS, this relation is determined by the endoscope lens, the position of the endoscope, and the location of the monitor. Like Worringham and Beringer, Holden et al. concluded that a consistent visual-motor mapping facilitates hand-eye coordination during MIS. In our study, the mapping from visually perceived instrument movements to hand movements was different for the two conditions. However, in both conditions, the mappings were consistent (i.e., constant). In condition 1, translations of the instrument tip consistently had to be mapped to pivoting movements of the hand. In condition 2, pivoting movements of the instrument tip consistently had to be mapped to pivoting movements of the hand. Therefore, the results of our study confirm the suggestion of Holden et al. that a consistent mapping from visually perceived orientation to motor orientation facilitates hand-eye coordination during MIS.

Another explanation for our results can be deduced from the verbal comment of all the subjects that the wide-angle lens offered better depth perception than the telephoto lens. This is why most subjects preferred the wide-angle lens. The effect of increased depth perception is well-known from photography. Photographers use wide-angle lenses to exaggerate the illusion of depth in their photos. Because of the perspective effect, objects close to the lens appear much larger than objects farther away. Possibly, the advantage of this effect eliminates the disadvantage caused by the perspective effect.

The manipulation task used in our experiments simulated a basic endoscopic surgery task and is not representative of complex tasks such as suturing and knot tying. Therefore, from the results of our study, it cannot be concluded that perspective distortion does not impair hand-eye coordination during complex endoscopic manipulation tasks. Further research on the perspective effect is needed to assess the effect on hand-eye coordination in clinical practice.

CONCLUSION

The use of wide-angle lenses in laparoscopy results in perspective distortion of the visual scene. Although the perspective effect significantly distorts the visually perceived movement information of the instrument tip, it did not influence task performance in the basic endoscopic positioning task used in this experiment.

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