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ORIGINAL ARTICLE

Performance on a Virtual Reality Angled Laparoscope Task Correlates with Spatial Ability of Trainees

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Abstract The aim of the present study was to investigate whether trainees' performance on a virtual reality angled laparoscope navigation task correlates with scores obtained on a validated conventional test of spatial ability. 56 participants of a surgery workshop performed an angled laparoscope navigation task on the Xitact LS 500 virtual reality Simulator. Performance parameters were correlated with the score of a validated paper-and-pencil test of spatial ability. Performance at the conventional spatial ability test significantly correlated with performance at the virtual reality task for overall task score ($p<0.001$), task completion time ($p<0.001$) and economy of movement ($p=0.035$), not for endoscope travel speed ($p=0.947$). In conclusion, trainees' performance in a standardized virtual reality camera navigation task correlates with their innate spatial ability. This VR session holds potential to serve as an assessment tool for trainees.

Keywords Spatial ability · Laparoscopy · Education

Parts of the data have been presented as a poster at the third annual joint congress of the Swiss Society of Surgery and the Swiss Society of Thoracic, Heart and Vascular Surgery held in Zürich, Switzerland June 8th–10th 2005.

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Introduction

The outcome of a surgical procedure depends mainly on optimal performance of the surgeon and his team. A number of studies have shown that spatial ability is one of the most important predictors of surgical skills and therefore seems to be a crucial factor for adequate performance in open and laparoscopic surgery. [1–5]

The aim of our current study was to investigate the influence of spatial ability on performance of navigation of an angled laparoscope, a major task in laparoscopic surgery. We hypothesized that correct laparoscope navigation in a virtual reality (VR) task is highly dependent on spatial ability.

Methods

Participants

56 trainees at an international laparoscopic training course (21st International Gastrointestinal Surgery Workshop Davos 2004) were included in the study. Their previous experience in laparoscopic surgery was assessed with a questionnaire they had to complete prior to the course investigating the number of previously performed laparoscopic interventions. Twenty participants had no previous experience in laparoscopic surgery at all, 36 participants had previous experience consisting of 17 participants who had previously performed 1–5 laparoscopic cholecystectomies, and 7, 10 and 2 participants, respectively, who had performed 6–20, 21–100 and >100 laparoscopic cholecystectomies, respectively. Men ($n=32$) and women ($n=24$) were equally distributed among the novices and the experienced group ($p=0.147$). Informed

consent for participation in the study was obtained from each participant.

Simulator Task

For the simulator task, the LS 500 Xitact (Xitact®, Xitact S. A., 1110 Morges, Switzerland) virtual patient laparoscopy simulator was used (Fig. 1a). The standardized VR task consisted in viewing a sphere suspended in three-dimensional space on the center of a target by using a 30° angled scope. After the sphere has been correctly centered on the target, a next sphere in a different position is presented until three spheres have been viewed. Surgical performance assessment software recorded data for each participant during each experiment measuring task completion time, economy of movement (tool tip travel distance in meters), endoscope travel speed (in meters/second) and number of completed targets. The score given (= total score) is generated by the LS 500 simulator and is based on the number of completed targets as well as the time and economy of movement. This specific VR task of the LS 500 VR surgical simulator was chosen because it uses an angled scope, it is complex and thus leads to a wide range of results of performance but still may be performed with no previous experience in laparoscopic surgery.

Conventional Test of Spatial Ability

The conventional spatial ability test consisted of six tasks of the validated 3-D-Cube paper-and-pencil test of mental rotation (Drei-dimensionaler Würfeltest, Beltz Test) [6]. In this test, six cubes with a different pattern on each side (of which three sides are depicted) should be compared to a given cube in order to find the cube that could correspond to the given cube if it was rotated (Fig. 1b). Six different sets of cubes were presented, for each correct answer one point was given.

Comparison of Different Levels of Experience

Test results were compared between different levels of experience in laparoscopy.

Correlation Between Simulator Task and Conventional Test of Spatial Ability

Performance at the conventional spatial ability test was correlated with performance at the angled scope VR task.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel 2003 and the SPSS statistical package (version 17.0) to conduct all analyses. Statistical significance of differences between two groups was tested using the independent sample t-test for continuous variables and the χ^2-test for categorical variables. An ordinal regression analysis was performed assessing relationship between the participant's score on the conventional spatial ability test and various performance measurements in the simulator task (overall task score, task completion time, endoscope travel distance, endoscope travel speed). In addition to the Spearman correlation, statistical significance was tested using a Kendall tau-b test. A p-value <0.05 was defined as statistically significant.

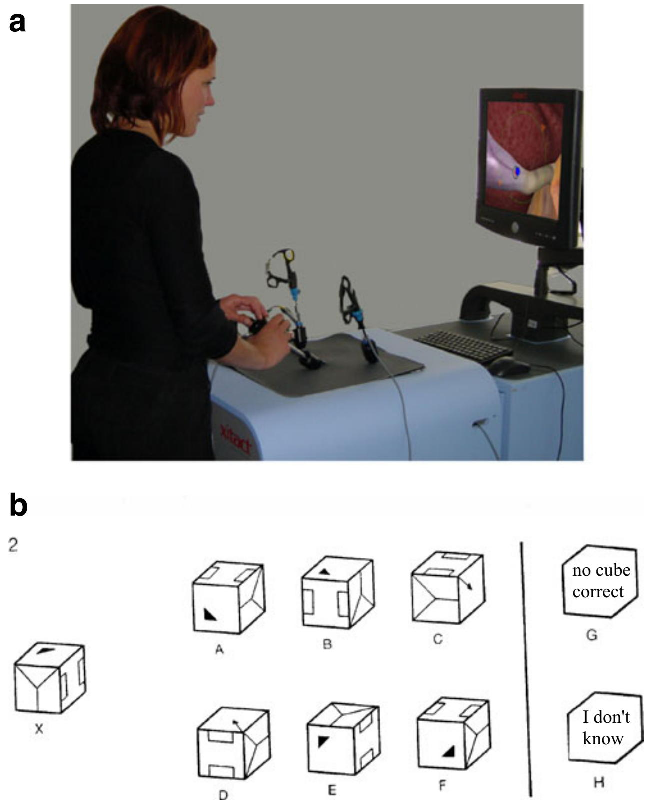

Fig. 1 **a** LS 500 Simulator. The LS 500 Xitact virtual patient laparoscopy simulator was used for the presented test series. **b** Spatial ability test [6]. Out of cube A-H the cube must be selected that could correspond to the given cube x if it was mentally rotated. Correct answer=C

Results and Discussion

Performance at The Simulator Task and The Conventional Test of Spatial Ability

The virtual reality task was completed in a mean of 129 seconds (range 40–183), travelling 1.81 meters (0.41–5.57) with the endoscope tip at a speed of 0.26 m/s (0.07–0.65) and reaching a score of 157.7 (0–550). The mean score of the spatial ability test was 2.96 with a range between 0 and 6 points.

Comparison of Different Levels of Experience

There was no significant difference in performance of novices (nov) as compared to trainees with previous experience in laparoscopic surgery (exp) concerning the virtual reality task (time: nov 127.5 s, exp 129.4 s, p=0.894, endoscope travel distance: nov 1.66 m, exp 1.90 m, p=0.467, endoscope travel speed: nov 0.24 m/s, exp 0.27 m/s, p=0.458, score: nov 157.9, exp 157.6, p=0.995), as well as the spatial ability test (nov 2.65, exp 3.14, p=0.381).

Further subanalysis showed that there was no significant difference in performance of novices with no experience in laparoscopic surgery and participants having previously performed 1–5 cholecystectomies [virtual reality task (time: p=0.804, endoscope travel distance: p=0.606, endoscope travel speed: p=0.404, score: p=0.736); spatial ability test (p=0.384)] and no significant difference in performance of those, who have performed 1–5 cholecystectomies and those who have performed 6 or more cholecystectomies [virtual reality task (time: p=0.453, endoscope travel distance: p=0.915, endoscope travel speed: p=0.614, score: p=0 .405) spatial ability test (p=0.792)].

Correlation Between Simulator Task and Conventional Test of Spatial Ability

There was a statistically significant correlation between the conventional spatial ability test score and overall task score, task completion time and endoscope travel distance on the VR task. The correlation was positive with overall task score and negative with task completion time and endoscope travel distance, i.e. participants with higher spatial skills scores also had higher VR task scores and completed the VR task in a shorter amount of time and with a higher degree of economy of movement. There was no significant correlation with endoscope speed (table 1).

Table 1 Correlation of the conventional spatial ability task score with VR task performance parameters

	Spearman correlation		Kendall tau test
	Correlation coefficient	p	p
overall task score	+ 0.454	<0.001	<0.001
task completion time	−0.454	<0.001	<0.001
endoscope travel distance	−0.282	0.035	0.021
endoscope speed	−0.014	0.947	0.929

Discussion

Our study demonstrates that a trainee's performance in navigation of an angled laparoscope in a VR task correlates with the score of a validated spatial ability test; and that there are significant interindividual differences among surgical trainees regardless of their previous level of surgical experience. As expected, we found a significant correlation for the VR parameters overall task score, task completion time and economy of movement, not for endoscope speed, the latter not being associated with adequate performance in laparoscopic surgery.

Since visual input information strongly outweighs haptic information in laparoscopic surgery, laparoscope camera guidance is therefore a critical factor for exposure of the operative site. The fact that the tip of the instrument moves in the opposite direction to the surgeon's hand creating a dissonance between visual and proprioceptive feedback is known as the fulcrum effect of the body wall on instrument manipulation. Not only the operating instruments, but also the endoscope is subject to this effect. Moreover, the instruments and the laparoscope have only a limited freedom of movement in laparoscopic surgery. In order to increase the range of viewing perspective, laparoscopes with the objective lens at an angle instead of in alignment to the endoscope axis are used, such as 30 degree angled scopes [4].

Navigation of the angled laparoscope and camera relies on a number of cognitive processes: the camera person has to process the two-dimensional image of the laparoscope and construct a mental representation of the three-dimensional anatomy. He subsequently has to imagine the various 2-D views that would be obtained from different locations of the laparoscope tip and direction of the angled lens and has to deduct the optimal scope position in order to achieve the desired exposure of the operative site. These mental processes rely mainly on the camera person's spatial ability, the aspect of motor performance in manipulating the scope is obviously of minor importance. Incorrect spatial processing may lead to visual illusions [7]. Spatial processing of the 2-D view is supported by a number of indirect depth cues of the image, such as interposition or overlap, lighting, outline, texture and motion parallax [8]. Moreover, we are able to see objects in their context and partially compensate for the lack of complete information [9].

We found a significant correlation of performance in angled scope navigation with a standardized test of spatial ability. This spatial ability cube test demands that the test person be able to imagine the correct 2-D view of the cube from a certain angle of perception. This indicates that the crucial step in angled scope navigation is the mental process of constructing a 2-D mental image on the basis of a virtual projection.

Psychometric research has clearly demonstrated that spatial ability is an important facet of intelligence. Intelligence and abilities represent an individual's innate performance characteristics not modifiable by practice [10]. This could be an explanation for the fact that, independent of the previous experience in laparoscopic surgery, we found a broad variation of skill level among the participants in the surgical skills training course. Thus, there was no correlation with the surgeons' experience. A draw back of our study is, however, that we did not evaluate operating room performance, but only VR performance. Moreover, the number of experienced surgeons in our study was relatively small, and there is no information on camera guidance experience of the study participants.

The described virtual reality training session holds great potential to serve as an assessment and training tool in laparoscopic surgery. Firstly, since performance in this task depends highly on innate spatial abilitiy, it allows objective assessment of a trainee's potential to learn adequate scope navigation. Candidates with clearly substandard performance scores could be identified. Secondly, it allows trainees with moderate spatial ability to practice specific strategies for scope navigation and improve their skills beyond their estimated potential. Despite the fact that spatial ability represents an individual's non-modifiable performance characteristic, psychological research has produced impressive training curricula which improve a trainee's task specific skills beyond his or her estimated potential. It appears that deficient spatial ability can be at least partially compensated for by practice of task-specific strategies. The fact that practice and surgical experience might outweigh the influence of visual spatial ability over time is supported by the results of a study investigating the influence of visual spatial ability and manual dexterity on surgical performance across three levels of expertise (student/resident/attending surgeon) [11]. There, no differences between groups in visual spatial ability or manual dexterity were found, but significant differences in surgical performance score in a spatially complex technical task showing increasing performance score with increasing levels of expertise. Among novices, visual spatial scores correlated significantly with surgical performance whereas advanced trainees and experts did not score any higher on the visual spatial tests.

According to the above-mentioned studies and our own results, training of basic skills such as camera navigation, nowadays should take place outside the operating room; this is supported by economic, ethical, medico-legal and educational considerations and addresses the problem of time restriction due to reduced working hours. Virtual reality simulation can be made available to trainees anytime and anyplace, and does not require any additional supplies or animal tissue. It is therefore the ideal training tool. A minor drawback is the fact that the computer image is not perfectly realistic with some indirect depth cues being less pronounced. Thus, virtual reality can be a valid tool for surgical assessment and training. Moreover, two randomized trials have shown that virtual reality training improves the performance in the operating room [12, 13].

In conclusion, trainees' performance in a standardized VR camera navigation task correlates with their spatial ability. Virtual reality is a valuable tool for trainees' assessment and has great potential to be used for specific training curricula.

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