Surgical Endoscopy (2020) 34:298–303
https://doi.org/10.1007/s00464-019-06766-2

Laparoscopic Simulation in Reverse and Side Alignment Impact on Forward Alignment Performance: A Randomized Controlled Trial

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Received: 10 October 2018 / Accepted: 18 March 2019 / Published online: 29 March 2019

Abstract

Background The influence of visual-spatial discordance during training on laparoscopic skills is poorly understood. It has been proposed that training in visual-spatial discordant situations can improve performance in the forward alignment, which was the basis of our hypothesis. Our study's aim was to conduct a randomized control trial to explore the impact of simulated training in visual-spatial discordant situations on forward alignment performance.

Methods The participants were 80 medical students who were randomized into four groups. Group A served as the control and performed all peg transfers in the forward alignment. Groups B, C, and D experienced varied rounds of either increasing or decreasing sensorimotor discordance. The students were trained and tested using the peg transfer task used in the Fundamentals of Laparoscopic Surgery curriculum. Based on the group, each student performed 10 peg transfer practice rounds in their assigned alignment. After each practice session, each student was tested and scored in forward alignment performance. A baseline test, followed by three practice sessions, and three tests were done.

Results Group A (control) demonstrated a statistically significant overall increase in scoring of 37.1% from baseline when compared to the final test. Groups B, C, and D showed improvements of 3.7%, 27.1%, and 19.3%, respectively, between baseline and the final test, yet none demonstrated consistent linear improvements. On multi-variate analysis, students who practiced in the side or reverse alignment positions scored 25 and 37 points lower, respectively, than students who practiced in the forward alignment.

Conclusion Our study suggests that training in visual-spatial discordant conditions does not lead to the development of forward alignment laparoscopic skills. This could have important implications when developing future laparoscopic skills training curriculums. To our knowledge, this is the largest study to date assessing the impacts of training in visual-spatial discordance situations on performance in the forward alignment.

Keywords Laparoscopic training practice · Laparoscopic skills · Visual-spatial discordant · Visual motor coordination · Education · Training

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Introduction

Laparoscopic procedures present viewing challenges not faced during open procedures. Although the natural viewing conditions seen in open procedures can be approximated laparoscopically by having the camera in the same alignment as the working instruments (0°), this often is not clinically attainable. During certain laparoscopic procedures (e.g., laparoscopic ventral hernia repairs), surgeons encounter circumstances in which the camera is aligned at 90° (side alignment) or 180° (reverse alignment). It has previously been demonstrated that surgeon performance decreases as the viewing axis increases from 0° to 180°, likely due to visual-spatial discordance: three-dimensional disorientation caused by non-naturalistic visual information [1, 2]. However, it has been proposed that training in these visual-spatial discordance situations (90° and 180°) can actually improve performance in the forward alignment (0°) [3]. Therefore, we hypothesized that forward alignment laparoscopic skills would improve following simulated experience in visual-spatial discordance conditions. The aim of our study was to conduct a randomized controlled trial to explore the impact of simulated training in the side and reverse camera alignment on forward alignment performance.

Since the advent of the Fundamentals of Laparoscopic Surgery (FLS) curriculum, simulators are increasingly being utilized as a means to improve laparoscopic skills without risk to live patients [4–6]. These simulators can be configured in different alignments to emulate the different viewing axes. To prove our hypothesis, we had participants practice using FLS simulators configured in different alignments (forward, side, and reverse) and tested their performance in the forward alignment.

Materials and Methods

Participants

Novice first- or second-year medical students (with no previous exposure to laparoscopic procedures or training) enrolled in the Michigan State University (MSU) College of Human Medicine (CHM), Osteopathic Medicine (COM), or Veterinary Medicine (CVM) were sent an email requesting voluntary participation in this study. Students were compensated for participation in the study. Inclusion criteria included age over 18 years and the ability to use both hands. The first 80 students responding to the email who met inclusion criteria were informed of study's objectives, participant role, and the time commitment involved (approximately 3-4 hours in one session). Following Institutional Review Board (IRB) approval, informed consent was obtained from each individual. Each participant completed an initial survey to collect demographic information (age, sex, college, and dexterity) and to inquire about video-gaming abilities (an expert, better than most, not as good as most, worse than most). Selected students viewed the FLS video tutorial introducing the peg transfer segment, and a standardized script was used to explain tasks and answer questions. Students were randomized into four groups.

Peg Transfer Exercise

The peg transfer task used in the FLS curriculum was selected for testing using a standard FLS training box. Each trainer box was configured to facilitate forward alignment (0°), side alignment (camera at 90° to working instruments), and reverse alignment (camera at 180° to working instruments) as demonstrated in Figure 1. For this task, six beads are transferred back and forth using a grasper to lift each bead with a mid-air transfer to the contralateral grasper. The bead is then placed on the peg, allowing for 12 possible peg transfers per round. A maximum time of 300

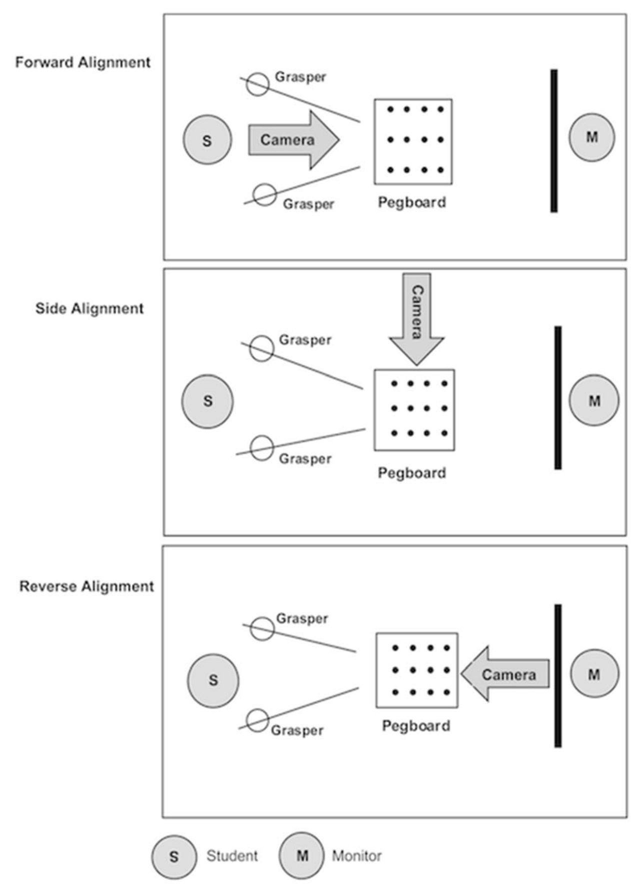

Fig. 1 FLS Trainer Box Configurations

seconds (5 minutes) was allowed per round and deductions were given if a bead was dropped out of the field of view. Beads dropped in the field of view did not count as a deduction since they could still be picked up and transferred. FLS scores (forward alignment only) were calculated according to the formula: *300 – (seconds to complete transfer) – (10 x number of pegs dropped out of view and/or not transferred)* [7]. Higher scores represent better performance. Group A served as the control and performed all peg transfers in the forward alignment. Groups B, C, and D experienced varied rounds of either increasing or decreasing sensorimotor discordance as shown in Table 1.

All groups began the exercise by completing three unscored practice rounds of the peg transfer task in the forward alignment to determine individual baseline scores. A maximum of 300 seconds was allotted to each practice round. Based on the group, each student performed 10 peg transfer practice rounds in their assigned alignment. Prior literature has demonstrated that student's learning curve reaches a plateau after 5 rounds, but due to the added visual-spatial discordance in our study, we chose to have 10 rounds [8]. After each practice session, each student was tested and scored in forward alignment performance. Each practice session lasted a maximum of 60 minutes: 10 peg transfer rounds (maximum of 300 seconds each) followed by a 10-minute break. Throughout the event, students were allowed to take breaks as needed and the entire event lasted up to four hours.

Statistical Analysis

The sample size for the study was based upon the difference in the testing scores between the four treatment groups. We assumed that the score for group A (all forward practice sessions) would be 30% less than any of the other three groups, that the scores for the other groups would be equal, that the standard deviation would 30% of the mean for the Group A, and that α=0.05 and β=0.20. With these assumptions, we would be able to detect a statistically significant difference with 16 subjects in each group, using the one-way analysis of variance (ANOVA). This amounted to a total of 64 subjects to enroll for the study. In order to account for additional variability, the decision was made to enroll 20 subjects in each group. It should be noted that the analytical plan evolved during data collection, but the decision was made to maintain the sample size of 20 subjects per group.

Quantitative data are expressed as the mean ± standard Deviation (SD). Nominal variables were compared using the *chi-square test* or the *Fisher's Exact* test, as appropriate. The pre-test scores for each group were compared using the one-way *analysis of variance* (ANOVA), followed by *Tukey's test*. Within-group scores were compared for each group separately, using a multilevel mixed effects general linear model, with the score as the dependent variable, the timing of the test (pre-test, first test, second test, third test) as the independent variable, and the random variable as the individual subject. If there was a statistically significant effect for the model, pairwise comparisons were performed using *Tukey's test*. An additional multilevel mixed effects model was performed, with the score as the dependent variable. The independent variables were Group (A, B, C, D; reference variable: Group A), gender (reference variable: female), age group (reference variable: < 25 years of age), college (MSU-CHM, MSU-COM, MSU-CVM; reference variable: MSU-COM), Training position (forward, reverse, side; reference variable: forward), and self-reported gaming ability (not as good/worse vs. better/expert; reference variable: not as good/worse), while the random variable was the individual subject. Significance was assessed at $p < 0.05$. All analyses were performed using *Stata v.15.0* (StataCorp, College Station, TX).

Table 1 Group training and testing allocations

	Group A (n=20)	Group B (n=20)	Group C (n=20)	Group D (n=20)
Practice 3 rounds	Forward	Forward	Forward	Forward
Baseline test score	T	T	T	T
Practice session[a]	Forward	Forward	Side	Reverse
Test 1 score	T	T	T	T
Practice session[a]	Forward	Side	Reverse	Side
Test 2 score	T	T	T	T
Practice session[a]	Forward	Reverse	Forward	Forward
Test 3 score	T	T	T	T

T Testing done in forward alignment

[a]Sessions composed of 10 peg transfer rounds

Results

All 80 originally selected students completed the study with 53% (n = 42) representing COM, 28% (n = 22) CHM and 20% (n = 16) CVM. The majority of participants [65% (n = 52)] were first-year medical students, 49% (n = 39) were female, 64% (n = 51) were between ages 21–24 years, and 88% (n = 70) were right-hand dominant. Individual group demographics are found in Table 2.

Performance scores for each group are summarized in Table 3. Groups showed increasing or decreasing performance scores with each subsequent exercise. Group A (control) demonstrated a statistically significant overall increase in scoring of 37.1% from baseline test. Groups B, C, and D showed improvements of 3.7%, 27.1%, and 19.3%, respectively, between baseline and Test 3, yet none demonstrated consistent linear improvements. Numerically, the highest score for groups B, C, and D was achieved following a forward practice session.

On multi-variate analysis, the only statistically significant predictor of score was the training position. Students who practiced in the side or reverse alignment positions scored 25 and 37 points lower, respectively, than students who practiced in the forward alignment (Table 4).

Table 3 FLS scores within group comparisons

	Group A	Group B	Group C	Group D
Baseline Test	167±31 ***a***	191±23 ***a***	177±45 ***a***	192±23 ***ab***
Practice	Forward	Forward	Side	Reverse
Test 1	214±11 ***b***	223±22 ***b***	194±20 ***a***	181±21 ***a***
Practice	Forward	Side	Reverse	Side
Test 2	223±18 ***bc***	210±22 ***bc***	181±34 ***a***	199±27 ***b***
Practice	Forward	Reverse	Forward	Forward
Test 3	229±13 ***c***	198±32 a***c***	225±18 ***b***	229±13 ***c***

FLS values are represented as Mean ± SD. Higher scores represent better performance. Comparisons are within each column. Values followed by a different letter are significantly different from one another at p < 0.05. For example, looking at group A, Test 1 is significantly different from the baseline test since the letters are different, but Test 1 is not significantly different from Test 2 since they both contain "b."

Discussion

Our randomized controlled trial to demonstrate an improvement in peg transfer skills in the forward alignment position following practice in various visual-spatial discordance views (side or reverse alignment) showed some interesting results. Our original hypothesis was disproven

Table 2 Group demographics

	Group A (%)	Group B (%)	Group C (%)	Group D (%)	*p* value
College					0.755
MSU-COM	10/20 (50)	11/20 (55)	8/20 (40)	13/20 (65)	
MSU-CHM	6/20 (30)	5/20 (25)	6/20 (30)	5/20 (25)	
MSU-CVM	4/20 (20)	4/20 (20)	6/20 (30)	2/20 (10)	
Year					0.532
1st Year	11/20 (55)	12/20 (60)	14/20 (70)	15/20 (75)	
2nd Year	9/20 (45)	8/20 (40)	6/20 (30)	5/20 (25)	
Age ≥ 25 years	6/20 (30)	5/20 (25)	6/20 (30)	10/20 (50)	0.348
Females	9/20 (45)	11/20 (55)	11/20 (55)	8/20 (40)	0.717
Right-handed[*]	19/20 (95)	14/20 (70)	19/20 (95)	18/20 (90)	0.076
Self-reported gaming ability					0.573
Expert	0/20 (0)	2/20 (10)	1/18 (6)	0/18 (0)	
Better	5/20 (25)	5/20 (25)	6/18 (33)	9/18 (50)	
Not as good	11/20 (55)	7/20 (35)	6/18 (33)	6/18 (33)	
Worse	4/20 (20)	6/20 (30)	5/18 (28)	3/18 (17)	
Pre-test score[‡]	167±31	191±23	177±45	192±23	0.046[†]

MSU-COM: Michigan State University College of Osteopathic Medicine; MSU-CHM: Michigan State University College of Human Medicine; MSU-CVM: Michigan State University College of Veterinary Medicine

[*] No one identified as ambidextrous

[†] Although overall *ANOVA* was significant, none of the pairwise comparisons were statistically significant ($p>0.05$)

[‡]Values represented by Mean ± SD

Table 4 Multi-variate regression analysis

	Reference Variable	Coefficient*	95% CI†	p value
Group	A			
B		8.79	− 2.52, 20.10	0.128
C		0.03	− 11.59, 11.66	0.996
D		3.53	− 8.41, 15.47	0.562
Gender	Female	4.69	− 5.59, 14.98	0.371
Age group	< 25 years	− 6.39	− 14.91, 2.12	0.141
College	MSU-COM			
MSU-CHM		0.26	− 8.96, 9.48	0.943
MSU-CVM		6.93	− 3.70, 17.56	0.201
Training position	Forward			
Side alignment		− 25.05	− 30.94, − 19.16	< 0.001
Reverse alignment		− 37.36	− 43.35, − 31.47	< 0.001
Gaming Ability‡	Not as good/worse	2.63	− 7.79, 13.05	0.621

MSU-COM: Michigan State University College of Osteopathic Medicine; MSU-CHM: Michigan State University College of Human Medicine; MSU-CVM: Michigan State University College of Veterinary Medicine

*Change in FLS score compared to reference variable

†Confidence Interval

‡Not as good/worse vs. better/expert

(Hypothesis: forward alignment laparoscopic skills would improve following simulated experience in visual-spatial discordance conditions). Only the control group that practiced and tested each time in the forward alignment position showed significant linear improvements. The three remaining student groups showed significant worsening in forward alignment performance following practice in either the side or reverse angles (except in group C, where a non-statistically significant improvement was noted following practice in the side alignment). Also, these three groups demonstrated significant improvement following practice in the forward alignment. Our data conclude that practice in the side and reverse alignment does not improve forward alignment laparoscopic skills.

It is less clear in the literature whether training in visually discordant situations could improve forward alignment performance, which was the premise of the current study. Holznecht et al. (n = 22) demonstrated a decrease in forward alignment performance following practice in the reverse alignment [7]. However, they did not explore the effect of side alignment practice. On the contrary, Dunnican et al. (n = 21) demonstrated an improvement in forward alignment performance following practice in the reverse alignment [3]. In our larger trial (n = 80; n control = 20, n experimental = 60), we were unable to replicate Dunnican's results.

Training in several alignments allowed us to compare the effects of varying degrees of visual-spatial discordance. To our knowledge, our study is the first study to assess the effects of side alignment training (apart from reverse alignment training). Our results demonstrated a sequential improvement in forward alignment scores as the visual-spatial discordance decreased. Our control group (group A) was trained and tested only in the forward alignment (no visual-spatial discordance). Group B was trained in a sequentially increasing level of visual-spatial discordance (forward → side → reverse). Group C and group D were initially trained in visual-spatial discordant situations and finished in the forward alignment to assess recovery from visual-spatial discordance. The outlier in our dataset was in group C, in which students demonstrated an improvement in forward alignment test performance, albeit non-significant, following training in the side alignment. They did demonstrate diminished performance following training in the reverse alignment, in agreement with the rest of our results. Group C and D demonstrated a significant improvement in performance after training in the forward alignment, despite initial training in side and reverse alignments. This suggests that the students were able to reorient themselves during a period of forward alignment training and suggests that the effect of the visual-spatial discordance dissipates. The consistent improvement in test scores following forward alignment training is likely due to the students practicing in the same alignment that they are tested in and is the premise of laparoscopic simulation that is supported in several studies [4–6, 9].

The current study suggests that training in visual-spatial discordant conditions does not lead to the development of forward alignment laparoscopic skills. Since the FLS curriculum is based on training in the forward alignment, this suggests that our study supports the current curriculum. It is important to consider that under clinical situations, surgeons may have to operate at odd angles, so it may still be important to practice under visual-spatial discordance [10]. Some institutions have suggested overcoming visual-spatial discordant situations by using image-reversing systems [11, 12]. Further study is needed to determine whether surgeons should learn to adapt to visual-spatial discordant conditions or if methods for correcting the visualization should be sought.

In summary, we have shown that training in visual-spatial discordant situations is not necessary to improve forward alignment laparoscopic skills. Training in the forward alignment improves those skills more effectively than training in visual-spatial discordant situations. This could have important implications when developing future laparoscopic skills training curriculums. To our knowledge, this is the largest study to date assessing the impacts of training in visual-spatial discordance situations on performance in the forward alignment.

Acknowledgements This research project was supported in part by a grant from the Graduate Medical Education, Inc. (GMEI) Resident-led Research Mini-Grant Program, and an NIH (National Institutes of Health) grant award R25HL108864-01 to Elahé Crockett. Nashwa Khogali-Jakary was a 2013 NIH-National Heart, Lung and Blood Institute (NIH-NHLBI) scholar, and her research training was supported through the above NIH award (5-R25HL108864-01).

Funding Funding received from the National Institutes of Health: National Heart, Lung and Blood Institute (NIH-NHLBI) award (Grant Number: 5-R25HL108864-01) to Elahé Crockett, Ph.D., MS, and Graduate Medical Education, Inc. (GMEI) Resident-led Research Mini-Grant Program (Grant Number: DS100069)

Compliance with ethical standards

Disclosures Dr. Nashwa Khogali-Jakary discloses that she reports grants from the National Heart, Lung, Blood Institute, during the conduct of the study. Drs. John Kanitra, Alan Davis, David Henry, Elahé T. Crockett, Srinivas Kavuturu, as well as Ms. Pamela Haan, Mr. Rama Gupta, Ms. Cheryl Anderson, Ms. Caroline Moon, and Ms. Terry McLeod have no conflicts of interest or financial ties to disclose.

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