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Baseline characteristics in laparoscopic simulator performance: The impact of personal computer (PC)–gaming experience and visuospatial ability☆

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ABSTRACT

Background: Learning via simulators is under constant development, and it is important to further optimize simulator training curricula. This study investigates the impact of personal computer–gaming experience, visuospatial skills, and repetitive training on laparoscopic simulator performance and specifically on the constituent parameters of the simulator score.
Methods: Forty-seven medical students completed 3 consecutive Minimally Invasive Surgical Trainer–Virtual Reality simulator trials. Previously, they performed a visuospatial test and completed a questionnaire regarding baseline characteristics and personal computer–gaming experience. Linear regression was used to analyze the relationship between simulator performance and type of personal computer–gaming experience and visuospatial ability.
Results: During the first 2 Minimally Invasive Surgical Trainer–Virtual Reality simulation tasks, there was an association between personal computer–gaming experience and the coordination parameters of the score (eg, EconDiath task 1: P = .0047; EconDiath task 2: P = .0102; EconDiath task 3: P = .0836). The type of game category played seemed to have an impact on the coordination parameters (eg, EconDiath task 1–3 for sport games versus no-sport games: P = .01, P = .0013, and P = .01, respectively). In the first Minimally Invasive Surgical Trainer task, visuospatial ability correlated with Minimally Invasive Surgical Trainer simulator performance but was abolished with repetitive training (overall Minimally Invasive Surgical Trainer score task 1–3: P = .0122, P = .0991, and P = .3506, respectively). Sex-specific differences were noted initially but were abolished with training.
Conclusion: Sport games versus no-sport games demonstrated a significantly better Minimally Invasive Surgical Trainer performance. Furthermore, repetitive laparoscopic simulator training may compensate for a previous lack of personal computer–gaming experience, low visuospatial ability, and sex differences.

INTRODUCTION

Today, laparoscopic surgery is the criterion standard for many surgical procedures [1]. Laparoscopic surgery has several important differences from the open approach, providing a 2-dimensional view of a 3-dimensional interior, which demands greater hand-eye coordination and gives less tactile feedback. The fulcrum effect, as described by Gallagher et al, is when the laparoscopic instruments' endpoints move in the opposite direction to the surgeon's hands because of the pivot point created by the abdominal wall through which the laparoscopic instruments passes, something that surgeons need to consider [2].

Virtual reality (VR) simulators provide an opportunity to training skills required for an entire laparoscopic procedure and to supply feedback to trainees on their performance [3]. Training in VR simulators has been shown to improve laparoscopic skills, and the skills acquired are transferrable to laparoscopic surgery [4–7].

Video Games Experience and Laparoscopic Simulator Performance. Several articles have previously evaluated the similarities between playing video games and performing laparoscopic surgery. Interviews with undergraduate medical students prior to performing a VR simulator task revealed an association between owning a video game device at home and better simulator performance [8]. In a study with fourth-year medical students and first-year residents who trained on the Minimally

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Invasive Surgical Trainer–Virtual Reality (MIST-VR, Mentice, Gothenburg, Sweden), those with video gaming experience completed the task faster and had a better score [9]. Although not all results are conclusive, 2 systematic reviews show a positive correlation between video games and simulator performance [10,11]. Still, there is no real consensus about which part of the simulation is enhanced by the video gaming experience [12–16].

Visuospatial Skills, Sex Differences, and Simulation Performance. Visuospatial abilities have been found to improve performance in endoscopic simulation [17]. Visuospatial ability also seems to impact performance in more advanced simulation tasks, which has been shown in 2 studies with specialists in endoscopy and gynecology [18,19]. In contrast to the above-mentioned support that visuospatial ability has on laparoscopic performance, one study presents contradictive findings, showing no significant difference between gamers versus nongamers regarding their baseline perceptual as well as visuospatial abilities. They further state that these 2 traits are resistant to any influence of prior experience and video game practice. As for the innate abilities, in regards to video games and its role in training surgical trainees, perhaps not all elements are relevant to surgical performance, stating that "the predictive value of these findings is uncertain" [20].

Additionally, supplementary instructions and recurrent training amplify performance, where prior advantage of visuospatial ability and also any sex-specific differences are being eliminated [21]. Several studies have also shown sex differences in laparoscopic simulator performance [21,22]. However, female students and students with no prior video game experience may "catch up" following additional practice and instructions [21]. Moreover, female residents underestimated their performance scores significantly compared to male residents, who also predicted their scores more accurately. These "surgical ability" estimation differences did not reflect the actual differences in performance [23].

Thus, the value of simulation training to improve surgical skills is well known. However, more research in this field is required regarding which factors influence the simulator performance the most to further optimize the design of training curricula.

Our hypothesis was to elicit whether different categories of video games provide similar results when tested on a laparoscopic simulator.

Study Aims. The aim of this study is to evaluate the impact previous personal computer (PC)–gaming experience (the types, or rather, categories of games played) has on the laparoscopic simulator performance, as well as the different parameters that constitute the simulator performance overall score. Furthermore, the study aims to analyze the impact visuospatial ability and sex may have on simulator performance. The data for this study are a further exploration of a recent study performed at the Karolinska Institutet where the performance in a low-cost Laparoscopic Box Trainer (BlackBox), evaluated by automated video analysis, and a MIST-VR was compared [24].

METHODS

Study Participants. Fifty-seven medical students volunteered to participate in the study during their surgical semester at Karolinska University Hospital. Prior to the simulation training, all participants completed an informed consent following a questionnaire with some baseline questions, for example, age, sex, experience of PC gaming, and categories rather than types of games that they played (role-playing games [RPG], first-person shooter [FPS], sport games [Sport], strategy games [Strategy]). Each participant could provide more than 1 answer to what prior types of video games played. For each participant, the whole procedure was performed in 1 sitting.

Assessing PC-Gaming Experience. Self-rated PC-gaming experience, as provided by the questionnaires, was evaluated by the participants on a visual analogue scale [25] where their answers from the questionnaire were subsequently transformed into a numeric value (1–100; given by a mark on a 10-cm drawn line). The median level of "PC gaming experience" was 60%, where "high" score was designated >60%. The visual analogue scale has been used by our group in previous studies [26–28].

Assessing Visuospatial Ability With the Mental Rotation Test–Version A. To assess visuospatial ability, prior to the trial, the trainees performed the Mental Rotation Test–version A (MRT-A) [29,30]. The MRT-A is one of the most commonly used tests for measuring spatial ability in which the participants compare 2-dimensional drawings of 3-dimensional geometrical figures [31]. The results are given as percentage. A

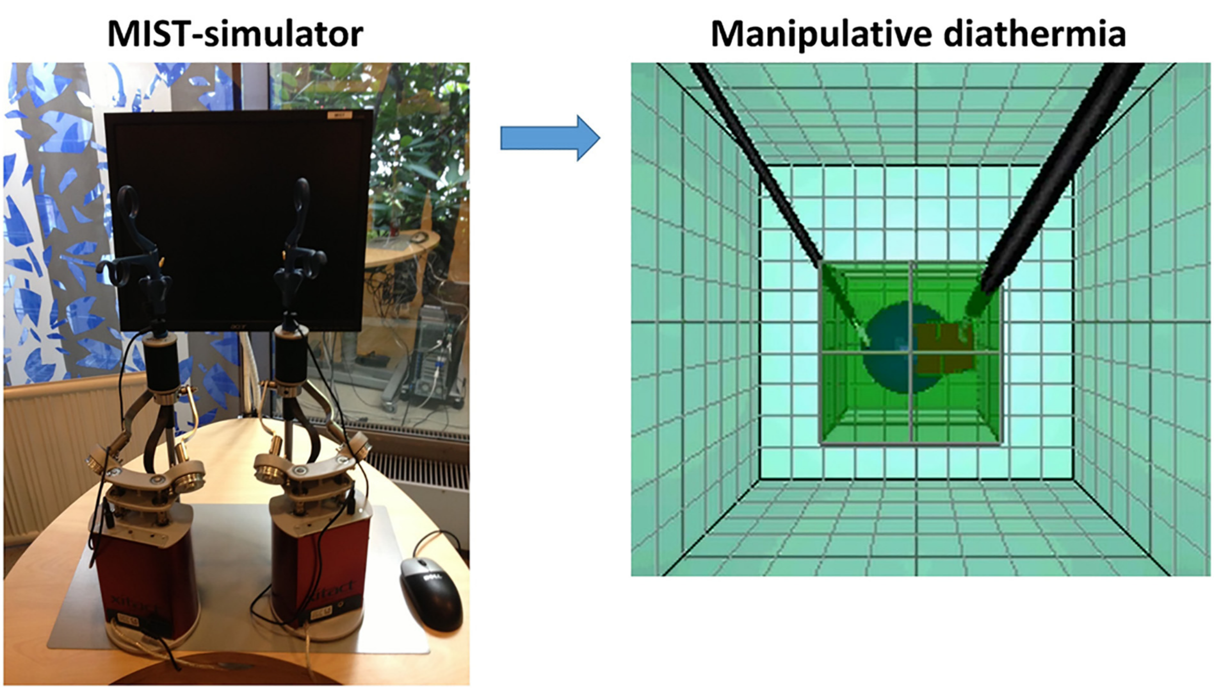

Fig 1. The MIST simulator and the Manipulative Diathermia Simulation test.

percentage score that was >49% was considered high visuospatial ability in this study.

Manipulative Diathermia Medium Tests in MIST-VR. The participants performed 3 consecutive manipulative diathermia medium tests in the previously validated and well-studied MIST-VR [4]. To accomplish the task, the participants first used the left handle to grasp a ball and then touched the ball using the right handle. In doing so, a cube around the ball was created. After withdrawing the right handle and reinserting it, the handle transformed into a diathermia hook. Using a pedal and correct positioning of the diathermia hook, the participants had to cauterize a small cube that showed up at different positions on the ball. With the left handle, the ball had to be exactly positioned within the surrounding cube to accomplish the cauterization and to make the small cube on the ball disappear (Fig 1). This procedure was repeated with the ball grasped with the right handle. Each trial included 6 procedures: 3 with the right hand alternatively guiding the diathermia hook and 3 with the left hand.

The performance of the trainee, thereafter, was automatically converted into a numeric value as provided by the built-in software of the MIST-VR simulator (the descriptions of each parameter are given by the MIST-VR manufacturer, as seen in Table 1), where a lower score indicates a better performance. For instance, the parameter Econ (Economy of Movement) provides a numeric value for the movement of the instruments inside the box, where large movements lead to higher score, which means worse performance. The total score was calculated based on multiple parameters, described in Table 1. Additionally, in Table 1, the MIST-VR parameters are described and subcategorized into clinically meaningful groups (coordination and precision) and, furthermore, attributed the PC games played into 4 main categories: Sport games, FPS, RPG, and Strategy games. This categorization was done to further see whether the types of games, rather than the actual games played, had any effect on the MIST performance.

Statistical Analysis. All statistical analyses were performed with JMP Pro 14.2.0 (SAS Institute Inc, Cary, NC). When comparing performance between the individual MIST trials, the matched-pairs test was used (Fig 2). When doing a regression analysis comparing 2 numerical variables (Tables 2 and 3), linear fit with analysis of variance was used. The Student *t* test was used when comparing the effect of the different PC-gaming categories on the outcome of the coordination variables (Table 4). A P value < .05 was considered statistically significant. A P value .05–.10 was considered a trend.

Ethical Considerations. The study was approved by the Regional Research Ethics Committee at Karolinska Institutet, Stockholm, Sweden (Dnr: 2013/2284-31/4). All subjects had to complete an informed consent prior to participation.

RESULTS

Baseline Demographics. Nine participants were excluded for not completing all 3 simulations in the MIST-VR. The reasons for their dropouts where stress due to future examinations ($n = 3$), exceeding the maximum time allowed to perform the task ($n = 2$), and loss of interest ($n = 4$). When presenting the data graphically, an outlier in the PC-gaming experience group was identified and excluded. Therefore, the final analyses were performed using 47 participants with mean age of 26.6 years ± 4.7 SD. There was a fairly equal distribution between men and women (23 men, 24 women) (Table 5). Regarding PC-gaming category, 48.9% played FPS (Table 5).

PC-Gaming Experience and MIST Score Parameters

In a regression analysis, we found no correlation between PC-gaming experience and the overall MIST-VR score (Table 2). However, there seemed to be a significant association between the PC-gaming experience and some of the variables of the score associated with coordination in both the first and second MIST trials. However, this association was abolished in the third MIST trial (Table 2). We found no convincing sex-specific differences in this pattern.

Regarding the variables constituting coordination (EconDiath, TmDiathAir, TipInSphOn, and TmDiathSph; see Table 1), we found that those that played Sport games performed significantly better in all MIST trials (Table 4). Almost similar results were seen for those who played FPS games, although, in contrast to those who played RPG, and even less for those playing Strategy games (Table 4).

Visuospatial Ability and MIST Score Parameters

In a regression analysis comparing the overall visuospatial ability and the MIST score, we noted an association between all of the MIST score variables and the visuospatial ability. This association diminished gradually in MIST task 2 and was completely abolished in MIST task 3 (Table 3).

Visuospatial Ability and Sex Differences

We found some interesting sex-specific differences in that, in the precision parameters of the MIST score as well as the coordination parameters, there was a significant association between the visuospatial ability and the scores in women during the first MIST trial. In men, we found no associations regarding these parameters. However, in men, there was an association between visuospatial ability and time in the first MIST trial which gradually disappeared with additional trials (Table 3).

Table 1
Description of the different MIST parameters, and their reciprocal attribution to practically meaningful categories

	Category	*MIST-parameter**	*Description*
Precision	Overall MIST score	Score	The final score of each test
	Time	Time L/R	Total time of the test
	DiaTipRem	DiaTipRem L/R	Number of times the error of removing the diathermy tool tip from the subtarget to be burned occurred.
	Econ	Econ L/R	Economy of movement for left and right hand, respectively. The ratio of actual tool movements during the task segments for each hand to the optimal calculated movement of the tools necessary to complete the task. Therefore, the best results are the ones that approach the value of 1.
Coordination	EconDiath	EconDiath L/R	Economy of diathermy results for left and right hand, respectively. It is represented by the ratio of time that diathermy pedal was pressed during the task segments for each hand to the optimal - shortest time necessary to burn off the subtargets. The best value of this parameter should approach 1.
	TmDiathAir	TmDiathAir L/R	The times pedal was pressed while the diathermy tool did not touch the main target object or any of the subtargets.
	TipInSphOn	TipInSphOn L/R	Number of times the error of making contact between diathermy tool tip and the main target while pressing the pedal was committed for each hand.
	TmDiathSph	TmDiathSph L/R	The time of contact between diathermy tool and main target while the pedal was pressed.

L, left; *R*, right.
* Abbreviations as given by the MIST-VR simulator.

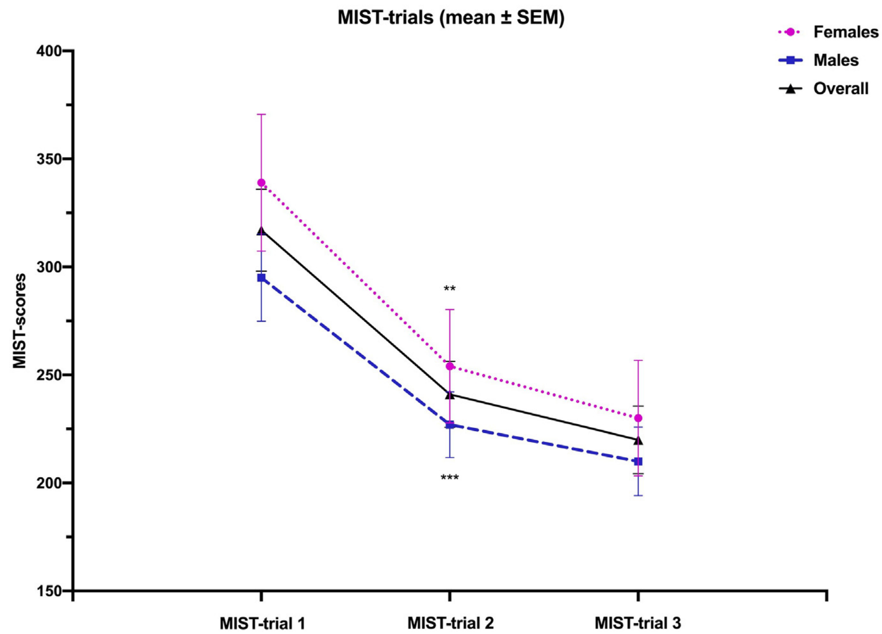

Fig 2. The final overall scores, as well as divided into sex, of the 3 consecutive MIST-VR trials. ***$P < .001$ between the first and second trial in men. **$P < .01$ between the first and second trial in women. Matched-pairs test used.

Simulator Performance

Simulator performance improved significantly between the first 2 MIST trials (Fig 2). The absolute scores of the third MIST trial were better than for the second MIST trial but not significantly so. Likewise, the absolute MIST trial scores for men were better when compared to women at each of the MIST trials, but no significant differences were registered (Fig 2).

DISCUSSION

In the literature, there are conflicting opinions on how PC-gaming experience and visuospatial ability affect laparoscopic performance. The studies in this field are heterogeneous when it comes to study design, definitions, type of simulator used, and the analysis of different parts of the simulation, thus making comparisons difficult.

Therefore, in this study, we attempted to evaluate the impact of previous PC-gaming experience and of visuospatial ability into (1) the different parameters constituting the overall laparoscopic simulator performance, (2) the type of games played, and (3) the impact of sex on simulator performance.

PC-Gaming Experience and Outcome on MIST Trial Performance. Although there was no association between PC-gaming experience and the final simulator overall score in the 3 MIST trials, we found an association between PC-gaming experience and the coordination parameters of the first 2 MIST-VR simulator tasks (Table 2). This is, to some extent, in line with the results of Kennedy et al who have shown a positive impact of previous video gaming, with the video gaming group being faster and having a shorter instrument path length, whereas no difference was found for instrument smoothness [20]. Furthermore, in a study be Grantcharov et al examining surgical residents with limited laparoscopic experience regarding sex, hand dominance, and PC-gaming experience and its impact on MIST-VR performance, they found that PC gamers made significantly less errors than the control group, whereas differences in time and "unnecessary movements" were not significant. They further found that right-handed surgical residents performed significantly better than the left-handed residents [12]. In contrast to our study, Van Dongen et al found better total scores, efficiency, and speed among adults with video gaming experience when tested in the LapSim VR simulator [16]. Accordingly, another study showed that video gaming experience results in both reduced time and less errors. That study also suggested that the number of hours spent playing video games resulted in better virtual reality laparoscopy skills outcomes [14]. Furthermore, in a review by Jalink et al, although positive correlations between video game experience and laparoscopic simulator skills were shown, other factors may affect the simulator performance, which should be taken into account [10]. However, a recent study contradicts the finding regarding transfer of skills, stating that

Table 2
Regression analysis between PC-gaming experience and the specific parameters of the MIST-simulator score

		PC-gaming experience								
		MIST task 1			MIST task 2			MIST task 3		
		Regression coefficient	P	R^2	Regression coefficient	P	R^2	Regression coefficient	P	R^2
	Overall MIST score	−0.41	.4740	0.01	−0.46	.3097	0.02	−0.15	.7401	0.00
Precision	Time	−0.10	.1940	0.04	−0.10	.1102	0.06	−0.04	.5202	0.01
	DiaTipRem	−0.03	.6649	0.00	−0.02	.6770	0.00	−0.02	.6285	0.01
	Econ	−0.01	*.0924*	0.06	−0.01	.1996	0.04	−0.01	.1527	0.05
Coordination	EconDiath	−0.18	.0047	0.16	−0.14	.0102	0.14	−0.06	*.0836*	0.07
	TmDiathAir	−0.37	.0097	0.14	−0.27	.0161	0.12	−0.11	.1251	0.05
	TipInSphOn	−0.06	.0049	0.16	−0.04	.0236	0.11	−0.01	.4105	0.02
	TmDiathSph	−0.17	.0013	0.21	−0.14	.0091	0.14	−0.06	*.0539*	0.08

Statistically significant P values highlighted in underline; trends ($P < .10$) in *italic*.

Table 3
Regression analysis between visuospatial ability and the specific parameters of the MIST simulator

		Overall visuospatial ability								
		MIST task 1			*MIST task 2*			*MIST task 3*		
		Regression coefficient	P	R^2	*Regression coefficient*	P	R^2	*Regression coefficient*	P	R^2
Precision	Overall MIST score	−3.10	.0122	0.13	−1.68	*.0991*	0.06	−0.98	.3506	0.02
	Time	−0.42	.0164	0.12	−0.27	*.0551*	0.08	−0.15	.2620	0.03
	DiaTipRem	−0.41	.0040	0.17	−0.17	*.0834*	0.07	−0.07	.5033	0.01
	Econ	−0.04	.0354	0.09	−0.02	*.0824*	0.07	−0.02	.3344	0.02
Coordination	EconDiath	−0.31	.0322	0.10	−0.09	.4905	0.01	−0.02	.8102	0.00
	TmDiathAir	−0.67	.0388	0.09	−0.18	.5024	0.01	−0.06	.7073	0.00
	TipInSphOn	−0.11	.0274	0.10	−0.02	.5742	0.01	0.01	.6527	0.00
	TmDiathSph	−0.27	.0320	0.10	−0.08	.5132	0.01	0.01	.8978	0.00
		Visuospatial ability: women								
		MIST task 1			*MIST task 2*			*MIST task 3*		
		Regression coefficient	P	R^2	*Regression coefficient*	P	R^2	*Regression coefficient*	P	R^2
Precision	Overall MIST score	−3.44	*.0819*	0.13	−1.43	.3975	0.03	−0.91	.5988	0.01
	Time	−0.27	.3010	0.05	−0.17	.4291	0.03	−0.10	.6188	0.01
	DiaTipRem	−0.63	.0094	0.27	−0.21	.2123	0.07	−0.06	.7540	0.00
	Econ	−0.04	.2206	0.07	−0.01	.6576	0.01	−0.02	.5547	0.02
Coordination	EconDiath	−0.44	.0437	0.17	−0.04	.8541	0.00	0.06	.6308	0.01
	TmDiathAir	−0.92	.0465	0.17	−0.06	.8653	0.00	0.12	.6501	0.01
	TipInSphOn	−0.18	.0289	0.20	−0.01	.9247	0.00	0.06	.2669	0.06
	TmDiathSph	−0.40	*.0525*	0.16	−0.04	.8431	0.00	0.06	.6245	0.01
		Visuospatial ability: men								
		MIST task 1			*MIST task 2*			*MIST task 3*		
		Regression coefficient	P	R^2	*Regression coefficient*	P	R^2	*Regression coefficient*	P	R^2
Precision	Overall MIST-score	−2.15	.1624	0.09	−1.75	.1297	0.11	−0.83	.4994	0.02
	Time	−0.56	.0237	0.22	−0.37	*.0687*	0.15	−0.20	.2929	0.05
	DiaTipRem	−0.06	.6743	0.01	−0.12	.3003	0.05	−0.02	.8327	0.00
	Econ	−0.02	.1283	0.11	−0.04	.0273	0.21	−0.02	.5468	0.02
Coordination	EconDiath	−0.04	.8372	0.00	−0.07	.6521	0.01	−0.10	.1764	0.09
	TmDiathAir	−0.16	.7536	0.00	−0.20	.6220	0.01	−0.27	.1591	0.09
	TipInSphOn	0.03	.4329	0.03	−0.01	.8267	0.00	−0.03	.3994	0.03
	TmDiathSph	0.03	.7572	0.00	−0.02	.8160	0.00	−0.02	.6094	0.01

Statistically significant *P* values highlighted in underline; trends ($P < .10$) in *italic.*

perhaps motivation to play video game (in this case, Underground) rather than actual skills would explain the results seen in performance [33]. Furthermore, in a recent review by Glassman et al, the amount of evidence backing up the effects of video games on surgical simulation performance was presented as limited, and furthermore, there was no evidence at all regarding its effects on laparoscopic surgery performance [11]. Thus, the above-mentioned articles present a somewhat diverse picture of the relationship between video gaming experience and simulator performance.

Interestingly, we note a learning effect in the final simulation attempt. The value of prior PC-gaming experience was reduced to a non-significant level (Table 2). A conclusion from this finding is that even though PC-gaming experience has an impact on the coordination performance of novices in the initial laparoscopic simulator session, a more important factor seems to be the repetitive practice of the laparoscopic procedure. We did not find any apparent sex-specific differences regarding PC-gaming experience and outcome of the MIST trials.

PC-Gaming Categories and Outcome on MIST-Trial Coordination Parameters. The type of categories of PC games that the participants played seemed to have an impact on the coordination parameters of the MIST trials (Table 4). Students who considered themselves to be in the sport-gaming category had significantly better values in all of the coordination parameters of the 3 MIST trials. In the FPS category, there was a similar pattern that, however, seemed to disappear somewhat in the last MIST trial. In the RPG and Strategy categories, there were, with the exception of 1 parameter in the first MIST trial, no differences (Table 4). These results are in line with the study by Schlickum et al, where 30 surgical novices were randomized to 5 weeks of systematic video game training in either an FPS game (Half Life) or a video game with predominantly cognitive demands (Chessmaster). The students who had trained in FPS performed better in both the MIST-VR as well as the endoscopic simulator GI Mentor II [34]. In our study, the students did a self-assessment of which category/categories they belonged to, and thus, we do not have any data as to exactly what games they played and with which frequency.

Visuospatial Ability and Outcome on MIST Trial Performance. This study reveals a significant association between visuospatial ability, as measured by the MRT-A, and simulator performance in the MIST-VR during the first of 3 consecutive exercises that gradually subsided during the following 2 exercises. This might indicate a training effect that compensates for variation in the visuospatial ability across study participants (Table 3). However, in a study by Kennedy et al, no impact of visuospatial score was found [20], whereas other studies have shown a clear correlation between visuospatial abilities and endolaparoscopic simulation performance [17,18].

Visuospatial Ability, PC-Gaming Experience, Sex, and MIST Performance. Visuospatial ability was associated with the precision parameter (DiaTipRem) as well as all the coordination parameters during the first MIST trial among women in their overall MIST performance. In men, only procedure time showed an association with visuospatial ability during the first MIST trial. Multiple previous articles have suggested that men perform better at simulator exercises in comparison to women [22,35,36]. This has partly been explained by men playing more video and PC games. In a study by Shane et al, no sex differences in the number of attempts to reach proficiency on a MIST simulator were found in the video gaming group. However, in the group with less or no video gaming experience, men performed better than women [9]. In contrast, Lin et al found that sex does not influence surgical performance [22].

Table 4
The effect of different gaming categories on the coordination parameters of the MIST score

Student t test

		RPG gaming		*No RPG gaming*		
		Mean	*SEM*	*Mean*	*SEM*	P
	EconDiath	7.50	1.85	13.28	3.39	.1424
	TmDiathAir	15.99	4.57	26.74	7.47	.2264
	TipInSphOn	3.86	0.88	6.02	1.07	.1261
MIST task 1	TmDiathSph	3.50	1.05	10.09	2.92	.0411
	EconDiath	6.06	1.84	10.82	2.75	.1574
	TmDiathAir	12.31	4.16	21.22	5.77	.2167
	TipInSphOn	2.81	0.63	4.63	0.95	.1162
MIST task 2	TmDiathSph	2.89	1.40	8.24	2.81	*.0956*
	EconDiath	3.77	1.03	7.24	1.64	*.0808*
	TmDiathAir	6.89	2.38	15.28	3.57	*.0568*
	TipInSphOn	2.53	0.66	3.34	0.65	.3852
MIST task 3	TmDiathSph	1.44	0.77	3.40	1.60	.2749

		FPS gaming		*No FPS gaming*		
		Mean	*SEM*	*Mean*	*SEM*	P
	EconDiath	6.80	1.54	15.16	3.97	*.0592*
	TmDiathAir	13.91	3.75	30.98	8.77	*.0833*
	TipInSphOn	3.89	0.67	6.44	1.29	*.0881*
MIST task 1	TmDiathSph	3.47	0.94	11.50	3.45	.0331
	EconDiath	5.10	1.32	12.73	3.26	.0377
	TmDiathAir	10.05	3.00	25.25	6.86	*.0508*
	TipInSphOn	2.65	0.43	5.17	1.15	.0493
MIST task 2	TmDiathSph	2.26	0.99	9.96	3.33	.0352
	EconDiath	3.75	0.73	7.98	1.98	*.0541*
	TmDiathAir	7.31	1.96	16.64	4.23	*.0540*
	TipInSphOn	2.54	0.48	3.50	0.81	.3158
MIST task 3	TmDiathSph	0.94	0.40	4.29	1.94	.1039

		Sport gaming		*No-sport gaming*		
		Mean	*SEM*	*Mean*	*SEM*	P
	EconDiath	4.72	1.32	13.24	2.88	.0100
	TmDiathAir	9.12	2.96	27.26	6.41	.0137
	TipInSphOn	2.71	0.71	6.04	0.94	.0071
MIST task 1	TmDiathSph	2.05	1.05	9.46	2.45	.0079
	EconDiath	2.73	0.35	11.15	2.38	.0013
	TmDiathAir	4.68	1.01	22.31	5.05	.0015
	TipInSphOn	1.75	0.41	4.69	0.82	.0024
MIST task 2	TmDiathSph	0.51	0.20	8.14	2.39	.0031
	EconDiath	2.83	0.53	6.97	1.44	.0100
	TmDiathAir	4.99	1.49	14.50	3.14	.0090
	TipInSphOn	1.88	0.57	3.43	0.60	*.0692*
MIST task 3	TmDiathSph	0.50	0.22	3.39	1.36	.0432

		Strategy		*No strategy*		
		Mean	*SEM*	*Mean*	*SEM*	P
	EconDiath	7.21	2.01	13.25	3.26	.1219
	TmDiathAir	15.03	4.88	26.93	7.19	.1777
	TipInSphOn	4.00	0.94	5.87	1.04	.1897
MIST task 1	TmDiathSph	3.58	1.22	9.83	2.82	.0490
	EconDiath	6.50	2.00	10.41	2.66	.2462
	TmDiathAir	12.45	4.17	20.85	5.64	.2380
	TipInSphOn	3.35	1.05	4.27	0.82	.4971
MIST task 2	TmDiathSph	4.07	2.07	7.40	2.63	.3260
	EconDiath	4.13	0.90	6.92	1.64	.1424
	TmDiathAir	8.15	2.34	14.29	3.55	.1558
	TipInSphOn	3.06	0.73	3.02	0.63	.9654
MIST task 3	TmDiathSph	1.25	0.54	3.45	1.58	.1948

Statistically significant *P* values highlighted in underline; trends ($P < .10$) in *italic*.

Although the absolute MIST trial scores in men were better than in women, they did not differ significantly (Fig 2). Men showed a steeper learning curve between MIST trials 1 and 2 as compared to women. Both sexes showed a similar pattern with an improvement over time, although it was only significant between trials 1 and 2 (Fig 2). However, in women, there was also a trend toward an improvement between trials 2 and 3 ($P = .0724$); no such trend was found in men.

Table 5
Baseline characteristics for study participants

		n	%
Sex	Male	23	48.9
	Female	24	51.1
PC-gaming experience	High	24	51.1
	Low	23	48.9
PC-gaming category	RPG	18	38.3
	FPS	23	48.9
	Sport	12	25.5
	Strategy	17	36.2
Visuospatial score	High	28	59.6
	Low	19	40.4

PC-gaming experience >60% was considered a high score.
Visuospatial score >49% was considered a high score.

The final scores of women improved between all 3 exercises, in contrast to men where the third trial only showed minor improvement, indicating an improved learning effect for women with repetitive simulator training. This suggests that there is value in identifying this group (women with low PC-gaming experience) to provide them with more opportunities for laparoscopic simulator training. When preparing a training curriculum or developing simulators, it is also important to take these differences into consideration and perhaps focus more on coordination and precision training for the group with women, something that does not necessarily involve simulator training in the initial phase.

Limitations of the Study. A rather small study group and a 16% dropout (9 of 57) of the original study participants are limiting factors in this study. Furthermore, video games differ in their causative outcome for simulator performance [34]. A better outlined prequestionnaire could help to distinguish between the gamer's choice of games. If this study was to be repeated, it would be interesting to also include an objective evaluation of PC-gaming skills and experience. One way to further evaluate the participants' gaming performance is by preparing more thoroughly designed questionnaires; gathering additional information, for instance, by focusing on what types of video games played, how much time spent playing, and perhaps also their motivation, satisfaction, and preferable types of games played; and comparing it with the participants' actual simulator performance. Furthermore, the use of the validated tests of the MIST-VR is arguable because newer and more sophisticated VR simulators are available. However, the MIST-VR has been widely used, and according to Gallagher and O'Sullivan, it does not attempt to simulate the tissue; rather, it focuses on the computer processing capacity and training the psychomotor skills in eye-hand coordination that are required in laparoscopic cholecystectomy [38]. Furthermore, in a review of a total of 24 studies contrasting high- and low-fidelity simulators, almost all studies presented no significant advantages of high- over low-fidelity simulators [39].

Conclusion

In conclusion, both PC-gaming experience and visuospatial abilities had a significant impact on various parameters in the laparoscopic MIST simulator. However, the differences of these factors were no longer apparent by the third simulation, a finding which indicates an important training effect that compensates for most of the differences in baseline skills. Nonetheless, sport games versus no-sport games showed a significantly better MIST performance in all 3 MIST tasks. Thus, the groups with low PC-gaming experience, those with low visuospatial score, and women will benefit not only from further repetitive simulator training but also (according to our study) by focusing more on training in coordination and precision. In conclusion, repetitive laparoscopic simulator training clearly enhances simulator performance.

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Availability of data and material

Because of Swedish regulations regarding privacy and integrity and also because of concerns regarding the possibility of identifying individual participants using their demographic information and survey answers, no datasets generated and/or analyzed during this study are publicly available. All datasets are unidentified and stored in the repository of Karolinska Institutet (https://owncloud.ki.se/), only available from the corresponding author on reasonable request, and will be destroyed after 10 years.

Authorship contributions

NO and LE conceived of the presented idea.
NO, LE and KG designed the study.
NO, PR and LE collected the data.
NO, LE and KG analyzed the data.
NO, PR and LE wrote the article.
KG reviewed the article.
All the authors discussed the results and contributed to the final manuscript.

Conflicts of Interest

All the authors have no conflict of interest to declare.

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