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Video Gaming in Children Improves Performance on a Virtual Reality Trainer but Does Not yet Make a Laparoscopic Surgeon

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Abstract

Background: In children, video game experience improves spatial performance, a predictor of surgical performance. This study aims at comparing laparoscopic virtual reality (VR) task performance of children with different levels of experience in video games and residents. *Participants and methods:* A total of 32 children (8.4 to 12.1 years), 20 residents, and 14 board-certified surgeons (total n = 66) performed several VR and 2 conventional tasks (cube/spatial and pegboard/fine motor). Performance between the groups was compared (primary outcome). VR performance was correlated with conventional task performance (secondary outcome). *Results:* Lowest VR performance was found in children with low video game experience, followed by those with high video game experience, residents, and board-certified surgeons. VR performance correlated well with the spatial test and moderately with the fine motor test. *Conclusions:* The use of computer games can be considered not only as pure entertainment but may also contribute to the development of skills relevant for adequate performance in VR laparoscopic tasks. Spatial skills are relevant for VR laparoscopic task performance.

Keywords

surgical education, simulation, business of surgery

Introduction

Spatial ability is one of the most important predictors of surgical skills and therefore seems to be a crucial factor for adequate performance in surgery.[1-3] Spatial tests have been shown to predict the potential to learn open[3] and laparoscopic[4,5] surgical skills.

Because of its special optical and mechanical conditions, laparoscopy represents a technique where spatial skills are of utmost importance. Restrictions as reduced degree of movements, reduced haptic feedback, dissociation of the visual and working axis, as well as loss of the third dimension must be outweighed by optimal camera navigation and exposure techniques. Surgical residents can efficiently acquire and train laparoscopic skills on virtual reality (VR) simulators.[6,7] These simulators are not only useful for training but also for assessment, since they can precisely and objectively measure laparoscopic performance parameters.

Many children and adults play video games, even on a daily basis. The influence of video gaming on performance on VR tasks has previously been investigated. Surgical residents with computer game experience performed better on VR laparoscopic[8] and better on VR endoscopic[9] simulators. Medical students with experience in video games, compared with those without, demonstrated a tendency toward better VR performance.[10] In a study involving 33 surgeons, past or current video game playing correlated with less errors, faster performance, and higher scores in laparoscopic basic skills and suturing on a porcine model.[11]

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In children, video gaming or home computer use influenced their activities and development such as physical well-being, cognitive and academic skill development, social development, and relationships as well as perception of reality.[12] Although the negative effects of extensive video gaming have been evaluated, several studies have shown the potential positive educational benefit of the use of video games in children.[13-18]

To date it is however unknown if early video gaming in children can influence the presence or development of skills such as those needed for laparoscopic surgery. Therefore, the aim of this study was to compare performance of children with low and high experience in video games to performance of surgical residents and experienced surgeons on a surgical VR simulator.

Participants/Materials and Methods

Study Population

Healthy children aged 8.4 to 12.1 years, trainees, and board-certified surgeons of the Department of Visceral Surgery of the Lausanne University Hospital were recruited for this study. Children of one local school were invited to participate in the study by their school teacher. Informed consent was obtained from all participants. For the children, assent was obtained from the child and informed consent from one of the parents. The study was approved by the local ethical committee of the University of Lausanne.

Questionnaire

A questionnaire was completed for general information such as age, gender, hand dominance, experience in video games, and specific information for the surgical trainees and board-certified surgeons on previous experience in VR as well as state of surgical experience. To determine the 2 groups of children with either high or low experience in video games, the following information was obtained and scored prior to analysis of the results: experience in video games (yes/no), frequency (never, every day, less than daily, rarely), and years of experience and type of game (action, platform, sport, adventure, strategy, puzzle, music, scoring higher those for which spatial skills are relevant). Among the adults, only 6 of 20 residents and 4 of 14 board-certified surgeons had experience in video games, none of them playing on a daily basis. Therefore, they were not divided into different groups of video game experience.

Test of Stereopsis

Stereopsis, the process in visual perception leading to perception of depth/3 dimensions, was examined using the Lang Stereotest I (Stereosehen, Professor J. Lang, Forch, Switzerland).

Conventional Tests

Validated tests of spatial ability and fine motor skills were performed to control for different psychomotor skill levels:

1. Wechsler Intelligence Scale for Children–IV (WISC-IV) cubes (David Wechsler, Paris, France; translated and adapted by permission. ©2003, 2005 Harcourt Assessment) for spatial ability. The test person used bicolored cubes to reproduce 12 given figures. The faster the picture had been copied, the more points were given. Using the test's references for each age group, the points were converted to an age-weighted score (Figure 1A).
2. Pegboard test (adapted from "Steckbrett" of "Zürcher Neuromotorik II") for fine motor skills. The test person had to insert as quick as possible 12 cylinders placed next to the pegboard in the 12 holes of the pegboard using only one hand. The test foresees the following modification for all participants aged 11 years or older: the cylinders that are already placed in the pegboard have to be turned around 180° and reinserted. The test was performed twice with the dominant and twice with the nondominant hand. Mean time for completion of the 2 trials was measured for the dominant/nondominant hand (Figure 1B).

Virtual Reality Tasks

The Xitact/Mentice hardware was used for the virtual reality tasks (Mentice SA, formerly Xitact SA, Morges, Switzerland; Figure 2A). It consists of a Pentium PC with a 19-inch high-resolution TFT monitor connected to 2 robotic force feedback devices (Xitact IHP instrument haptic ports) acting as bidirectional interfaces for the laparoscopic instruments and a third unidirectional electromechanical interface (Xitact ITP instrument tracking port) to direct the laparoscope. The software runs on Windows XP operating system and simulates with real-time high-resolution graphic and force feedback. A choice of laparoscopic instruments are simulated, such as graspers, scissors, clip applier, and hook electrode with realistic instrument handles connected to the manipulation robots.

The software of LapMentor basic tasks module (Simbionix USA Corp, Cleveland, OH) was used. It records a number of parameters such as task completion time in seconds, tool tip travel distances in centimeters (the lower the higher the economy of movement) as well

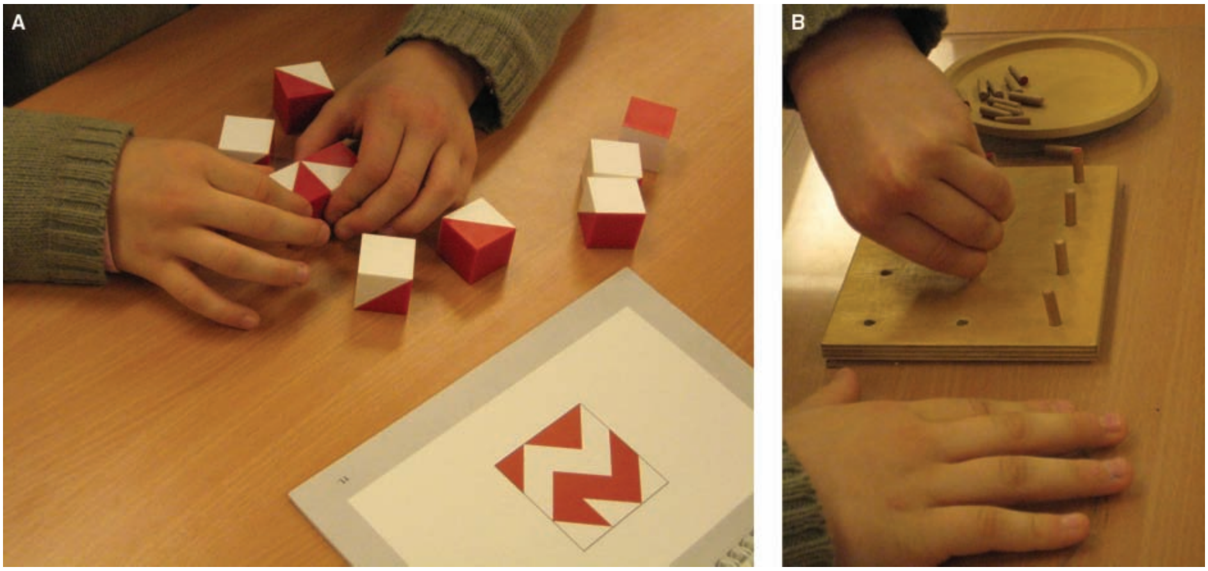

Figure 1. Conventional tests
A, Wechsler Intelligence Scale for Children–III (WISC-III) cubes. B, Pegboard test.

as depending on the task efficiency, safety, accuracy, and horizon maintenance in percentage. For this study, the basic task (bt) number 1 (camera manipulation), bt3 (hand–eye coordination), bt6 (2-handed maneuvers, Figure 2B), bt7 (cutting), bt8 (electrocoagulation), and the procedural task (pt) number 2 (clipping and cutting) were performed twice, and the mean of the 2 trials was used for subsequent analysis. Time was omitted as a parameter for basic task 8 because the task was performed by all participants during 3 minutes. In total, for all the tasks taken together, 23 parameters were considered.

The Simbionix software has been chosen for this study since it has been validated in various studies. Noncamera skills were shown to be able to distinguish between laparoscopically naïve and experienced surgeons.[19] The LapMentor was able to discriminate for the eye–hand coordination task of its basic module between subjects of different laparoscopic experience of the nondominant hand (not the dominant hand).[20] Surgical trainees and surgeons found the LapMentor module to be realistic.[21] Moreover, a randomized, double-blinded study showed that prior training on the LapMentor simulator leads to improved resident performance of basic skills in the animate operating room.[22]

Comparison of Participants

Performance of children with low video game experience was compared with performance of those with high video game experience and both to trainees in surgery (residents) who in turn were compared with board-certified surgeons (primary outcome). This part of the study aimed at evaluating the effect of previous experience in video gaming in children on VR performance in an observational, noninterventional manner. Moreover, it evaluated feasibility of using VR for individuals with no prior experience in laparoscopic surgery and no medical background.

Comparison of Tests

Performance at the VR tasks of all participants taken together was correlated with performance at the conventional tests (secondary outcome).

Statistical Analysis

All questionnaires and data gathered from the experiments were anonymously stored in a specially designed Excel 2003 spreadsheet (Microsoft Corp, Seattle, WA). For descriptive analysis and correlations, statistical analysis was performed using SPSS 10.1 statistical software package (SPSS Inc, Chicago, IL). Bivariate correlations were computed using both the Pearson and Spearman's rank correlation coefficient. For the comparison of groups and the resulting graphs, the R system for statistical computing[23] was used. We were faced with 27 endpoints (4 conventional test parameters and 23 VR parameters). For each endpoint a (nonhierarchical) family of hypotheses was to be tested, comprising 4 of 6 possible pairwise comparisons (children with low/high experience: (*a*) versus each other and (*b*/*c*) each versus residents as well as (*d*) residents versus board-certified

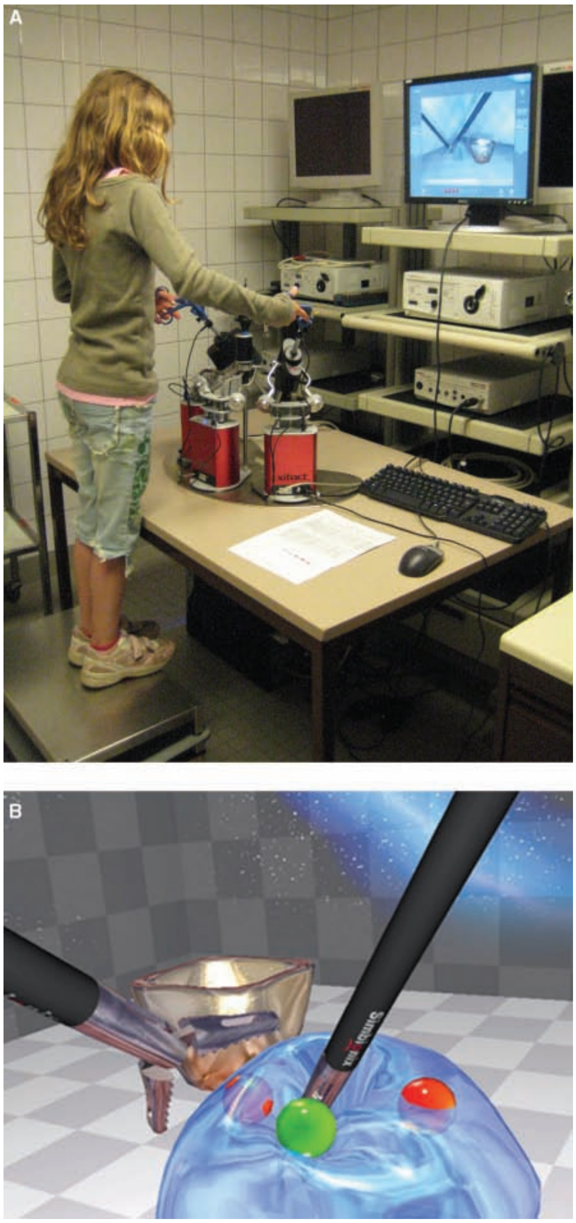

Figure 2. Virtual reality
A, Virtual reality simulator (Mentice SA, formerly Xitact SA, 1110 Morges, Switzerland). B, Virtual reality simulator task: basic task number 6 (two-handed maneuver) LapMentor basic tasks module (Simbionix USA Corp, Cleveland, OH).

surgeons). If we add for each endpoint the overall hypothesis that the location parameters are the same in each group, this family becomes hierarchical. We applied a 2-stage approach as follows. First, we conducted Kruskal–Wallis tests for all 27 outcomes and adjusted the resulting P values for multiplicity using the Bonferroni–Holm procedure.[24] Second, the 27 P values obtained were ordered such that $P_{(1)} \leq \ldots \leq P_{(27)}$. If and only if there was evidence for differences between the 4 groups, we applied pairwise Wilcoxon rank sum tests. The 4 respective pairwise comparisons of interest were also corrected for multiplicity using the Bonferroni–Holm procedure. Specifically, the corresponding multiple test had to control the multiple level $0.05/(27 - j + 1)$, where $j = 1, \ldots, k$ and k denotes the number of rejected hypotheses in the first stage.

Because VR tasks were not corrected for age, we compared the effect of video gaming in children with and without adjustment for age in a median regression model.

Sample size calculation was performed using Primer of Biostatistics Version 4.02 (McGraw-Hill) considering a single pairwise comparison only. Specifically, for a 10 units hypothesized difference between the mean performance of 2 selected groups and assuming an expected standard deviation of 10 for both groups, a necessary sample size of 9 per group was calculated to attain a power of 80% with a type I error rate of 0.05 (2-sided).

Results

General Characteristics

A total of 66 participants were involved in the study: 32 children with a median age of 10.3 years (range 8.4-12.1 years) of whom 9 had low experience and 23 had high experience in video games; 20 residents aged 30.1 years (range 24.8-38.3 years); and 14 board-certified surgeons aged 41.2 years (range 32.5-51.1 years). Lang Stereotest revealed stereopsis in all 66 participants. Table 1 gives an overview of the general characteristics.

Results of Conventional Tests and Virtual Reality Tasks

Table 2 gives an overview of the results of the conventional tests and of the performance at the virtual reality tasks.

Comparison of Participants

Performance of children with low and high video game experience was compared (*a*) to each other and (*b*/*c*) each to the performance of residents as well as (*d*) the latter to board-certified surgeons (Table 2).

1. Concerning the conventional tests, we found residents to perform better than children concerning the not-age-weighted WISC points, a difference which expectedly was not significant considering the age-weighted WISC score. There was no significant difference in

Table 1. General Characteristics of the Participants

	n (%)		
Group	Children (n = 32)	Residents (n = 20)	Board-Certified Surgeons (n = 14)
Gender			
Female	14 (43.8)	5 (25.0)	0 (0.0)
Male	18 (56.2)	15 (75.0)	14 (100.0)
Hand dominance			
Right	28 (87.5)	19 (95.0)	13 (92.9)
Left	4 (12.5)	1 (5.0)	1 (7.1)
Stereopsis			
Yes	32 (100.0)	20 (100.0)	14 (100.0)
Experience VG			
Yes	30 (93.8)	6 (30.0)	4 (28.6)
No	2 (6.2)	14 (70.0)	10 (71.4)
Experience VR			
Yes	0 (0.0)	5 (25.0)	5 (35.7)
No	32 (100.0)	15 (75.0)	9 (64.3)
Experience laparoscopy			
Yes	NA	18 (90.0)	14 (100.0)
No	32 (100.0)	2 (10.0)	0 (0.0)
Performed cholecystectomy			
0	32 (100.0)	10 (50.0)	0 (0.0)
1-5	NA	4 (20.0)	0 (0.0)
6-20	NA	4 (20.0)	0 (0.0)
21-100	NA	2 (10.0)	3 (21.4)
>100	NA	0 (0.0)	11 (78.6)
Performed other laparoscopic interventions			
0	32 (100.0)	8 (40.0)	0 (0.0)
1-5	NA	4 (20.0)	0 (0.0)
6-20	NA	5 (25.0)	0 (0.0)
21-100	NA	3 (15.0)	2 (14.3)
>100	NA	0 (0.0)	12 (85.7)

Abbreviations: VR, virtual reality; VG, video games; NA, not applicable.

the Pegboard time. Performance of residents did not significantly differ from performance of board-certified surgeons; nor did the one of children with low versus high experience in video games in any of the conventional tests.

2. Comparison of performance at the VR tasks showed a trend of lowest performance of children with low experience in video games, followed by those with high experience, residents, and board-certified surgeons (examples in Figures 3A to 3E). Prior to correction for both multiple endpoints and multiple comparisons, the difference between residents and children with low or high experience in video games was significant for most parameters, whereas the comparison of children with low versus high experience in video games and of residents versus board-certified surgeons was significant for some parameters (data not shown). With correction for multiple testing to give strong control of the family-wise error rate, only the difference between residents and either group of children remained significant for some parameters (Table 2).

The analysis including the adjustment for age in a median regression model showed for 16 of 23 parameters, for which a trend of better performance in the group with high video game experience was found, a persisting but less pronounced effect of video gaming in 9 of 16 parameters, and an increase of the effect of video gaming in 2 of 16 parameters. In 5 parameters, the effect disappeared.

Comparison of Tests

Performance at the VR tasks was compared with performance at the conventional tests. Overall, VR performance correlated moderately with the Pegboard test and well with the points of the WISC cube test, not with its age-weighted score, as shown in the density estimates for the correlation between the conventional tests and all VR outcome parameters taken together (Figure 4).

1. WISC cube test. A correlation coefficient of >.5 absolute value was found for 15 of 23 (Pearson) and 12 of 23 (Spearman) parameters concerning the non-age-weighted WISC points. Concerning the age-weighted WISC scores, correlation was low (Pearson, 0-0.33, absolute value; Spearman, 0-0.11, absolute value; Table 3, Figure 4).
2. Pegboard test. Correlation was moderate (Pearson, 0.3-0.52, absolute value; Spearman 0.1-0.48, absolute value; only overall data shown in Figure 4).

Discussion

This study demonstrates lowest VR performance of children with low experience in video games, followed by those with high experience, residents, and board-certified surgeons (primary outcome). To our knowledge, this is the first study evaluating VR laparoscopic performance in children as well as the influence of their previous video gaming on this performance. With this study, feasibility of having individuals with no prior experience in laparoscopic surgery and no medical background performing these tasks was demonstrated.

Children, residents, and surgeons had comparable age-related spatial abilities with good correlation between VR

Table 2. Results of the Conventional Tests (WISC, Pegboard) and VR Tasks of the Children With Low and High Experience in videogames, Residents, and Board-Certified Surgeons[a]

Group	Children LE (n = 9)	Children HE (n = 23)	Residents (n = 20)	Board-Cert. (n = 14)	*P* (Residents vs Children LE)	*P* (Residents vs Children HE)
WISC						
Total points	46 (18-55)	45 (22-60)	58 (45-64)	57 (46-64)	.027[c]	<.001[c]
Score	12 (2-14)	11 (4-17)	10 (6-13)	10 (6-13)	NS[b]	NS[b]
Pegboard						
Time dominant hand	24 (19-29)	25 (18-35)	21 (14-27)	21 (19-25)	1.0	.121
Time nondominant hand	28 (21-41)	26 (19-38)	22 (17-36)	24 (19-33)	NS[b]	NS[b]
bt 1						
Time (s)	132 (92-259)	117 (76-237)	70 (56-138)	66 (60-87)	.002[c]	.001[c]
Path length (cm)	318 (251-556)	358 (184-626)	260 (211-421)	234 (195-383)	.473	.331
Accuracy target hits (%)	77 (52-100)	87 (70-100)	98 (81-100)	94 (83-100)	.067	.014[c]
Maintaining horizon (%)	51 (34-91)	58 (36-84)	84 (41-95)	91 (73-100)	.955	.004[c]
bt3						
Time (s)	95 (78-137)	86 (70-130)	62 (38-87)	48 (34-58)	.007[c]	<.001[c]
Path length right instrument (cm)	164 (115-453)	177 (120-260)	112 (76-138)	107 (92-153)	.002[c]	<.001[c]
Path length left instrument (cm)	159 (97-365)	164 (106-248)	101 (73-153)	109 (83-167)	.046[c]	<.001[c]
Accuracy target hits (%)	78 (50-100)	84 (63-100)	95 (80-100)	95 (92-100)	.045[c]	.003[c]
bt6						
Time (s)	246 (144-516)	242 (94-417)	125 (67-290)	97 (72-144)	.085	.012[c]
Path length right instrument (cm)	712 (408-2022)	552 (363-1025)	279 (173-520)	281 (208-353)	.001[c]	<.001[c]
Path length left instrument (cm)	604 (296-1370)	442 (224-993)	184 (108-459)	189 (151-378)	<.001[c]	.001[c]
bt7						
Time (s)	259 (120-428)	194 (128-368)	132 (66-294)	87 (64-118)	.040[c]	.103
Path length right instrument (cm)	810 (298-1673)	456 (275-1081)	258 (144-728)	219 (134-403)	.037[c]	.124
Path length left instrument (cm)	556 (36-1025)	204 (76-700)	120 (36-400)	103 (38-182)	.250	.494
Accuracy cutting (%)	96 (90-100)	99 (87-100)	100 (98-100)	100 (99-100)	.020[c]	.005[c]
Safety retraction (%)	3 (1-63)	19 (1-83)	51 (1-100)	44 (1-100)	NS[b]	NS[b]
bt8						
Path length right instrument (cm)	291 (200-480)	265 (145-488)	209 (106-349)	230 (164-301)	.136	.204
Path length left instrument (cm)	235 (130-369)	172 (17-308)	153 (99-355)	212 (96-304)	NS[b]	NS[b]
Efficiency of cautery (%)	85 (62-100)	83 (51-100)	90 (72-97)	94 (81-99)	NS[b]	NS[b]
Accuracy highlighted bands (%)	100 (69-100)	91 (66-100)	96 (83-100)	100 (89-100)	NS[b]	NS[b]
pt 2						
Time (s)	143 (96-190)	139 (84-225)	104 (57-234)	68 (52-106)	1.0	.691
Path length right instrument (cm)	133 (101-282)	142 (86-314)	81 (45-185)	73 (57-99)	.550	.054
Path length left instrument (cm)	73 (34-215)	80 (28-163)	41 (19-153)	33 (26-48)	.392	.031[c]

Abbreviations: WISC, Wechsler Intelligence Scale for Children; VR, virtual reality; LE, low experience; HE, high experience; Board Cert., board-certified; bt, basic task; pt, procedural task.

[a]Values are given as median (range) or percentages. *P* value for the comparison between residents and children LE/HE. *P* values for the comparison of children LE versus children HE and residents versus board-cert. were all nonsignificant and are not shown.

[b]NS indicates not significant in the Kruskal–Wallis test.

[c]Significant in the pairwise Wilcoxon rank sum test.

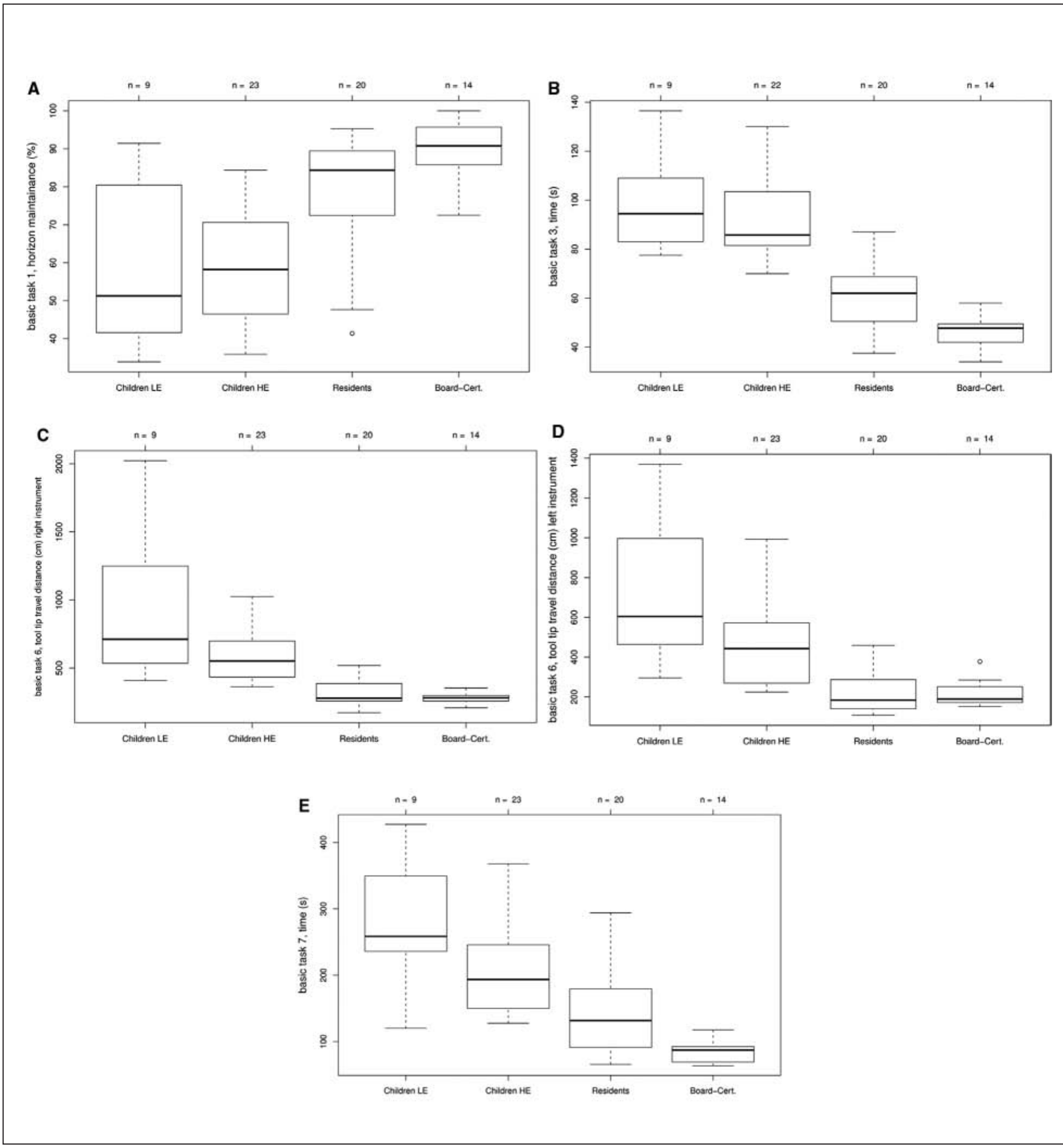

Figure 3. Comparison of participants at the virtual reality (VR) tasks
Abbreviations: Children LE/HE = children with high/low experience in video games; Board-Cert., board-certified surgeons.
A, Basic task 1, horizon maintenance (%). B, Basic task 3, time (s). C, Basic task 6, tool tip travel distance (cm) right instrument. D, Basic task 6, tool tip travel distance (cm) left instrument. E, Basic task 7, time (s).

task performance and spatial abilities, as measured by the points of the conventional cube test (secondary outcome).

Video game experience has previously been shown to improve performance of surgeons.[8,11] A recent study on 22 surgical novices showed that not only past experience with video games improved performance on a VR task but also systematic video game training: Residents matched and randomized into a group training with a three-dimensional (3D) first person shooter (FPS) game performed better than those in the 2D non-FPS group.[25]

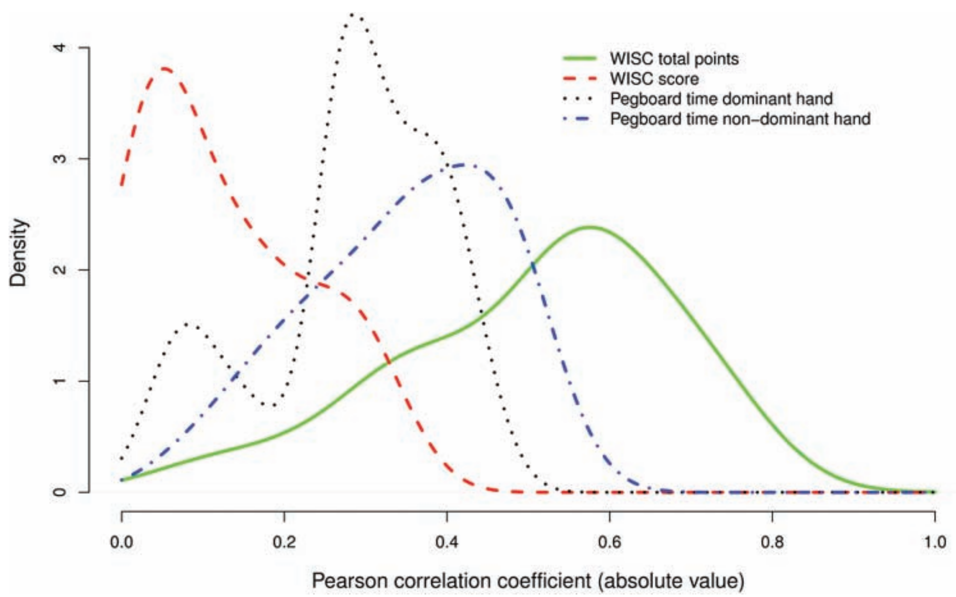

Figure 4. Relationship between performance at the 6 virtual reality (VR) tasks and the 2 conventional tests: kernel density estimates of the correlations of the 23 outcome parameters of the 6 VR tasks with the 2 conventional tests—Wechsler Intelligence Scale for Children (WISC) test (points and age-weighed score) and Pegboard (time for the dominant and nondominant hand)

Differences between former video game players and non-players may result either from the exposure to video games or reflect other differences between these 2 groups, such as differences in innate potential leading to the decision to play video games (self-selection effect).[26] Thus, for our study, it is impossible to distinguish between innate or video game–related differences. The findings of the systematic video game training,[25] however, support the assumption that skills acquired during video game tasks may be transferred to other tasks, which is in line with the literature showing the potential of video games to improve the visual, attentional, and spatial skills.[13,18,26,27]

For today's children, video games must not only be considered as a pure entertainment, but it appears that they also have a clear educational potential.[17] Video gaming was significantly more effective in improving spatial performance than a computerized word game, especially in children who initially presented relatively poor spatial skills.[13] In a cross-cultural setting (United States and Italy), exposure to computer technology over the long term (as part of the culture) or in the short term (as part of the computer game experimental setting) was associated with better decoding of scientific and technical information graphically represented on a computer screen.[14] Furthermore, computer games improved strategies for keeping track of several different things at the same time, therefore increasing visual attention skills.[15] Long-term but not short-term video game practice had a beneficial effect on spatial skills of mental paper folding.[16] Moreover, it has been shown that perceptual learning by playing action video games leads to training-induced increase in performance not only specific for the trained task but also for a range of visual skills.[18]

Our findings of a trend of better VR performance in children with high experience in video games as compared with those with low experience support these results of the literature.

This trend actually persisted after adjustment for age within the children in 11 of 16 parameters and was found decreased in 9 parameters and even increased in 2 parameters. Therefore, the trend of better performance with video game experience cannot simply be attributed to age. However, we did not find a better performance in children with high experience in video games as compared with residents. This may be explained by the lack of experience in surgery and virtual reality, as well as by the wide difference in age. The score given by the simulator, the conventional Pegboard task time and the WISC point results are not age-weighted. In contrast, the WISC score is age-weighted and as expected did not show a significant difference between any of the groups. To take into account the age difference, further studies could evaluate if older children or adults with experience in video games and no knowledge in surgery perform better than residents with no experience in video games. For the simulator used in the present study, construct validity has

Table 3. Correlation of Performance at the VR Tasks (bt 1, bt 3, bt 6, bt 7, bt 8, pt 2) and Performance at the Conventional Test WISC (Point- and Age-Weighted Score) for All Participants With Complete Observations (n = 65)

	Points		Score	
WISC	Pearson	Spearman	Pearson	Spearman
bt 1				
Time (s)	−0.58	−0.63	−0.08	0.03
Path length (cm)	−0.54	−0.41	−0.13	0.05
Accuracy target hits (%)	0.56	0.49	0.15	0.07
Maintaining horizon (%)	0.55	0.55	0.10	0.00
bt 3				
Time (s)	−0.63	−0.63	−0.03	0.03
Path length right instrument (cm)	−0.71	−0.66	−0.30	−0.08
Path length left instrument (cm)	−0.64	−0.53	−0.28	−0.03
Accuracy target hits (%)	0.53	0.49	0.05	−0.04
bt 6				
Time (s)	−0.71	−0.64	−0.26	−0.11
Path length right instrument (cm)	−0.74	−0.69	−0.33	−0.11
Path length left instrument (cm)	−0.72	−0.56	−0.27	0.03
bt 7				
Time (s)	−0.51	−0.51	−0.03	0.05
Path length right instrument (cm)	−0.60	−0.49	−0.19	0.00
Path length left instrument (cm)	−0.41	−0.48	0.00	−0.02
Accuracy cutting (%)	0.44	0.52	0.01	−0.04
Safety retraction (%)	0.31	0.25	0.05	0.00
bt 8				
Path length right instrument (cm)	−0.35	−0.30	−0.04	0.07
Path length left instrument (cm)	0.10	0.03	0.13	0.11
Efficiency of cautery (%)	0.34	0.16	0.06	−0.01
Accuracy highlighted bands (%)	0.21	0.15	−0.07	−0.03
pt 2				
Time (s)	−0.35	−0.43	0.00	0.03
Path length right instrument (cm)	−0.57	−0.58	−0.19	−0.09
Path length left instrument (cm)	−0.57	−0.57	−0.20	−0.10

Abbreviations: VR, virtual reality; WISC, Wechsler Intelligence Scale for Children; bt, basic task; pt, procedural task.

previously been established in a study involving 103 medical students, residents and fellows, and experienced laparoscopic surgeons.[19] There, the simulator was able to differentiate between laparoscopically naïve and experienced. However, to our knowledge, there are no studies comparing adults with no medical experience but good video game experience to surgeons. In surgical novices (26 fourth-year medical students and first-year surgical residents), previous video game experience shortened the time to achieve proficiency on a VR simulator as compared with no such experience.[28] However, there was no comparison with advanced surgeons. In another study involving 26 medical students, residents, and attending gynecologic surgeons, using a simulation software different from that used in our study, increased operating room experience and age were associated with a lower simulator performance.[29] The authors hypothesize that experienced laparoscopists expect certain tactile, visual, and contextual feedback not provided by the simulator and that younger individuals were more likely to have experience in video games, which was however not controlled for in that study. Thus, it may well be possible that an adult with no medical experience but good video game experience performs better on a simulator task than a surgeon who is focusing on expected and familiar feedbacks from the operating room.

After correction for multiple testing, the difference seen between children with low versus high experience in video games and between residents and board-certified surgeons did not reach statistical significance anymore. It is quite likely that this conservative correction for false positive values led to more false negative results.

The comparison between residents and board-certified surgeons showed no difference for the conventional tests; however, on the simulator, board-certified surgeons showed a trend of being faster than residents with no difference in accuracy and economy of movement, for which apparently the flat part of the learning curve is first reached, an important finding considering residents operating on patients. Typically, learning curves are steepest in the beginning and subsequently reach a plateau and are theoretically expected to follow a log-linear model.[30] As a matter of fact, we could confirm this hypothesis in a previous test of repeated VR tasks in medical students and residents for important performance measurements such as time, economy of movement, and accuracy, expectedly not for the instruments' maximum speed being not an indicator of good performance.[10] As a consequence, in the steep part of the learning curve, we will detect differences between 2 different groups, such as residents and board-certified surgeons. In our VR setting, residents showed an accuracy and economy of movement comparable with board-certified surgeons, suggesting that they have reached the flat part of the learning curve for these parameters. However, they were not able to finish the tasks as fast as board-certified surgeons. This is in accordance with significantly longer operating times in the operating room for patients operated on by residents as compared with board-certified surgeons,[31,32] whereas the complication rates have been reported to be either higher for some procedures performed by residents[32] or similar.[31] In our own experience, surgical training with tutorial assistance did not result in a higher rate of surgical site infections if trainees are adequately supervised and interventions carefully selected.[33] The clinical implication of the finding that residents present steeper learning curves for accuracy and economy of movement than for time is that they may safely perform a task but need to be adequately supervised and actively supported in order to show a reasonable task progression with the ultimate goal to ensure patients' safety.

The comparison of VR performance and conventional test performance showed high correlation for all participants taken together for WISC points, but not WISC score. This is an expected finding because of the fact that the WISC points and the VR task performance are not age-weighted. The fact that VR performance correlates well with a conventional test of spatial skills suggests spatial skills being relevant for VR laparoscopic task performance. The Pegboard correlation with the VR task was existent but less pronounced, which could be explained by the fact that the Pegboard task requires less complex skills than the WISC test and the VR task or by the fact that for the VR tasks fine motor skills are less relevant than spatial skills.

Our study has some limitations. First of all, it would have been interesting to have a group of children with no experience in video games at all, which in our setting was difficult to find. This could suggest a selection of children from a higher socioeconomic background. However, many children had access to video games not at home, but through their friends. Second, the information obtained provides insight in some developmental aspects of learning in children rather than in adult surgeons, although the study did not include a longer follow-up of these children. Spatial skills seem to develop progressively during childhood as confirmed by the difference in the cube test points (not in the age-weighted score) and may be improved by practicing, such as using video games, and may lead to a better performance in VR. These findings confirm the relevance of spatial skills for laparoscopic surgery and of early training of these skills. This might have an impact on training curricula in surgeons. Further studies should include adults or older children with high experience in video games but no experience in surgery to additionally exclude confounding by age. Last, the study was observational and not interventional, therefore participants were not randomized to either receive or not receive a structured video game training.

In conclusion, video game experience has been shown to improve spatial performance in children and surgical performance in adults. Our VR simulation study shows that children with high video game experience have a tendency to perform better than those with low experience for some parameters and residents perform better than children. The use of computer games can be considered not only as a pure entertainment but also may contribute to the development of skills relevant for adequate performance in laparoscopic surgery which may be measured in children in a VR laparoscopic task setting. Spatial skills are relevant for VR laparoscopic task performance.

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