Validation of a video game made for training laparoscopic skills
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Chapter 6

The effect of a preoperative warm-up with a custom-made Nintendo video game on the performance of laparoscopic surgeons

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Abstract

Background: It has previously been shown that short, pre-operative practice with a simulator, box trainer, or certain video games can temporarily improve one’s basic laparoscopic skills; the so-called warm-up effect. In this experiment we tested the hypothesis that Underground, a video game made for training basic laparoscopic skills, can also be used for a pre-operative warm-up.

Methods: 29 laparoscopic experts were randomized into two different groups, which were tested on two different days. Group 1 (n=16) did a laparoscopic skill baseline measurement using the FLS peg transfer test and the Top Gun cobra rope drill on day 1, and did the same tests on day 2 after a 15 minute session with the Underground game. Group 2 (n=13) did the same, but started with the video game, followed by baseline measurement on day 2. This way, each participant served as its own control. Video recordings of both tasks were later analyzed by two blinded reviewers.

Results: On day 1, group 2 was 14.33% (P = 0.037) faster in completing the peg transfer test. A trend toward better cobra rope scores is also seen. When comparing the average improvement between both days, group 1 – which used the game as a warm-up on day 2 – showed a 19.61% improvement in cobra rope score, compared to a 0.77% score decrease in group 2 (P = 0.002).

Conclusions: This study shows that the Underground video game can be used as a pre-operative warm-up in an experimental setting.
Introduction

The concept of “warming up” is defined as “to engage in exercise or practice especially before entering a game or contest; broadly: to get ready” and is commonly seen in a wide variety of professional and skilled activities, such as sports, dancing, and music. It has been shown that a warm-up can improve endurance performance of sports and can increase voice quality in singers amongst others. In the past few years, research has shown that a short, preoperative warm-up can also enhance surgical performance, in particular in laparoscopic surgery.

The first to describe this were Do et al., who showed that residents and medical students who performed a simple transfer task in a box trainer were significantly better after a 10 minute warm-up with the same exercise. However, this experiment fails to distinguish between a learning effect and an actual warm-up. Kahol et al. performed several experiments, which showed that a 15-20 minute warm-up on a simulator can result in a significant decrease of errors, and an increase in speed when performing a different, simulated task. This was seen in various groups with different experience levels. Conversely, Kroft et al. found that only senior residents (in comparison to junior residents) performed a validated intracorporeal suturing task significantly better after a 15 minute practice round.

The first to demonstrate the impact of the warm-up effect in the actual operating theater setting were Calatayud et al. Their study found that a 15 minute warm-up on a virtual reality laparoscopic simulator significantly improved the performance of surgeons conducting a laparoscopic cholecystectomy. Similarly, Moldovanu et al. showed that a 15 minute warm-up with a virtual reality simulator increases the “respect for tissue” of a single surgical team, performing fifteen uncomplicated laparoscopic cholecystectomies, but failed to show an increase in other properties, such as “depth perception” and “bimanual dexterity.” Lee et al. found that a similar exercise significantly improved the technical performance of the mobilization of the colon during laparoscopic interventions performed by urology trainees, and Mucksavage et al. described how a single urologist reduced his surgical time of laparoscopic nephrectomies by 50 minutes, after he started doing a routine, preoperative warm-up of 15-20 minutes of suturing exercises on a box trainer. Finally, Chen et al. recently demonstrated in a large group of gynecological residents (n=91) that subjects, who performed three warm-up exercises on a box trainer prior to various laparoscopic
interventions, were rated significantly higher by their (blinded) attending surgeon, irrespective of the difficulty of the operation.  

Interestingly, this pre-operative warm-up cannot only be achieved with laparoscopic box trainers and virtual reality simulators, but also with video games. The first to report this were Sadandan et al., who demonstrated that the laparoscopic skill, assessed by means of three tasks in a box trainer, of medical students, ob/gyn residents, and attending gynecologists improved significantly after playing the game Super Monkey Ball (SEGA Corp., Ota, Tokyo, Japan) for just 10 minutes. Unfortunately, the researchers didn’t include a control group to distinguish between a learning effect and the actual warm-up effect. Plerhoples et al., however, did include a control group. In their experiment with a similar game, Super Monkey Ball 2 for mobile phones, they found that laparoscopic novices, who used the game to warm-up for 10 minutes, made significantly fewer errors on a laparoscopic simulator than the control group. Bokhari et al. used a custom-made add-on for the motion sensitive Wii controller (Nintendo Co., Ltd., Kyoto, Japan) to play the commercially available game Kororinpa: Marble Mania (Hudson Soft Co., Ltd., Tokyo, Japan). Surgical residents that had completed 50 levels of the game finished an electrocautery task on a laparoscopic simulator faster, more proficient, and with fewer errors than a control group. The most comprehensive study was performed by Rosser et al. Over the course of the years, 123 surgeons, who were enrolled in Rosser’s Top Gun laparoscopic suturing course, were asked to play three different video games (six minutes per game) prior to performing certain validated exercises of the course in a box trainer, including intracorporeal suturing. Again, it was found that, compared to a control group (n=180), the subjects that had used video games as a warm-up were significantly faster, and made fewer errors.

The Dutch company Cutting Edge has developed a video game for Nintendo’s Wii U game console that is specifically designed to improve basic laparoscopic skills. In this game, called Underground, players have to use two, large, robotic arms to manipulate the environment of a mine, so that other, smaller robots can escape to the surface. The game is played with custom-made hardware, shaped like laparoscopic instruments, which can be used to maneuver the robotic arms in the video game world (figure 1). The motion sensitive Wii Remote controllers, which are inserted into the special hardware, determine their position by detecting four infra-red LEDs on a base plate, using a built-in infra-red camera. This way, the player can play a video game using the same movements as made during laparoscopic surgery. The
hardware has already shown to possess solid face, construct, and concurrent validity. However, experimental validity – the actual effect of the game on one’s basic laparoscopic skills – has not yet been studied.

Figure 1: a photo of the custom-made Underground hardware and an in-game screenshot of the game

Goals and hypothesis
The goal of this study is to test the warm-up effect of Underground on expert laparoscopic surgeons and experienced surgical residents. Given the previously discussed evidence of preoperative warm-up, it is our hypothesis that playing the Underground video game for 15 minutes prior to performing a laparoscopic test in a box trainer will significantly reduce operating time. Our null hypothesis is that the game will have no influence on one’s laparoscopic skill at all.

Methods
Participants
Participants were recruited at the University Medical Center Groningen (Groningen, The Netherlands) by means of an individual e-mail, which was sent to all surgeons, gynecologists, urologists, and surgical residents with laparoscopic experience. In total, 29 laparoscopic experts participated in this study. Experts were defined as surgeons or residents that have performed more than 30 laparoscopic interventions as the primary surgeon in the past three years. Exclusion criteria included physical disabilities that would prevent participants to partake in the experiment, and medical reasons to avoid video games, such as epilepsy. In total, 16 surgeons, 5 surgical residents and 8 gynecologists participated in the trial. Demographic data are shown in table 1.
Table 1: Demographic data

<table>
<thead>
<tr>
<th></th>
<th>Surgeons (n=16)</th>
<th>Surgical residents (n=5)</th>
<th>Gynecologists (n=8)</th>
<th>Total (n=29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (% male)</td>
<td>75%</td>
<td>100%</td>
<td>0%</td>
<td>58.6%</td>
</tr>
<tr>
<td>Age (years), mean (SD)</td>
<td>43.4 (7.8)</td>
<td>32.0 (1.4)</td>
<td>38.5 (4.8)</td>
<td>40.1 (7.6)</td>
</tr>
<tr>
<td>Hand dominance (% right)</td>
<td>93.8%</td>
<td>100%</td>
<td>87.5%</td>
<td>93.1%</td>
</tr>
<tr>
<td>Laparoscopic interventions, mean (SD)</td>
<td>144 (115)</td>
<td>190 (22)</td>
<td>107 (47)</td>
<td>142 (92)</td>
</tr>
<tr>
<td>Mean GE as a child</td>
<td>1.7</td>
<td>3.8</td>
<td>1.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Mean GE as an adolescent</td>
<td>2.2</td>
<td>4.6</td>
<td>1.8</td>
<td>2/5</td>
</tr>
<tr>
<td>Mean GE as a student</td>
<td>2.4</td>
<td>3.0</td>
<td>1.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Mean GE as a resident</td>
<td>2.3</td>
<td>1.8</td>
<td>1.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Mean GE as an attending</td>
<td>1.8</td>
<td>--</td>
<td>1.0</td>
<td>1.8</td>
</tr>
</tbody>
</table>

GE = self reported game experience on a scale from 1 to 7

**Apparatus and tasks**

There is no real gold standard for measuring laparoscopic skill\(^\text{19}\), but several methods have been validated to do so, such as the *Fundamentals of Laparoscopic Surgery (FLS) Manual Skills testing program*\(^\text{20,21}\) and the *Rosser Top Gun Laparoscopic Skill and Suturing program*\(^\text{22,23}\). In this study, laparoscopic performance was measured using two different box trainer tasks from both programs. The first task was the *peg transfer test* of the FLS program\(^\text{20,21}\); the second task was the *cobra rope drill*, which is part of the Top Gun program\(^\text{22,23}\). Both tasks have been tested and validated to ensure that they reflect multiple basic laparoscopic skills, such as eye–hand coordination, inverted movements, depth perception, and ambidexterity, all skills that are aimed to be trained using Underground\(^\text{21,22,24}\). All exercises, performed in a box trainer with standard measurements and a fixed camera position, were recorded with an external camera. The recordings were analyzed afterwards by two blinded reviewers. The inter-observer intraclass correlation coefficient for the peg transfer test was 0.992 (95% confidence interval 0.987-0.995) and for the cobra rope drill 0.993 (95% confidence interval 0.988-0.996). To minimize inter-observer variability, scores that varied more than 3 seconds were analyzed for a third time by an unblinded person to determine which reviewer was correct. Participants were allowed to get acquainted with the materials before performing their tasks, but were not allowed to do a full practice round to prevent them from warming-up with the tasks themselves. All tasks were performed once, and the amount of errors and the time to completion of each task were recorded.
The first task, the *FLS peg transfer test*, consists out of a pegboard with twelve pegs and six rubber rings. Participants have to lift every rubber ring using a grasper in their non-dominant hand, transfer it in mid-air to a grasper in their dominant hand, and place it on a peg on the opposite side of the board. After moving all six rings, every ring has to be moved back to the other side of the peg board, but in reversed order. Errors were defined as rings dropped out of reach or out of sight and were counted as a 17 second penalty. The maximum time limit was set at 300 seconds.

The second task, the *Top Gun cobra rope drill*, requires participants to pass a string using two laparoscopic graspers, while only grasping the red colored sections of the rope. Participants start with their dominant hand and pass each colored section to their non-dominant hand. The complete rope has to be unwrapped in this rhythmic fashion. The time to complete the task was noted as the final score. Errors were not counted, but subjects were strictly monitored by an official Top Gun instructor. This way, the tasks were completed according to protocol.

In this study, the cobra rope drill was performed without an electronic proctor.

The Underground video game consists out of three parts; a 15-inch (16:9) flat-screen TV, a Nintendo Wii U game console running the Underground video game software, and the previously described hardware (figure 1). The hardware was placed on a height-adjustable tripod in front of the TV, and participants were standing while playing. In the game, the player manipulates the environment of a dangerous mine, so that small, friendly robots can traverse it safely. This is done by utilizing the specially developed laparoscopic input device. In order to solve the puzzles in the levels, players need to master basic laparoscopic skills, such as depth perception, inverse movements, and ambidexterity. The various gameplay elements, which gradually get harder over time, are based on actual movements made during laparoscopic surgery. This way, it is hoped that players continuously train their basic laparoscopic skills while playing a video game. All participants played the game, all starting from the very first level, for 15 minutes and were continuously supervised to make sure they were playing the whole time and did not get stuck. During this experiment, there was no pre-set in-game goal that had to be reached, since this study solely focused on the warm-up effect of simply playing with the game.
Assessment
At the start of the study, participants filled in a demographic questionnaire on age, gender, hand dominance, video game experience, and exclusion criteria (table 1). Participants performed their tasks on two consecutive days. On one day, baseline laparoscopic skills were measured using the two laparoscopic skills tasks. The other day, participants had to play Underground for 15 minutes straight right before performing the laparoscopic skills tasks. Each participant served as his/her own control. To distinguish between a learning effect and a warming up effect, all participants were randomized into two groups; a group that performed the baseline measurement on the first day and the intervention on the second day, and a group that did the intervention on the first day and the baseline measurement on the second day (figure 2). Randomization was done via an online randomization tool. Participants did not perform any laparoscopic operations prior to participation, nor did they play any video games in this period. If possible, participants were tested at the beginning of their workday.

**Figure 2: flow-chart of the research design**

Power analysis
Power analysis for a t-test was conducted in G*Power for Windows, version 3.1.9 (University of Düsseldorf, Düsseldorf, Germany) to determine a sufficient sample size using an alpha of 0.05, a power of 0.80, an expected large effect size ($r = 0.5$), and one tail (since the direction
of the effect of the intervention was already known). On the basis of the aforementioned assumptions, the desired sample size was 27.

**Evaluation**

All data were analyzed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 22 (IBM, Armonk, NY, United States of America). Alpha was set at 0.05. Because a small data set was used, normality was tested with the Shapiro–Wilk test. Homogeneity of variance was tested using Levene’s test.

**Ethics**

All participants enrolled on a voluntary basis and were given informed consent before enrollment. The ethics committee of the University Medical Center Groningen was consulted before the experiment was started. The committee ruled that this experiment did not need their official approval.

**Results**

Data were analyzed in two different ways. First of all, the mean scores of the peg transfer test and the cobra rope drill were compared. Data for the cobra rope scores on day 1 and the peg transfer scores on day 2 were normalized using a square root transformation. An independent samples t-test showed a significant difference (14.33%) on day 1 in peg transfer test scores between group 1 (control) and group 2 (game), which is in favor of the latter. There is also an 8.93% difference in cobra rope scores, but this is not significant. Data for both days are shown in table 2 and figure 3.

**Table 2: Participant’s scores on day 1 and 2 (in seconds)**

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (n=16)</th>
<th>Group 2 (n=13)</th>
<th>P (1-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peg transfer test total score (SD)</td>
<td>143.31 (30.51)</td>
<td>122.77 (28.19)</td>
<td>0.037 *</td>
</tr>
<tr>
<td>Cobra rope score (SD)</td>
<td>82.44 (21.84)</td>
<td>75.08 (15.15)</td>
<td>0.164</td>
</tr>
<tr>
<td>Day 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peg transfer test total score (SD)</td>
<td>132.88 (32.98)</td>
<td>132.62 (39.17)</td>
<td>0.465</td>
</tr>
<tr>
<td>Cobra rope score (SD)</td>
<td>68.63 (12.48)</td>
<td>74.23 (19.01)</td>
<td>0.185</td>
</tr>
</tbody>
</table>

* Statistically significant difference (a = 0.05)
Secondly, the mean individual score improvements (as a percentage) in both research groups were compared with an independent samples t-test (1-tailed). The peg transfer scores were normalized using a square root transformation. These data, as depicted in figure 4, showed that participants who played the game as a warm-up on day 2 (group 1) were significantly ($P = 0.002$) better in the cobra rope drill. Similarly, these participants were slightly better at the peg transfer test, but this score difference is not significant.

* Statistically significant difference ($a = 0.05$)
Discussion

It has previously been shown that short, pre-operative practice with a simulator, box trainer, or certain video games can temporarily improve one’s basic laparoscopic skills; the so-called warm-up effect. Although warm-up is considered normal practice in sports and theater \(^{10}\), pre-operative warm-up is not (yet) considered a common habit in surgery \(^7\). However, such a practice can be of considerable importance to patient outcomes, since a reduction in surgical and anesthesia time can save costs and reduce postoperative complications \(^{10}\).

In this study, we showed that the Underground video game, a game that is specifically aimed at training basic laparoscopic skills, can be used for pre-operative warm-up in an experimental setting. Laparoscopic experts that have played the first part of the game for 15 minutes are 20.54 seconds (14.33\%) faster in completing the FLS peg transfer test than those who didn’t. Similarly, participants that served as a control group (group 1) showed a 19.61\% increase in their Top Gun cobra rope scores when using the game as a warm-up on a second day, compared to a 0.77\% decrease in participants that did the same test on the second day without a warm-up (group 2). This improvement is large and significant. The fact that the participants in group 2 also scored better on the peg transfer test on their second day can be attributed to a learning effect.

Limitations of the study

Previous studies have shown that a pre-operative warm-up can lead to an actual improvement in operating theater efficiency \(^{7-11}\). This study, however, was performed in an experimental setting, and we did not look at a direct effect of the game on one’s operating performance in the operating theater. Although a correlation, based on previous research by others, can be assumed, we cannot state that the positive effect of a warming-up with Underground is actually transferable to the operating theater. To do so, further research is needed.

Despite a large and significant increase in the score of the cobra rope drill, we did not find a similar difference in the peg transfer task scores. Participants in group 1 were just as good as the participants in group 2. This is unforeseen, because both tests are validated to give an objective measure of the same basic laparoscopic skills and therefore similar results are to be expected. This phenomenon could be attributed to the fact that the peg transfer test, which has several different steps and can be performed using many techniques (e.g.: there are many ways the rubber ring could be grasped and transferred to the other grasper), is more complex.
to explain and to perform than the cobra rope drill. So it is a possibility that participants have (subconsciously) thought of a better way to perform the test on day 2 and thus show a bigger improvement without a warming-up. A third group, which only did the baseline tests for two days straight, could have given answer to this.

**Conclusion**

The Underground video game and hardware could be used as a pre-operative warm-up to improve operating times and thus reduce postoperative complications. However, the positive results in this study were only found in an experimental setting, which means that further research is needed to make sure that this video game can actually benefit laparoscopic surgeons and their patients in the actual operating theater.
References


