VIRTUAL REALITY TRAINING FOR ENDOSCOPIC SURGERY

COMPOSING A VALIDATED TRAINING PROGRAM FOR BASIC SKILLS

Koen Willem van Dongen

Virtual reality training for endoscopic surgery. Composing a validated training program for basic skills

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Voor Ruud.
Omdat ik nooit neuroloog geworden ben.

Contents

Chapter 1

General introduction

Endoscopic surgery

In the late eighties endoscopic surgery was introduced as a routine surgical technique in the general surgical practice. In endoscopic surgery a large incision is replaced by a number of small incisions. Instruments are introduced through trocars, which are specifically designed canullas that facilitate this technique. A special purpose camera (endoscope), visualises the operating area on a video monitor. Endoscopic surgery minimises trauma to the body wall. It has advantages for the patient such as less pain, shorter hospitalisation, better cosmetic results and faster recovery to normal physical activity[1-3]. Endoscopic surgery does require different skills. Visualisation of the operation field is fundamentally different. Instrument handling is more difficult and endoscopic surgery is limited in the degrees of freedom as compared to open surgery[4-6]. Therefore the revolutionary introduction of endoscopic surgery has posed new challenges in surgical education. Whilst endoscopic skills can be acquired in the operating room successfully, it may not be the most appropriate or efficient environment to acquire such skills, given the steep learning curve.[7-9] Furthermore, financial and ethical issues, as well as limited residential work hours impose a need to provide technical skill training in a laboratory setting[10;11].

Virtual reality simulation

Virtual reality (VR) simulators have been developed to train basic endoscopic skills. A unique advantage of VR simulators is that they are both a training tool and an assessment device. During training, objective measurements of performance are registered by the VR simulator and stored in its database. The database, in turn, provides the trainer or assessor with factual information on trainee performance status, without the need of being physically present.

However, discussion arises how to integrate these simulation based training modalities into the surgical training curriculum. Prior to implementation some questions are to be answered.

What are the expectations and desires of surgical residents on endoscopic training programs in teaching hospitals in the Netherlands?

First the current status of endoscopic technical skills training in the Netherlands should be mapped to understand whether adjustments are required and possible. In turn, this provides an insight in the role and place of virtual reality training in a standardized training curriculum for endoscopic skills. A survey is carried out to compare their expectations to the current endoscopic surgery training programs offered *(Chapter 2)*.

Does the LapSim® virtual reality simulator show construct validity?

Obviously a simulator must be properly validated. It must have "construct validity", i.e. the degree to which the results of the "training session" as carried out by the trainee on the simulator should also reflect the actual skill of the trainee who is being assessed[12;13].

The performance of subjects with different levels of experience in endoscopic surgery is compared using measurements of performance by the computer *(Chapter 3)*. Furthermore the learning curves for basic endoscopic skills as measured by the simulator's outcome parameters (speed, efficiency and precision) are compared. After an initially rapid improvement, training results tend to plateau to a stable outcome performance. The process of learning psychomotor skills takes longer than for endoscopic surgery, as compared to open surgery [7-9]. The effectiveness of a basic virtual reality simulator to discriminate novice and experts by comparing their learning curve for basic endoscopic skills is tested *(Chapter 4)*.

Is it possible to determine the number of repetitions needed for a novice to reach expert levels?

The learning curves of novices and experts during 15 repetitions are evaluated to answer this question *(Chapter 4)*.

Is it possible to reach consensus on the settings of these exercise configurations and training programs?

The LapSim® VR simulator basic skills module consist of nine psychomotor skill tasks. The end points relate to execution time, instrument path, damage and other adverse effects. Training design can be adjusted for both exercise configurations as well as for "pass or fail" outcomes (assessment thresholds). The exercise configuration settings and exercise programs used for validation of this simulator in studies published so far were either default settings, or were based on personal (arbitrary) choice of the tutors[14-20]. An international group of experts is gathered in order to discuss the exercise configurations and training programs. Thereafter, the training program configured is validated, in order to set criterion levels to design a proficiency based training program with expert performance as the benchmark to define assessment thresholds *(Chapter 5)*.

What is the effect of distributed and massed training on the initial development and retention of psychomotor skills on a virtual reality simulator?

Working hours of residents are limited and technical skill training should be as efficiently as possible. Therefore it is very important to understand the concepts of training schedules. There is a choice between a distributed and a massed set-up. Distributed training is defined as short training periods, with rest periods in between[21;22]. Massed training is defined as training in continuous and longer training blocks[21;22]. In studies on sports and psychology there is a preference for distributed training[22;23]. Few studies have investigated the influence of training schedules on surgical technical skills acquisition[24;25]. These studies also show a preference for distributed training. The training results of four groups are compared. Two groups train in a distributed fashion, one group trains in a massed fashion and the last group does not train at all *(Chapter 6)***.**

Are surgical residents willing to train endoscopic skills on a voluntary basis when VR simulators are indeed readily available and what is the effect of competitive incentives on the frequency and duration of simulator training?

Dutch surgical residents feel training endoscopic skills outside the OR is useful[26]. Unfortunately it appears that insufficient simulator access leads to minimal or no voluntary endoscopic skills training at all[27]. A study is carried out to test this amongst 21 surgical residents in training. *(Chapter 7).*

Will the "playstation-generation" become better endoscopic surgeon?

A frequently aired speculation is that the current "playstation-generation" would have superior baseline psychomotor skills. To date there is no conclusive evidence on a relationship between video game experience and superior psychomotor skills despite numerous studies on this subject [28-36]. A study to investigate the impact of experience in playing video games on the performance of basic endoscopic skills of the "playstation-generation" as well as of medical student interns, using a virtual reality simulator is conducted *(Chapter 8).*

Does the LapSim virtual reality simulator show face and construct validity in gynecology?

Gynecologists also perform endoscopic surgery on a routine basis. A validity study is designed for the LapSim® VR simulator in gynecology. It investigates face validity, e.g. the degree of resemblance between a concept instrument (simulator) and the actual construct (endoscopic procedure) and the construct validity (as described at chapter 3 and 4) *(Chapter 9)*.

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Submitted

Chapter 2

The status of training in endoscopic surgery for residents in the Netherlands

Abstract

Background

The purpose of this article is to outline the results of a nationwide survey among Dutch surgical residents on endoscopic training programs; in comparison to training programs actually available in the Netherlands. This inventory identifies existing gaps between current clinical practice and upcoming Dutch legislation in the area of minimally invasive surgical training.

Methods

A validated questionnaire on expectations of endoscopic training and the actual training programs was sent to all residents-in-training for general surgery. Expectations were compared to the available training programs. "Box plots" were used to measure equality of distribution.

Results

The questionnaire was sent to 456 surgical residents. The response rate was 47%; responses being equally distributed between teaching hospitals. Of respondents, 8.6% reported to participate in a structured endoscopic training curriculum. The majority of residents (89.9%) participating in a training program stated that this type of training was mandatory. Over 70 % of respondents would prefer to train over 20 hours per year, whereas only 30-40% actual did do so. A mere 24,8 % of the subjects have received training in handling the endoscopic equipment safely and properly. Almost all respondents expect to be able to perform basic endoscopic skills autonomously on completion of their surgical residency. However, only 18.2% of residents expect the current surgical training program to prepare them adequately for the autonomous performance of advanced endoscopic surgical procedures.

Conclusions

The need for a certified, well- endorsed endoscopic training curriculum as formally stressed by the Dutch Healthcare Inspection and the surgical teaching community is supported by residents. Residents indicate they require additional training hours for endoscopic surgery. Our results stress the need for implementation of uniform endoscopic training curricula with proper certification criteria. Endoscopic surgery should not be engaged upon by residents, prior to successfully completing this curriculum. In order for successful implementation, a culture shift in the surgical community and their teaching hospitals is required

Introduction

Endoscopic surgery is a widely accepted surgical approach for numerous operative procedures. The skills required to perform endoscopic surgery successfully and safely are markedly different from skills for open surgery[1,2,3]. The need for an endoscopic training curriculum has been formally stressed by the Dutch Healthcare Inspection, on basis of their report on safety in endoscopic surgery in The Netherlands[20]. In fact, it is stated that "untrained users of medical technology" are the key risk factor for "avoidable patient injury ". It is further recommended that implementation of potentially hazardous medical technology such as endoscopic surgery must be performed by individuals who are properly certified for the task.

The Dutch Society for Endoscopic surgery (NVEC) and the Working group for Endoscopic Surgery (WEC) of the Dutch Society for Surgery have developed a protocol with training goals and an outline of the certification process, about to be implemented[26].The purpose of this study was to register the expectations and needs of surgical residents on endoscopic training programs in teaching hospitals in the Netherlands; in comparison and contrast to actual training opportunities in endoscopic surgery offered to them.

Materials and Methods

Questionnaire

A previously validated questionnaire[4,17] was adapted to fit the context of the working environment of residents-in-training for surgery in the Netherlands. Each resident received an email with the questionnaire attached. Distribution of the questionnaire was approved by the Dutch Society for Endoscopic Surgery. Non-responders were sent reminder emails and attachments after 2, 4, 6, 8 and 10 weeks in order to maximize the response rate.

Scope of the questionnaire

General matters such as demographic information, years of training, presumed differentiation in surgery and future work perspectives were addressed. Furthermore, ambition in performing endoscopic surgery, and the specific endoscopic training programs offered in their residency training curriculum were addressed.

The classification of 'basic' and 'advanced laparoscopic procedures' is in accordance with the guidelines of the Society of American Gastrointestinal Endoscopic Surgeons (SAGES)[14]. Procedures other than the laparoscopic cholecystectomy, the diagnostic laparoscopy and the laparoscopic appendectomy were considered advanced endoscopic procedures[13].

Subjects

The questionnaire was sent to all residents-in-training for surgery who were registered as such in the Netherlands in 2008.

Statistical analysis

Data was collected and analyzed using the Statistical Package for the Social Sciences (SpSS) version 15.0 (SpSS, Chicago, IL, USA).

Results

Demographic background

A total of 88 subjects could not be reached by e-mail. This is to be considered random dropout; and therefore no threat to the interpretation of results. Of the returned questionnaires, four were deemed inappropriate for analysis, due to incomplete response. A total of 173 of the 364 (47%) questionnaires was analysed.
The average age of respondents was 31.7 years (range 26-37 years). Gender distribution was 60.8% male; 39.2 % female. Of respondents, 65.3% worked in a non-universitairy teaching hospital, 34.7% worked in an academic medical centre. The distribution according to year of training and the eight surgical training regions is shown **Figure 1 and 2** respectively. The distribution showed equal distribution when graphically depicted using box plots.

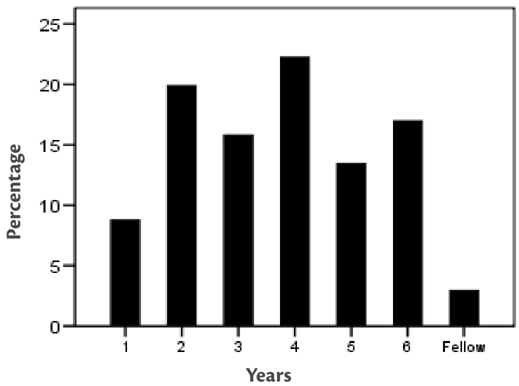

Figure 1 Distribution of respondents' year of surgical training

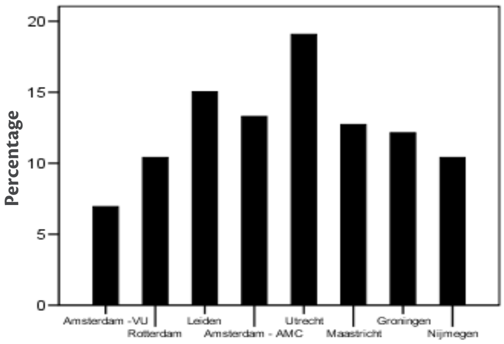

Figure 2 Distribution of respondents' surgical training region

The desired differentiation in future surgical subspecialty is shown in **Figure 3**.

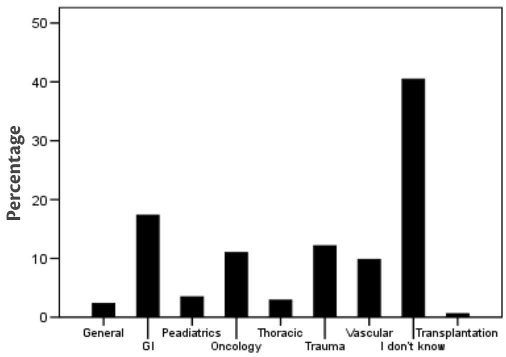

Figure 3 Respondents' desired differentiation in surgical subspecialty

Expectations on education and skills

Table 1 shows the results of the preferred number of hours versus actual hours trained in the first two years of surgical training.

A quarter (25.6%) of questioned residents state that one should be allowed to perform endoscopic surgery procedures as first operator in the operating theatre, without participating in an offered pre-clinical training program. In case of failing a certification exam, 9.4% of residents feel this should be no obstacle for them in performing endoscopic surgery.

Of the residents, 86.5% state it is the duty of the Dutch Association of Surgeons (NvvH) to offer a structured and objective training program. All participants reply it is important to very important to be able to perform basic endoscopic skills by the end of the surgical residency.

Table 1				
Hours trained	**preferred 1st year**	**actual 1st year**	**preferred 2nd year**	**actual 2nd year**
0	14.3 %	25%	4.2%	11%
0-5	4.8%	5.2%	1.6%	13.4%
5-10	30.4%	15.7%	5.7 %	26.7%
10-20	15.5%	18.6%	17.2 %	19.8%
> 20	58.2%	35.5%	71.3%	29.1%

Current status of endoscopic skills training within the surgical training curriculum

Nearly all (89.9 %) of the subjects stated that their presence at an endoscopic basic surgical skills course was mandatory, however, consequences on a 'no-show' for those courses are not known nor mentioned by residents.

Currently, 78.6% of the questioned residents state that such a structured endoscopic surgery skills training are embedded in their surgical training curriculum.

Less than half of the research population (47.9%) indicated there were certain criteria to be met during their training. In case criteria were to be met, the actual results were checked in 79.5% of the residents prior to participating in endoscopic procedures in the operating theatre.

Nowadays, still nearly one third (30.1%) of residents state not to have had any endoscopic surgery skills training prior to participating in endoscopic procedures in the operating theatre.

Furthermore, less than a quarter (24.8 %) of the subjects state to have received adequate instruction on safe use of endoscopic instruments, equipment and operating environment.

Over seventy percent (70.8%) of participants have been trained using a box trainer with inanimate materials. Other training modalities, e.g. a box trainer with an ex vivo organic specimen, a live animal and VR-training settings for endoscopic training are mentioned equally (50.5%, 47.7 %, 46.7 % respectively).

When looking at the interest in autonomous performance of endoscopic surgery, 88.5% of the responders indicate to be (highly) interested.

Nearly all respondents expect to be able to perform basic procedures autonomously by the completion of their surgical residency (99.4% laparoscopic appendectomy, 100% laparoscopic cholecystectomy and 99.4% diagnostic laparoscopy).

In contrast, for the autonomous performance of advanced endoscopic surgical procedures, only one-fifth (18.2%) of residents expect the current surgical training program to prepare them sufficiently.

Discussion

Although a response rate of 47% is not very high, respondents are evenly distributed across parameters 'year of training' and 'region of training'. Therefore, this cohort is presumed to be a very representative sample (in fact, being half of the total population) of surgical residents in the Netherlands. The response rate is slightly lower than in previous surveys held by Schijven et al (65%)[17] in The Netherlands and Chiasson et al (60%)[4] in Canada; but far higher than those of Rattner et al (8.6%)[11] in the US.

Resulting from our study, over 25% of residents boldly state that one should be permitted to perform endoscopic surgery in the operating room, *despite* being absent from the offered courses. One out of ten feels confident enough to perform procedures even having shown to be incompetent in a testing environment. Perhaps one should look first at what is being offered, for at the moment, half of the courses are not designed well in educational terms, as end points and competency testing. Starting end of the nineties (and revised in 2005) the Royal College of Physicians and Surgeons of Canada have identified the so-called core competencies; which are generic to all specialists in order to meet the needs of society[28,29]. The result was the CanMEDS framework. The seven CanMEDS Roles or thematic groups of competencies, as defined by the framework and have since obtained growing international acceptance in medical education. Since January 2010, the first year residents in the Netherlands are trained following a structured and well defined plan, partly based on these seven competencies ("plan SCHERP")[27, 28, 29]. Within "plan SCHERP" knowledge, skills and professional behavior of surgical residents is monitored by regulated OSATS measurements; short clinical observations and 360 degree feedback forms next to actual operative volume.

It is promising that nearly all residents in fact agree on mandatory certification. Nevertheless one tenth state that failing a certification exam should not prevent the resident from performing endoscopic surgery. A reason behind this may be a high confidence level in the teaching surgeon during endoscopic surgery. On the other hand it could be explained by overestimating their own capabilities, a known problem in surgery[1].

Nearly all residents consider offering a structured and objective training program is the responsibility of educators.

Although about 80 % of subjects have been offered skills training residents do prefer an increase in length of training (> 20 hours a year).

The authors are concerned by the fact that only a quarter of the surgical resident population have received adequate education on proper use of instruments, equipment and operating environment. Verdaasdonk et all have shown that in 30 procedures registered, 87% of the procedures experienced problems with endoscopic equipment[22]. Therefore training programs should focus on use and understanding of the equipment. Unfortunately, not much has changed in five years[17].

Despite 90% of our respondents indicating training should be prerequisite, one-third of all residents state to have performed endoscopic surgery prior to participating in any skills training program. Integration of mandatory training appears already widespread. However, it is not. A universal training program for basic endoscopic surgery, built on sound educational standards and competency testing, is still to be integrated and enforced into the surgical training curriculum. Apparently surgeons still happily allow residents to perform endoscopic surgery, without having participated in such a training program. A culture change in teaching hospitals is required ánd mandated to overcome this situation. The fact that less than half of the residents stated that there were certain criteria to be met during the training reinforces this issue. The survey by Schijven et. al.[19] amongst general and orthopaedic surgeons, urologists and gynaecologists in The Netherlands shows that of the general surgeons questioned 100% think these criteria ought to be met. However, one-fifth (20%) of residents surveyed state that they indeed had to meet certain objective criteria, but were not checked if they really did do so.

It is promising that residents do expect to be able to perform basic endoscopic surgical procedures autonomously on completion of their surgical training. These numbers are higher than those reported by Schijven et. al[17] in 2004 and Chiasson et al[4]; (99% versus 88.5% and 92% respectively). This may be indicative for a shift in attention for training in endoscopic surgery for the better in recent years. Another explanation could be the higher number of young staff surgeons able to perform procedure such as the appendectomy and cholecystectomy laparoscopically, and thus to teach the procedure in the OR.

Only 18.2% of residents-in-training believe current training to be sufficient for the performance of the advanced endoscopic surgical procedures. This problem was already highlighted by Schijven et al and Chiasson[17,4] (18% for both), and proved to be an international problem[11]. Rattner et al[11] found that residents did not perform sufficient advanced endoscopic surgical procedures to feel confident when becoming a certified surgeon and 47% of their respondents felt additional training would be required. Our study shows that Dutch surgical residents-in-training are highly interested in the autonomous performance of endoscopic surgical procedures; in contrast, to date no educational training scenarios outside the operating theatre exist.

Future perspectives

The implementation of “plan SCHERP” may accelerate the process of educational project in endoscopic surgery. Unfortunately certified endoscopic training curricula are not described in “plan SCHERP” as of yet.

The authors believe that procedural virtual reality training, measuring integrative outcome parameters beyond outcome parameters as “time” and “pathlength” would provide the opportunity to objectively test and re-test multiple competencies needed to perform endoscopic surgery safely .

Conclusion

The need for a certified, well- endorsed endoscopic training curriculum as formally stressed by the Dutch Healthcare Inspection[20] and the surgical teaching community [2,3] is supported by the residents. Residents indicate they need additional hours to train. Results show there is ample reason to implement uniform endoscopic training curricula for the basic endoscopic procedures such as the laparoscopic appendectomy, laparoscopic cholecystectomy and diagnostic laparoscopy. Training scenarios for the much demanded higher-end endoscopic procedures are lacking to date. Endoscopic surgery should not to be allowed prior to successfully completing a certified, objective training program. In order to implement these curricula a culture shift in the teaching hospitals needs to be overcome urgently.

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Chapter 3

Construct validity of the LapSim

Can the LapSim virtual reality simulator distinguish between novices and experts?

Abstract

Background

Virtual reality simulators may be of invaluable assistance in training and assessing future endoscopic surgeons. The purpose of this study was to investigate if the results of a training session reflect the actual skill of this trainee who is being assessed and thereby establish construct validity for the LapSim virtual reality simulator (Surgical Science Ltd., Gothenburg, Sweden).

Methods

Forty-eight subjects were assigned to one of three groups; 16 novices (0 endoscopic procedures), 16 surgical residents in training (>10, <100 endoscopic procedures) and 16 experienced endoscopic surgeons (>100 endoscopic procedures). Performance was measured by a relative scoring system which combines single parameters measured by the computer.

Results

The higher the level of endoscopic experience of a participant, the higher the score. Experienced surgeons and surgical residents in training showed statistically significant higher scores than novices for both overall score, as well as for efficiency, speed and precision parameters.

Conclusions

Our results show that performance on the various tasks on the simulator corresponds to the respective level of endoscopic experience in our research population. This study demonstrates construct validity for the LapSim virtual reality simulator. It thus measures relevant skills and can be integrated in an endoscopic training and assessment program.

Introduction

The technological revolution of endoscopic surgery has posed new challenges in surgical education. Particularly since the skill set required for endoscopic surgery is different from the skill set required for traditional 'open' surgery, because of the different operating environment. Endoscopic surgery requires 3-D orientation in a 2-D representation of the operating scene, as well as endoscopic instrument handling [5,8,9]. Although endoscopic skills can be developed in the operating room successfully, it may not be the most appropriate or efficient environment to acquire such skills, given the steep learning curve that surgeons go through[1,7,11,12]. Furthermore, financial and ethical issues, as well as limited residential work hours impose a need to provide technical skill training in laboratory setting.

For the purpose of developing endoscopic skills virtual reality simulators have been developed. A unique advantage of VR simulators is that they are both a training tool and an assessment device. During training objective measurements of performance are registered by the VR simulator and stored in its database. The database, in turn, provides the trainer or assessor with factual information on trainee performance status, without the need of being physically present.

Prior to simulator implementation in the surgical curriculum, systematic objective validation is required. The first step in objective validation is establishing "face validity". Face validity is the degree of resemblance between the concept instrument, the VR simulator, and the actual construct, psychomotor training, as perceived by a specific (target) population (surgeons and trainees)[2,14]. Face validity is established by measuring the degree to which surgeons and trainees believe in the purpose and merits of the simulation environment. After having established face validity for the simulator, the simulator must be tested for its "construct validity", the degree to which the results of the "training session" as carried out by the trainee on the simulator, reflects the actual skill of the trainee who is being assessed[2,14].

The notion of including virtual reality training into the surgical curriculum has only recently been suggested and therefore validation testing for simulation concepts is a very recent development[3,4,6,10,13-17]. For the LapSim virtual reality simulator (Surgical Science Ltd, Göteburg, Sweden), construct validity has been tested in three separate studies, with different methodology and results[3,4,16].

The purpose of this study therefore was to establish construct validity for the LapSim virtual reality simulator (Surgical Science Ltd., Gothenburg, Sweden).

Materials and methods

Participants

Forty-eight participants participated in this study. Each participant was assigned to one of three groups, subject to their level of experience in endoscopic surgery. Group one consisted of 16 student interns lacking any form of endoscopic surgical experience. Group two consisted of 16 surgical residents in training that carried out more than ten but less than 100 endoscopic procedures. Group 3 consisted of 16 experienced endoscopic surgeons (having carried out over 100 procedures).
None of the participants has had any prior experience with the virtual reality simulator.

Apparatus and tasks

The LapSim virtual reality simulator uses the Virtual Laparoscopic Interface (VLI) hardware, (Immersion Inc., San Jose, CA, USA) which includes a jig with two endoscopic handles. The VLI has an interface with a 2600 MHz hyperthreading processor Pentium IV computer running Windows XP and is equipped with 256 RAM, a GeForce graphics card and a 18-inch TFT monitor.
The system features LapSim Basic Skills 2.5 software (Surgical Science Ltd, Göteburg, Sweden), from the LapSim Basic Skills package, consisting of 8 tasks. The knot tying task, in our opinion, does not represents the actual procedure. Therefore only the following seven tasks were selected and object of research; camera navigation, instrument navigation, coordination, grasping, lifting and grasping, cutting and clipping and cutting.

Tasks

A description of each of the selected tasks as well as the test by which the skill of the participants was assessed is defined below. In addition, the parameters measured and registered from each training session are described as indicative of the participant's skill in a particular task.
The ability of a participant to successfully execute the selected tasks within a reasonable time frame whilst causing as little tissue damage as possible was measured as the total number of events causing damage (#) and maximum depth of damage (mm).
The camera navigation module's purpose is to train the navigation of a scopic camera by finding and focussing on a number of balls appearing at random in a virtual environment. The size and number of balls, the time and pattern of appearance can be varied. In addition the camera angle (30°), field-of-view and zoom size can be adjusted. Parameters measured are time, misses, drift, trajectory and angular path of the camera and tissue damage (total times and maximum depth).

The instrument navigation module's objective is to accustom to manoeuvring and positioning endoscopic instruments. A number of balls appear in the virtual environment and has to be touched by two endoscopic instruments (one controlled with the right and one with the left hand). Again number and size of the balls, time and pattern of appearance can be varied. Camera position can be rotated and put into motion. Assessed parameters are left and right instrument time, misses, path length and angular path and tissue damage (total times and maximum depth).

The co-ordination module combines the instrument and camera navigation modules and consequently mimics the situation in a diagnostic laparoscopy. One hand holds the camera, the other holds an instrument. Virtual balls appear randomly and have to be found by the camera, picked up with the instrument and delivered in a target area. The difficulty can be varied conform the instrument and camera navigation module.

Grasping is the module that teaches to grasp, position and navigate an object using a grasper. An appendix shaped object has to be grasped, stretched until it releases and positioned into a target area, alternating the right and left instrument. Object number, size, timeout and placement can be changed. The target size is variable as well. Camera options can be varied according to the instrument navigation module.

Parameters are the same as in the co-ordination module.

The lifting and grasping module aims at training bi-manual handling. While lifting a box shaped object an underlying needle has to be grasped and moved to a target area. Camera, object and target configuration can be varied again as in the other modules. Parameters are the same as described for instrument navigation.

The cutting module focuses on grasping and handling an object with care and cutting it using ultrasonic scissors. After grasping and stretching a vessel, which will be torn off and haemorrhage if not handled with care, a coloured area appears on the vessel. This has to be grasped and burned using a foot pedal. The excised segment then has to be moved to a target area. Number, size and timeout of the segments and stretch sensitivity of the vessel can be adjusted. Rip and drop failure are 2 additional parameters measured as compared to the aforementioned modules.

Training

Three programs were designed with increasing level of difficulty; 'beginner', 'intermediate and 'advanced'. The easiest level was the manufacturer's default settings. The configuration of the adjustable options in the advanced level are challenging even for experienced endoscopic surgeons (>100 endoscopic procedures). Objects are smaller, have time restraints, and camera view can be unstable or based on a 30 degree view. The adjustable options of the intermediate level were configured between the configuration of the beginner and of the advanced level. After one familiarization run, which includes all of the selected tasks on all three levels, to get acquainted with the software, the actual formal training session was started. The participants started with the easiest task and ended with the most challenging task.

Assessment

There were 178 different parameters measured in total, as discussed in the material and methods section. For each of the 178 parameters, the participants were ranked by score. The scores on these different parameters were stored per participant. A ranking for all parameters was conducted by classifying the scores of individual trainees in the top 25% (first quartile), the mean 50% (second and third quartile) or the bottom 25% (fourth quartile) If the score of a participant ranked in the first quartile, he or she was awarded 2 points, if the participant score ranked in the second and third quartile, he or she was awarded 1 point. The participant did not receive any points for ending in the fourth quartile. Consequently, the maximum score any participant could achieve was 356 points (2 times 178).
The parameters were clustered into three categories (**Table 1**): speed, efficiency of instrument handling and precision/accuracy.

Table 1 Parameters per group

Speed	Efficiency	Precision
Time (s)	Path (m)	Tissue damage (n)
(instrument) misses (%)	Angular path (°)	Maximum damage (mm)
		Stretch damage (%)
		Incomplete areas (n)
		Bad clips (n)
		Dropped clips (n)
		Blood loss (l)

Evaluation

All training tasks were evaluated for each level of difficulty (beginner, intermediate, advanced). All training tasks were evaluated for their respective level of difficulty. Data analysis was done using SPSS, version 12.0. The one-way analysis of variance (ANOVA) with Post Hoc test Tukey-Bonferroni was used to determine differences in mean scores between the three groups, where a p value ≤ 0.05 was considered statistically significant.

Results

In general, the higher the level of endoscopic experience of a participant, the higher the score.

The differences between the groups are demonstrated at all three levels (beginner, intermediate and advanced). At the advanced level the scores are most explicit and are therefore set out below.

Experienced surgeons (group 3) and surgical residents in training (group 2) showed statistically significant higher scores ($p \leq 0.00$, $p \leq 0.00$) than novices (group 1) (**Figure 1**), although the differences between the residents and the surgeons were not statistically significant. ($p \leq 0.13$) Nevertheless, a trend in favour of group 3 was demonstrated.

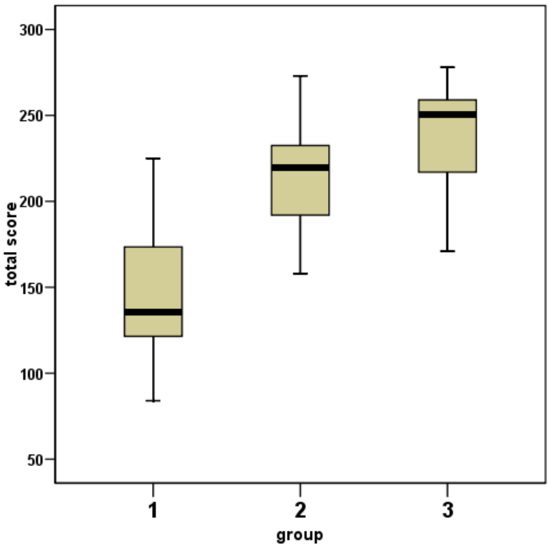

Figure 1 Boxplot of total score by the three groups

The scores for efficiency, speed and precision (**Figure 2**, **3 and 4**) are consistent with the overall score. Surgeons and residents demonstrate a higher score for parameters of efficiency ($p \leq 0.000$, $p \leq 0.000$), speed ($p \leq 0.000$, $p \leq 0.000$) and precision ($p \leq 0.000$, $p \leq 0.010$) than the inexperienced novices. The surgeons achieve higher scores than residents for all three parameters, although not statistically significant (efficiency; $p \leq 0.295$, speed; $p \leq 0.396$, precision; $p \leq 0.275$).

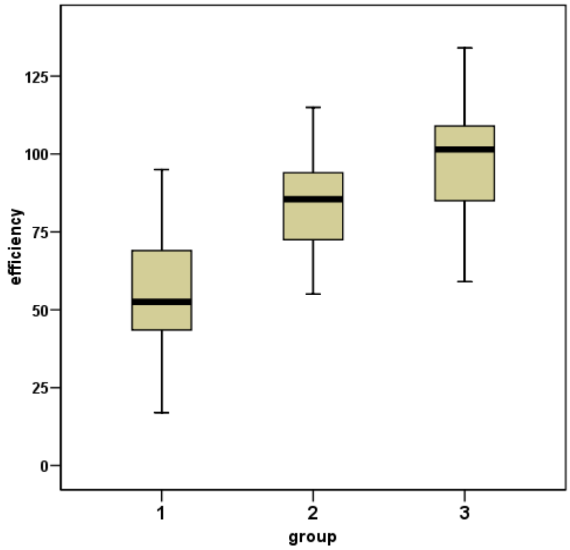

Figure 2 Boxplot of efficiency score by the three groups

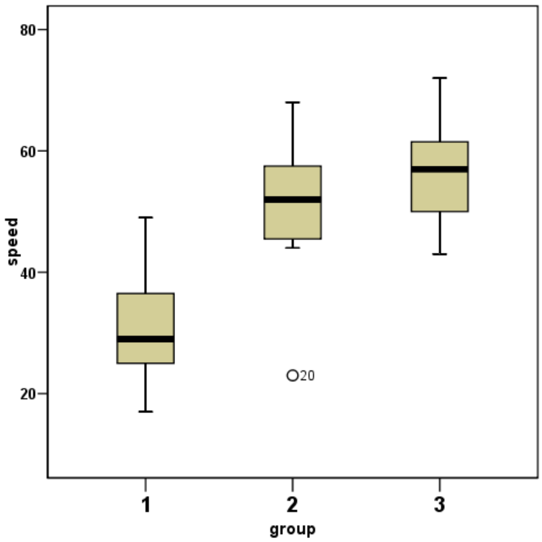

Figure 3 Boxplot of score for speed by the three groups

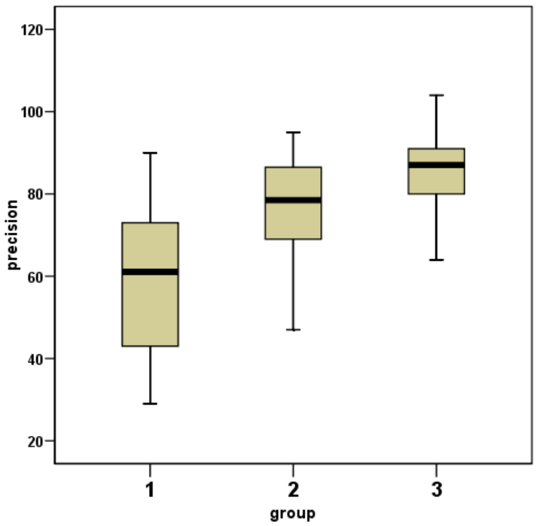

Figure 4 Boxplot of precision score by the three groups

The standard deviation of almost all the scores is lowest in the group of surgeons, indicative of a smaller variability in outcome between participants in group 3 or a consistent experience level (**Table 2**).

Table 2 Means. N = number of participants; SD = standard deviation

Group	N	Speed		Efficiency		Precision		Total	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	16	30.,4	9,04	55,31	20,72	60,75	18,55	147.81	40,99
2	16	51,56	10,37	85	17,15	76,63	13,98	214.63	30,09
3	16	56,63	8,51	96,5	19,77	85,44	9,4	239.56	29,53
Total	48	46,38	14,48	78,94	25,75	74,27	17,52	200,67	51,34

Discussion

This study demonstrates that the LapSim virtual reality simulator discriminates between participants of different endoscopic surgical experience, although the study has not tested the full range of skills and knowledge required to perform all varieties of endoscopic surgery. Specific objective end-parameters (**Table 1**) that measure psychomotor skills were chosen as an indicator for estimating actual endoscopic performance.

Establishing construct validity reflects the degree of empirical foundation of a concept instrument, e.g. the simulator[2,14]. In practise, this is often established by measuring a logical difference in outcome between research populations with different levels of experience on a specific task of interest. Multiple studies have been conducted to validate different virtual reality systems as tools for training endoscopic surgery skills [3,4,6,10,13-17]. These studies demonstrated construct validity for these systems. With regard to the relatively new LapSim virtual reality simulator, construct validity was investigated in three independent and separate studies[3,4,16].

Eriksen *et al*[4] compared only two groups of surgeons. Group 1 (>100 procedures, N=10) and inexperienced (<10 procedures N=14). Both groups performed all seven basic skills at an intermediate level, where the settings were configured to be challenging for an intermediate experienced endoscopic surgeon (>30, <50 procedures). The parameters were analysed separately. Time and efficiency parameters demonstrated statistically significant differences for all tasks. No statistically significant difference could be demonstrated for several of the error scores, in contrast to the present study. Residents and experts gained statistically significant higher scores for the combined error scores. The authors suggest either small study size or poorly defined difficulty configurations to cause these parameters to be non-valid measures for surgical performance. These parameters could have been statistically significant if they would have been combined into a similar relative scoring system as designed in the present study, or if linked to time for completion, as demonstrated by the "time–error" score of Sherman *et al*[16].

Sherman *et al*[16] have demonstrated construct validity based on formulas calculating a 'time-error' score and a 'motion' score. A total of 24 participants, in three groups (seven naïve participants with no endoscopic surgical experience, 10 juniors with experience in < 25 endoscopic procedures and seven experts with experience in > 50 endoscopic procedures) completed a training session of three tasks with increasing difficulty. The tasks were "grasping", "cutting" and "clip applying" The authors argue that time is not the exclusive indicator for a correct completion of a task. Consequently, they used "time-error" scores, which takes both the time to complete a task and task-specific penalties into consideration. The results demonstrated statistically significant differences between the groups of participants for both scores. The task-specific scores as constructed by Sherman *et al*[16] are similar to our precision scores. In our study, the standard deviation of the parameter 'precision' shows the largest variability between the groups, e.g. novices to experts (18.5 versus 9.5). Experts therefore appear to be more consistent in their performance than novices. Our results support the statement that accuracy is a concept that might not be addressed enough by the standard outcome parameters that are generated by the simulator. The parameter 'speed' is both easy to measure and, in general, appealing to participants. Participants tend to prefer fast completion of a task over accuracy.

A time-error score appears to be an improvement in assessing performance as compared to the standard manufacturers' end-parameters.

The 54 participants in the study by Duffy *et al*[3], executed basic skills tasks, with criteria based on manufacturer recommended settings for individual exercises. There was no scoring system used, consequently the parameters were analysed separately. Three groups of participants, junior residents (novices), senior residents (intermediates) and experts (surgeons) were compared. Only a few parameters measured could discriminate between novices and experts.

The lack of a comprehensive scoring system, as designed for our study, limits possibilities to demonstrate differences in performance between novices and residents. The most complex task (suturing) showed the most pronounced discrimination. A time-based analysis for task completion discriminated statistically significant between novices and intermediates, as well as between intermediates and experts. The authors conclude that their study demonstrates construct validity.

In our study, the implementation of a scoring system enabled us to further assess the aspects of performance. Results demonstrate the importance of combining the different parameters. The assessment parameters of the simulator can be set according to individual preferences, therewith providing opportunities to adjust for desired combinations or outcome parameters.

Coalescence of parameters seems a useful benefit for a reliable assessment of psychomotor skills. A combined scoring system, set by experts, enables the creation of performance benchmarks that must be achieved by residents to achieve a predefined accreditation level.

Our results demonstrate that the registered performance scores show statistically significant differences between experts/residents and novices. Therewith, in concordance to earlier studies[3,4,16], our study proves construct validity for the LapSim VR simulator. The LapSim psychomotor VR trainer can therefore be regarded upon as further established, and therefore, firmer empirically grounded.

To measure overall simulator performance based on these parameters, a relative scoring systems was designed. This scoring system classifies participants' performance on each of the measured parameters in percentiles and therewith relative to the overall research population. Because of the different measurement units of the parameters (seconds, millimetres, degrees etc.) an over-all scoring system is required to enable related parameters to be combined into one end score.

Limitations of the Study

It must be stated that all three aforementioned studies, as well as our study lack a power calculation for the group size. In retrospect, based on the results of time-scores in the study of Duffy et all [3], with a power of 0.8 and alpha set at 0.005 , the group size should have been 17 instead of the chosen 16 persons per group.

Conclusion

This study demonstrates contruct validity for the LapSim virtual reality simulator (Surgical Science Ltd., Gothenburg, Sweden). Our results show that performance on the various tasks on the simulator indeed corresponds to the respective level of endoscopic experience in our research population. Provided the other validation steps that need to be taken to complete the simulators validation process are favourable, the LapSim VR simulator may be of invaluable assistance in training future endoscopic surgeons.

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Submitted

Chapter 4

The impact of surgical experience on the learning curve of endoscopic skills acquired in a basic virtual reality simulator

Abstract

Background

Training basic psychomotor skills for minimal invasive surgery is shifting from operating theatres to skills laboratories. Virtual reality simulator are introduced to train and assess basic skills for endoscopic surgery. These results can be depicted in a learning curve. This study is undertaken to analyse the effectiveness of a VR simulator to discriminate novice and experts by comparing the learning curve. Secondly, we would like to assess the number of repetitions needed for a novice to reach expert levels.

Methods

Forty participants were divided into two groups according to their experience in endoscopic surgery. All subjects participated in 5 training sessions on the VR simulator. In every session seven tasks were performed at three different levels (beginner, intermediate, advanced). In total all participants performed 15 repetitions. The increase of scores and the speed of the learning process were analysed for total score, speed, efficiency and precision.

Results

The learning curve of the novices is significantly steeper The same is shown for the scores of speed and efficiency. The sores on precision do not show any difference in learning rate. After 15 repetitions the final score of novices does not reach the expert baseline score.

Conclusion

The difference in overall learning gradients between expert and novice endoscopic surgeons proofs the virtual reality simulator is both a valuable training and assessment tool. In this study, 15 repetitions as performed by novices were not enough to reach the levels of the expert group. A professional training program should preferably contain reference points (end-scores) based on expert scores, to be able to establish proficiency based training programs instead of training curricula based on a fixed number of repetitions.

Introduction

Training basic psychomotor skills for minimal invasive surgery is shifting from operating theatres to skills laboratories due to concerns on patient safety, a shortened training curriculum and cost-effectiveness[1-4]. Training these technical skills by standardized repetition in the operating room has shown to improve overall performance[5-10]. After an initially rapid improvement, training results tend to plateau to a stable outcome performance. This is graphically depicted as a steep performance line (initial learning phase) defined by a curve-specific asymptote; after which a 'plateau phase' occurs. Such a performance line is usually called a learning curve[11]. Learning curves have shown to be longer for endoscopic surgery, as compared to open surgery[12-14]. Thus, endoscopic skills need to be acquired by dedicated training programs. For this purpose virtual reality (V.R.) simulators are developed, which not only train these skills, but also measure parameters that may be used to assess the level-of-skill of a surgeon (in training)[15;16]. Due to the possibility of measuring outcome parameters, the learning curve for these psychomotor skills can be monitored objectively.
Several studies have shown "construct validity", which is the degree to which the results of the "training session" as carried out by the trainee on the simulator, reflects the actual skill of the trainee who is being assessed[5;16-21]. Construct validity refers to the concept that a novelty actually mimics what it intends to mimic, by direct or indirect objective standards. It is satisfied when test performance is logical and consistent with parameters of interest. Fundamentally, it is concerned with explaining individual differences in scores among subjects by relating the various outcomes with anticipated ones. A valid system should be able to differentiate between different levels of skill[20;22] This study is undertaken to analyse the effectiveness of a basic virtual reality simulator to discriminate novice and experts by comparing the learning curve for basic endoscopic skills for subjects with different endoscopic surgical experience; as measured by the simulator's outcome parameters (speed, efficiency and precision). It is expected that, in time, experts will reach their plateau phase earlier when compared to novices. Secondly, we would like to assess the number of repetitions needed for a novice to reach expert levels.

Materials and methods

Participants

Forty participants were included in the study and divided into 2 groups according to their experience in endoscopic surgery. Group one consisted of 20 novices (no surgical endoscopic experience) and group two consisted of 20 experts (> 100 endoscopic procedures). None of the participants has had any prior experience with a virtual reality simulator.

Apparatus, tasks and training

The simulator of study was the LapSim virtual reality surgical simulator, featuring LapSim Basic Skills 2.5 software (Surgical Science Ltd, Göteburg, Sweden). The following seven tasks (as described by van Dongen et al) were selected and object of research; camera navigation, instrument navigation, coordination, grasping, lifting and grasping, cutting and clipping and cutting[21].

All subjects participated in 5 training sessions. In every session all seven tasks were performed at three different levels (beginner, intermediate, advanced). The sessions were completed at 5 different occasions with one session every week. Therefore in total all participants performed 15 repetitions.

Assessment

Scores are derived from the 178 measured parameters which were categorized, based on the quartile scores of 48 subjects of a prior study (as described by van Dongen et al)[21]. In the above mentioned study a ranking on all parameters was conducted by classifying the scores of individual trainees in a top, middle or bottom group, awarding respectively two, one or no points.

These parameters were clustered into three categories (**Table 1**): speed, efficiency of instrument handling and precision/accuracy.

The total score, as well as scores for efficiency of movement, precision of instrument handling and speed were analyzed to assess the learning curve. All training tasks were

Table 1 Parameters per group

Speed	Efficiency	Precision
Time (s)	Path (m)	Tissue damage (n)
(instrument) misses (%)	Angular path (°)	Maximum damage (mm)
		Stretch damage (%)
		Incomplete areas (n)
		Bad clips (n)
		Dropped clips (n)
		Blood loss (l)

evaluated at the advanced level. Therefore the figures show the scores at session one until session five, which depict repetition three, six, nine, twelve and fifteen .

Evaluation

Data analysis was done using SPSS, version 15.0. The increase of scores and the speed of the learning process were analysed for the different groups using a Mann-Witney non-parametric test, whereas a *p*-value ≤ 0.05 was considered to be statistically significant.

Results

After a first familiarization session, all participants showed a steep learning curve between session one and two, with a comparable increase gradient of 5 for group one (novices) and 5,05 for group two (experts (p=0.636) **Figure 1**).
The scores for experienced surgeons (from 77 to 87) demonstrate a slight increase during the following sessions. With 18 points (from 37 to 55) the scores of the novices shows a bigger inclination. Their final score does not even reach the expert baseline score of the second session (**Figure 1**).

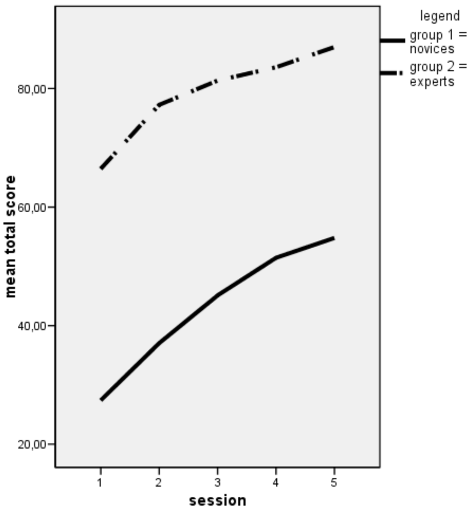

Figure 1 Mean total scores

The same figures are shown for the speed and efficiency parameters (**Figure 2 and 3**). However, the scores for precision show a comparable increase for the 2 groups during all the sessions (**Figure 4**).

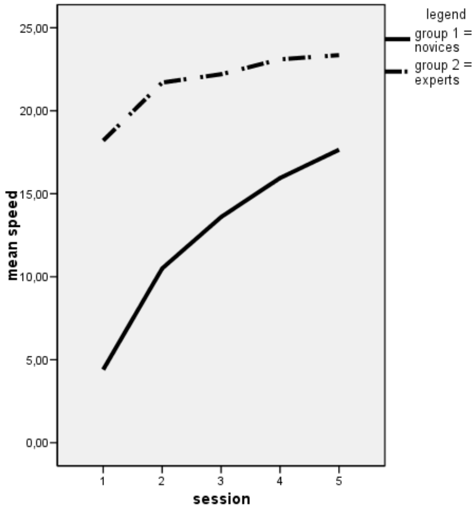

Figure 2 Mean speed scores

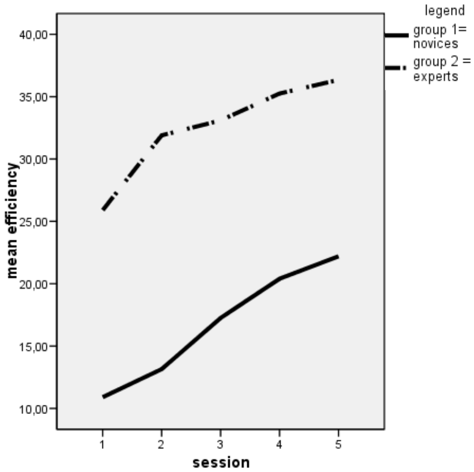

Figure 3 Mean efficiency scores

Learning curves

When focussing on their learning curves the overall learning gradient of the experts (1.55) is smooth from the second session onwards. The learning curve of the novices is with an inclination of 4 significantly steeper (p=0.036) (**Figure 1**).
These same figures are shown for the scores of speed and efficiency (p= 0.000 and p=0,021 respectively) (**Figure 2 and 3**).
When focussing on precision both groups show comparable inclination in scores and therefore do not show any difference in learning rate (p=0.3) (**Figure 4**).

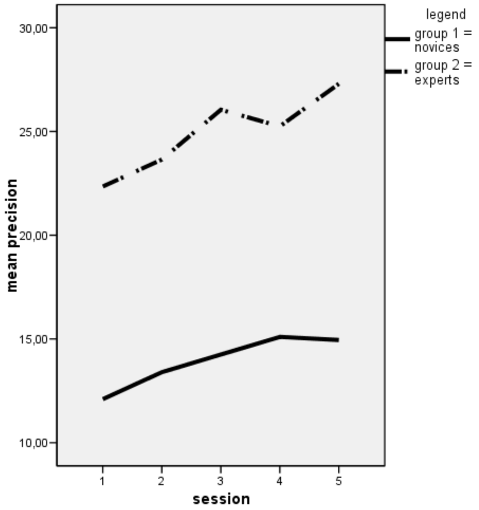

Figure 4 Mean precision

Discussion

The goal of this study was to analyse the effectiveness of a basic virtual reality simulator to discriminate novices and expert endoscopic surgeons by comparing their learning curves for basic endoscopic skills.

Overall, novices showed a much steeper learning curve for basic endoscopic surgical skills.

The comparable increase gradient during the first session demonstrates the fact that, regardless of experience level, all groups have to familiarize with the simulator and simulation setting alike.

Figure 2 demonstrates the learning curve for the endparameter 'Speed'. These curves show a significant higher learning gradient for novices compared to experts (p=0.000). Earlier studies on the MIST-VR as well as on the LapSim have shown comparable results[16;23;24].

The results of the end parameter 'Efficiency' (**Figure 3**) also show better scores for experts, with an significantly steeper learning gradient for novices (p=0.021). These results are in accordance with the results of Sherman et al investigated three tasks of the LapSim only and found significant difference between novices and experts on efficiency of motion at baseline. At iteration 2 and 3, scores for efficiency reached plateau already for both novices and experts, although novices scores did not reach expert scores.

Figure 4 indicates the results of the end parameters "Precision". As observed here also, experts score better than novices. More notable is the fact that the experts have an unstable learning curve, whereas the residents' learning rate is flat. No significant difference is shown between both learning curves. These results demonstrate that in this training model, a plateau phase is observed for the outcome parameter of 'Speed' early, while still improving on the outcome parameter 'Efficiency'. Novices seem to focus on speed in particular. To avoid misinterpretation because of this problem , Sherman et al introduced an outcome parameter 'time related error score', thereby wisely shifting the attention to performance where errors are measured relating them to speed of the performance[23]. Authors think it is advisable in the future to also adjust the outcome parameters in order to relate outcome parameters of 'Speed' to 'error' related outcome parameters.

Gallagher et al show that novices may perform as good as experts after 10 trials, apart from the outcome parameters 'diathermy usage' and 'error'[24]. Both our studies show that more emphasize on error related scores is important during the training progress. Both tutors of surgical curriculum and software engineers of virtual reality simulators should be aware of this, when using and / or manufacturing simulator software. In authors opinion, the definition of what an error is, must be more than 'what a software engineer can easily measure'. It should be a reflection of a decisive key-element; especially when engaging into the more procedural simulation environment.

Much controversy exists on the duration of learning curves in a virtual reality for training endoscopic basic psychomotor skills. In our study, all subjects completed 15 repetitions. This number of repetitions proved to be insufficient for novices to be able to reach expert scores. Previous work with the MIST-VR virtual reality simulator has shown between 2 to10 repetitions are needed for novices to reach expert levels[3;16]. Brunner et al have shown continuing learning curves up to 30 repetitions[25]. These were not compared to expert end-scores and are therefore of less importance. Hogle et al do show a plateau phase after 8 repetitions[26]. They compare single parameters only. The misses and damage parameters achieve a plateau, where the time parameters do not. Again, the combination of both is more important than each parameter separately. This is reflected in our study by the parameter 'total score'; which is indeed least susceptible to random error. A surgeon should be safe and improve in time related parameters. Andreatta et al identified almost no learning curve at all on the LapMentor, regardless the endoscopic experience of the subjects[27]. The authors conclude correctly that this is probably due to a mismatch between parameters measured and the true level of ability in this specific trainer. Therefore the used parameters do not reflect specific endoscopic psychomotor skills. Schijven et al as wel as Grantcharov et al demonstrated four distinct groups of performance profiles to exist[11;28]. One group with a high level of innate abilities, group 2 with a moderate level of innate abilities, gaining improvement and stability trough VR training, group 3 with a moderate level of innate abilities, not gaining improvement through VR training and last group 4 with a low level of innate abilities, also not gaining improvement through VR training.

A wide range of individual performance implies that a fixed number of repetitions will not be sufficient for all trainees and therefore inappropriate. A training curriculum should instead been based on proficiency, which is appropriate level of performance. Trainees with a high level of innate abilities will not have to unnecessarily spent time on training psychomotor skills and extra sessions can be scheduled for those who are indeed in need of it. Hereby enhancing the efficiency of skills training.

In conclusion, the difference in overall learning gradients between expert and novice endoscopic surgeons shows the ability of a basic virtual reality simulator to discriminate between level of experience with laparoscopic surgery. Therefore, it is both a valuable training tool as a potential powerful assessment. In this study, 15 repetitions as performed by novices were not enough to reach the levels of the expert group; and experts were unable to reach to a steady plateau within these 15 repetitions. A professional training program should therefore contain reference points (end-scores) based on expert scores, to be able to establish proficiency based training programs instead of training curricula based on a fixed number of repetitions.

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Chapter 5

European consensus on a competency-based virtual reality training program for basic endoscopic surgical psychomotor skills

Abstract

Background

Virtual reality simulators have demonstrated to improve basic psychomotor skills in endoscopic surgery. The exercise configuration settings used for validation in studies published so far are either default settings, or are based on personal choice of the tutors. The purpose of this study was to establish consensus on exercise configurations and on a validated training program for a VR simulator, based on experience of international experts in order to set criterion levels to construct a proficiency based training program.

Methods

A consensus meeting with eight European teams, all extensively experienced in using the VR simulator was organized. Construct validity of the training program was tested by 20 experts and 60 novices. The data were analysed using the t-test for equality of means.

Results

Consensus was achieved on training designs, exercise configuration and examination. Almost all exercises (seven out of eight) showed construct validity. In total 50 out of 94 parameters (53%) showed significantly difference.

Conclusions

A European multicenter validated training program was constructed according to general consensus of a large international team with extended experience in virtual reality simulation. Therefore a proficiency based training program can be offered to training centres which use this simulator for training basic psychomotor skills in endoscopic surgery.

Introduction

Since the late nineties virtual reality (VR) simulators have been used to train residents in basic psychomotor skills for endoscopic surgery. Several studies have demonstrated a positive learning curve as well as improvement of skills in the operating room after training on these type of simulators.[1-10] Because these simulators allow accurate assessment of these skills, they may be used to define a skills level required for trainees to start surgical training in the actual operating theatre. At this moment only one study has been published on the development of an evidence-based VR training program for technical skills prior to progression into the operating theatre.[11] The optimal introduction of a VR simulator into an evidence-based, efficient and cost-effective surgical skills curriculum is a core issue and is still open for discussion.

The LapSim® VR simulator basic skills module consist of nine psychomotor skill tasks. The end points relate to execution time, instrument path, damage and other adverse effects. The training design can be adjusted for both exercise configurations as well as for "pass or fail" outcomes (assessment thresholds). The exercise configuration settings and exercise programs used for validation of this simulator in studies published so far are either default settings, or are based on personal choice of the tutors.[11-17] Before claims on competency may be stated, consensus should be established on the settings of these exercise configurations and training programs. Secondly, such a training program should be constructed with expert performance as the guideline to define assessment thresholds.

The purpose of this study was to establish consensus on exercise configurations and on a training program for the LapSim® VR simulator, based on experience of international experts. Furthermore the training program based on these configurations was validated in order to set criterion levels to construct a proficiency based training program.

Methods

Equipment and tasks

The LapSim virtual reality simulator uses the Virtual Laparoscopic Interface (VLI) non-haptic enhanced hardware platform, (Immersion Inc., San Jose, CA, USA) which includes a jig with two endoscopic handles. The VLI has an interface with a 2600 MHz hyperthreading processor Pentium IV computer running Windows XP and is equipped with 256 RAM, a GeForce graphics card and a 18-inch TFT monitor. The systems feature LapSim Basic Skills 3.0 software (Surgical Science Ltd, Göteburg, Sweden), from the LapSim Basic Skills package, comprising nine tasks for training basic psychomotor skills .

The computer stores and displays between seven and fourteen parameters of performance per task. These parameters are either *time related* parameters (s), *error related* parameters; e.g. tissue damage (mm and #), maximum stretch damage (0-100%) instrument misses (#), badly placed and dropped clips (#), blood loss (ml), rip failure (#), burn damage (#) or *efficiency of instrument handling* related; e.g. path length (m), angular path degree (°) and drift (mm). Time, path length and angular path degrees are measured for all nine tasks. The other parameters are measured subject to the nature of the task.

Training design and exercise configurations

In order to obtain an optimal structure for the training design and optimal configurations a two day consensus meeting was organized hosting eight European teams, all extensively experienced in using the LapSim® VR simulator in surgical resident training programmes. Participating centers to the consensus meeting were: Karolinska Hospital, Stockholm, Sweden, Glostrup Hospital, Copenhagen, Denmark, Surgical Skills Centre, Dundee, Scotland, Sahlgrenska University Hospital, Goteborg, Sweden, St. Mary's Hospital, London, United Kingdom, University of Milan, Milan, Italy, Cisanello Hospital, Pisa, Italy, University Medical Center, Utrecht, the Netherlands.
A structured questionnaire was used to determine the optimal training design (**Table 1**). All experts proposed their personal exercise configurations. Consensus on preferable configuration was established by training and discussing all different configurations during a testing day.

Table 1 questionnaire to determine training and examination design
Which exercises should be used?
Modules with different difficulty?
If, yes, how many?
Which level should be examination level?
Thresholds based on expert scores?
If yes, mean score or mean + 1 x sd, mean + 2 x sd?
Maximum exposure time?
Should trainees pass exam once or more consecutive times?
Massed or distributive training?
Sd = standard deviation

Expert performance

A time frame of six months was set to test a maximum of five experts per centre. The experts should at least have performed more than 100 endoscopic procedures and perform advanced endoscopic surgical procedures themselves (that is; not perform basic endoscopic procedures defined as diagnostic laparoscopy, laparoscopic cholecystectomy and laparoscopic appendectomy only).
Every task was started with a try out, which is considered to be a familiarisation run to get comfortable with the simulator. Immediately after the familiarisation run a second run was performed to measure performance on the particular level. To avoid benefits resulting from immediate training, there had to be a break of one hour between each level tested per expert. The results of the second run of experts were used comparing results of novices on the same level, in order to test for construct validity.

Novice performance

Every level of difficulty was tested with twenty novices. Because training on an easy or moderate level will lead to experience, novices were tested on one level only.
Therefore 60 novices were randomised, using the closed envelop method, into a training group at easy (20), moderate (20) or difficult (20) level. The novices, being students or interns, had no previous experience performing or assisting in endoscopic surgery and displayed serious interest in a surgical career. When a parameter showed "construct validity" determined by a significant difference between the mean value of the experts and the mean value of the novice, this parameter was used as a threshold for the examination module.

Statistical analysis

The data were analysed using SPSS (Chicago, IL) version 12.0.1. using the t-test for equality of means. A power analysis on the data of van Dongen at al16 show that with a power of 0.8 and alpha set at 0.005 , the sample size should be at least 17. Therefore a minimal group size of twenty was chosen.

Results

Consensus on training design

The results of the two day consensus meeting are shown in this paragraph. In the discussion the rationale for the consensus protocol is described.
The proposed training program exists of eight basic skills exercises on three different levels (easy, moderate and difficult) and the suturing task.

It was agreed on that trainees should start at the easy level , being tutored during their first familiarisation run. If any of the parameters in this study shows "construct validity" these parameters will be set as a threshold. Ultimately the "difficult level" of the training program will also be the accreditation level.

Consensus on exercise configurations.

In general, targets will become smaller, disappear faster or will be more vulnerable according to level of difficulty. The complete training schedule is available upon request.

Construct validity and thresholds

Six of the centres provided data of a total of twenty experts within the set timeframe of six months. The scores showing significant difference between novices and experts, and thus showing construct validity will be used as a threshold during training and examination of residents. The threshold is set at the mean score plus twice the SD of the experts scores. In total 50 out of 94 parameters (53%) showed significantly difference between the expert group and novice group scores in favour of the expert group. **Table 2** shows the p-values of these repeating parameters for which the experts perform better than novices. Time shows construct validity for all tasks. Efficiency of movement parameters validate in 18 out of 32 cases (56%). A minority with 21 out of 51 of the error scores validate (41%).

Table 2 significant parameters and p-values of general parameters / task

Parameters Task	Sign parameters / Total parameters	Time (L&R)	Path length (L&R)	Angular path (L&R)	Tissue damage	Maximum damage	Misses (L&R)
Camera Navigation	2 / 7	**0.0**	0.3	0.3	0.2	0.2	**0.000**
Instrument Navigation	7 /10	**0.0/0.0**	0.13/**0.08**	0.5/0.4	**0.0**	**0.0**	**0.0/0.0**
Coordination	5 /10	**0.0**	0.3/0.5	0.4/0.8	0.4	**0.01**	**0.0**
Grasping	6 / 10	**0.0/0.0**	0.5/0.4	1/0.3	**0.01**	**0.04**	**0.0/0.0**
Lift & grasp	7 / 9	**0.0**	**0.04**/0.2	**0.0/0.0**	**0.05**	0.06	**0.0/0.0**
Cutting	9 / 11	**0.0**	**0.0/0.0**	**0.0/0.0**	**0.0**	0.15	N.A.
Clip Applying	7 / 10	**0.0**	0.6/**0.03**	0.8/**0.02**	N.A.	**0.04**	N.A.
Fine dissection	3 / 14	**0.01**	0.6/**0.08**	0.6/0.3	N.A.	N.A.	N.A.
Suturing	5 / 14	**0.01**	0.1/0.9	0.2/0.7	0.1	0.2	N.A.

Sign. = significant, (L&R) = Left and right, N.A. = not applicable, significant parameters in bold

Column 2 of **Table2** also shows the number of significant parameters in regard to the total number of parameters per task. Time, path length and angular path were measured for every task. Tissue damage and maximum damage is measured for all tasks but clip applying and fine dissection. The same accounts for misses, which is also not applicable to the cutting and suturing tasks.

Consensus on examination

All the sessions (easy, moderate and difficult) are to be trained up to threshold levels, based on the construct valid expert scores. When failing in three consecutive runs in any exercise, the trainee will be advised to continue to the next exercise and try this particular exercise later on again. The trainees will have an official exam at the difficult level. The thresholds are based on the mean scores of the experts plus twice the standard deviation (SD). The trainees should pass these requirements twice. Of course the training sessions should be organised according to logistic possibilities of the training centres and or hospitals, but distributed training is preferred. A maximum exposure time of 45 minutes per training session is advised. A training session will be stopped after 45 minutes or after finishing a level with success.
The trainees should pass the exercises within one training session; otherwise they should perform the examination later again.
Residents in training should ideally not be allowed to start with endoscopic surgery before passing this virtual reality training curriculum.

Discussion

A European multicenter validated training program was constructed according to general consensus of a large international team with extended experience in virtual reality simulation.

Consensus on the training program

The LapSim® VR simulator is programmed with default training settings by the manufacturer, if desirable these settings can be adjusted according to buyer's preference . All training programs described in earlier studies are using default settings or are based on personal choice.[11-19] The default settings tend to be unrealistic at difficult level.[11] The optimum training settings are not yet known and therefore we organised a meeting with eight European centres to reach consensus. These centres have all had extensive experience with control of settings for the LapSim® Virtual reality simulator. This experience served as the starting point to reach consensus on preferable exercise configuration and training design.

All eight basic skills were planned to be implemented into the training program, as well as the suturing task. It has been discussed if suturing should actually be a part of a basic skills training program. Although suturing can be considered a more demanding task, novices should be familiar with suturing before entering an operating theatre, in order to be able to solve minor complications if necessary.

Three different levels (easy, moderate and hard) of difficulty were chosen to teach the residents the basic psychomotor skills gradually. In order to provide an efficient equipment familiarisation, trainees should be properly instructed during the first training sessions by a tutor.

All centres reported that consecutively failing of a particular training task is likely to result in heightened levels of frustration among trainees. When failing a task three times in succession, frustration levels appear to influence the concentration level. Consequently, residents are to be advised to stop training a specific task, after failing this task three times in a row.

A training session exceeding a duration of 45 minutes is likely to result in a decrease in concentration and accuracy, and must be avoided. Furthermore several studies have shown that distributed training, with rest in between training sessions, is superior to massed training for obtaining psychomotor skills.[20, 21] Although within every hospital or training centre training schedules will depend on local possibilities, distributed training, with sessions of 45 minutes is advised. Moreover a training session of the eight basic skills exercises can also be finished within this time-frame.

Construct validity and thresholds

As shown in **Table 2** the time related and efficiency of instrument handling parameters always show construct validity. The parameters showing efficiency of instrument handling validate very often with 21 out of 32 parameters (65 %) showing construct. These particular construct parameters are used to define the thresholds for a proficiency based training program.

The suturing task shows construct validity in only five out of fourteen parameters. Most likely this is due to a lack of realism of the thread and the virtual tissue in this particular task. Consequently, the suturing task of this simulator cannot be considered as a validated training task assessing suturing skills. In contrast to these result, Munz at al showed that there is transfer in skills from this suturing task to knot tying in a box trainer.[22] Twenty participants completed a correct knot as compared to only five participants (25%) before training the suturing task. Time to completion was 66% faster and knot quality 45% better after training. Further research should be done to show the benefit of the virtual reality suturing task in training endoscopic surgical skills.

The fine dissection task shows construct on a few parameters. At the easy and moderate level time is the only parameter showing construct. The exercise should therefore not be a component of the training program, because it can be passed when performing very fast, while causing a lot of damage.

Consensus on examination

The most challenging exercises are those with levels set at the most difficult level. Using this level, most parameters show construct validity. One may conclude therefore, that passing a test with parameter set at this level provides the best chance on appropriate basic skills in real surgery. Therefore, the difficult level is chosen as the accreditation level.

Schijven and Jakimowicz[23] have shown different performance profiles of trainees in acquiring basic skills. Some trainees need more training compared to others and therefore proficiency based training is preferred. This means the residents should train until a pre-set level is reached, showing this basic level of proficiency. In our opinion the pre-set levels should be based on expert scores. Attaining basic psychomotor skills at an expert level could lead to shortened learning curves in patients. This, due to the fact that residents have attained technical basic psychomotor skills, combined with the fact that they might be able to perform surgery at a more automated level since they are less likely to 'think' about their movements. During training in the operating theatre residents will be able to focus on the procedure and the decision making during surgery, instead of focussing on their psychomotor skills. Aggarwal at al[24] bring up another advantage of an exam based on expert scores. They state that the confidence of residents in their own performance might be increased, having the knowledge that they are at least able to perform psychomotor skills at an expert level. Trainees should show consistence in attained basic psychomotor skills by passing the examination two times. Passing the examination only once is more likely to be outcome of chance.

The authors are aware of the fact that this simulator trains and measures trainees' psychomotor skills solely. Since the acquisition of psychomotor skills has shown to decrease the learning curve in laparoscopic cholecystectomy,[2,10] this is, in our opinion, the minimum of objective assessment that should be performed before allowing residents to be active surgical team member in the operating theatre.

Even though endpoint parameters are defined scientifically and the training program settings are chosen based on consensus of international experts, this particular training program should also show predictive validity. Therefore, a study should be commenced to assess if this training program predicts future performance and if the trained skills transfer to the operating theatre.

Conclusion

A multi-centred European broad training program was constructed according to general consensus of eight LapSim® VR simulator user teams, who all had personal experience in validating this simulator. The results of this study define the parameters which can be utilised for the benchmark criteria of a training program. Therefore a proficiency based training program can be offered to training centres which use this simulator for training basic psychomotor skills in endoscopic surgery.

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Submitted

Chapter 6

Distributed versus Massed Training

Efficiency of training psychomotor skills

Abstract

Background

Virtual reality simulators have shown to be valid and useful tools for training psychomotor skills for endoscopic surgery. Discussion arises how to integrate these simulators into the surgical training curriculum. Distributed training is referred to as short training periods, with rest periods in between. Massed training is training in continuous and longer training blocks. This study investigates the difference between distributed and massed training on the initial development and retention of psychomotor skills on a virtual reality simulator.

Methods

Four groups of eight medical students lacking any experience in endoscopic training were created. Two groups trained in a distributed fashion, one group trained in a massed fashion and the last group not at all (control group). All performed a post-test immediately after finishing their training schedule. Two months after this test a second post- test was performed. Non-parametric testing (Mann-Whitney) was used to determine differences in mean scores between the four groups, whereas a p-value ≤ 0.05 was considered to be statistically significant.

Results

Distributed training resulted in higher scores and a better retention of relevant psychomotor skills. Distributed as well as massed training resulted in better scores and retention of skills than no training at all.

Conclusions

Our study clearly shows that distributed training yields better results in psychomotor endoscopic skills. Therefore, in order to train as efficient as possible, training programs should be (re)-programmed accordingly.

Introduction

The introduction of endoscopic surgery has introduced new challenges in surgical education. A difference in skills is required for endoscopic surgery compared to traditional 'open' surgery, because of the different operating environment. Endoscopic surgery requires 3-D orientation in a 2-D representation of the operating scene, as well as endoscopic instrument handling[1-4]. Virtual reality simulators have shown to be valid and useful tools for training these psychomotor skills[5-9]. Working hours of residents have been limited during the last years and technical skill training should be as efficiently as possible. Therefore it is very important to understand the concepts of training schedules. Essentially one can choose between a distributed and a massed set-up.

Distributed training is referred to as short training periods, with rest periods in between[10;11]. Massed training is described as training in continuous and longer training blocks[10;11]. In studies on sports and psychology there is a difference in favour of the distributed training, both for initial results as well as for retention of knowledge and skills.

Only a few studies have investigated the influence of training schedules on surgical technical skills attainting[9,12]. These studies also show superiority for distributed training.

The purpose of this study therefore was to investigate the effect of distributed and massed training on the initial development and retention of psychomotor skills on a virtual reality simulator.

Methods

Sample size

A power analysis based on the results of time-scores analysis (relative difference 18.7%) in the study of Verdaasdonk et all[16], with a power of 0.8 and alpha set at 0.05, demonstrate a group size of 8 participants for each group.

Participants

A total of 32 Medical students without any prior experience in endoscopic basic skills training were recruited from the Faculty of Medicine of the Utrecht University and randomly assigned into four groups of eight subjects each (**Table 1**).

Apparatus, tasks and training:

The simulator used was the LapSim virtual reality surgical simulator, featuring LapSim Basic Skills 2.5 software (Surgical Science Ltd, Göteburg, Sweden). The following seven tasks at easy, medium and hard level were selected and object of research; camera navigation, instrument navigation, coordination, grasping, lifting and grasping, cutting and clipping and cutting[13]. All participants performed the same training program. In every session all seven tasks were performed at three different levels (easy, moderate, hard). Scores were derived from the 178 measured parameters which were categorized, based on the quartile scores of 48 subjects in a prior study[13]. Scores are represented in percentages (0-100%) relative to a pre-set benchmark score, derived from expert performances. An 80 percent score on an exercise equals 80 points. All exercises were explained to the participants and they were allowed to try all exercises once at easy level to get acquainted with the simulator. All participants then performed a pre-test.

Table 1 demographic group characteristics

Groups	**1**	**2**	**3**	**4**
	8	8	8	8
Characteristics				
mean age (range)	24 (21-28)	24.4 (21-30)	23.9 (19-29)	24 (19-33)
male:female	4:4	5:3	5:3	3:5
right hand dominance (N)	7	8	7	7
medical background (N)	8	8	8	8
computer game experience (N)	3	3	3	2
playing an instrument (N)	6	5	6	5

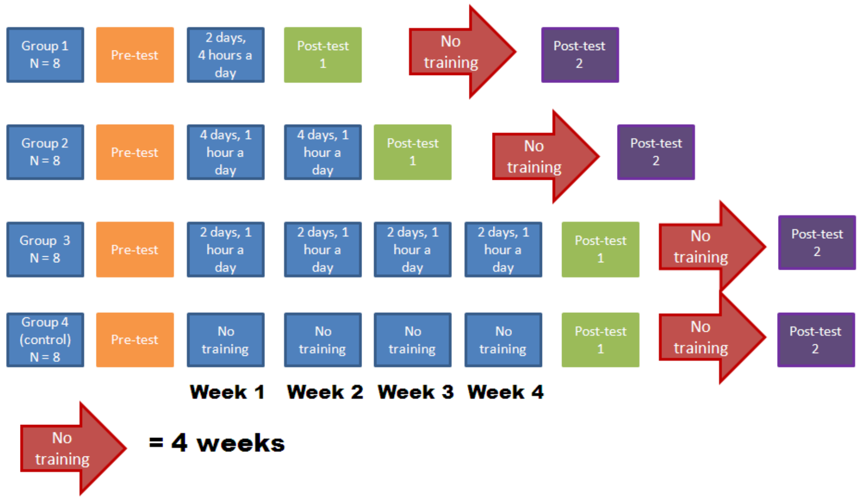
Training schedules

Group one trained on two separate days within one week. Each day they trained four consecutive hours (massed training). Group 2 trained on eight separate days within two consecutive weeks, (distributed). Each day they trained one hour. Group three trained on eight separate days within four consecutive weeks (wide distributed). Each day they trained one hour. Group four is a control group, which did not train at all. All performed a post-test immediately after finishing their training schedule (post-test 1). Two months after post test 1 a second post- test was performed (post-test 2). Group four performed their post-test 1 one month after the pre-test (conform the longest training schedule) (**Table 2**).

Evaluation:

All training tasks were evaluated at the hard level. Data analysis was done using SPSS, version 15.0. The one-way nanlysis of variance (ANOVA) with Post-Hoc test Tukey-Bonferroni was used to determine differences in mean scores between the four groups, whereas a *p*-value ≤ 0.05 was considered to be statistically significant.

Table 2



Results

Table 1 shows the characteristics of the groups. There is a normal distribution of the characteristics and data concerning other possible contributors to improving basic psychomotor skills.

Table 3 and **Figure 1** show the results of the four groups for every test.

Table 3 Mean total scores (range) per test, per group.

	Group 1	Group 2	Group 3	Group 4
pre-test	434 (259-529)	444 (312-503)	422 (341-521)	405 (298-516)
post-test 1	686 (525-847)	809 (742-866)	795 (730-881)	374 (341-449)
post-test 2	546 (369-750)	679 (402-814)	678 (479-824)	357 (257-530)

Pre-test

Table 3 shows the scores of the four groups during the pre-test which do not differ significantly different (p=0.841). All groups achieved a comparable score between 405 and 444 points.

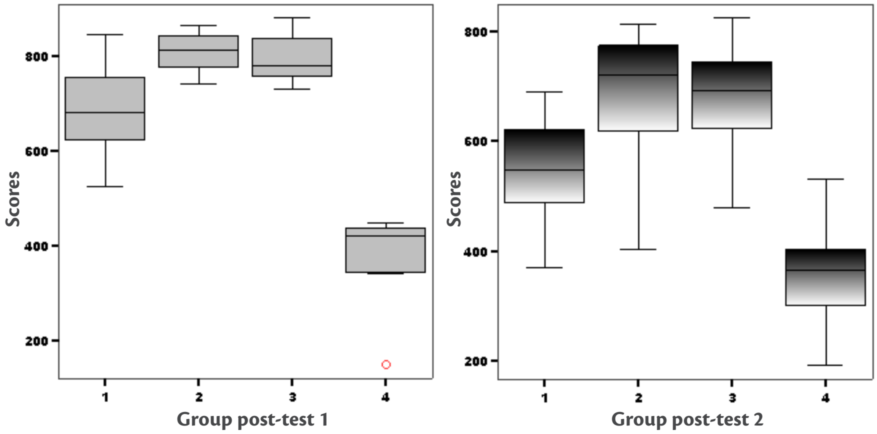


Figure 1 Scores of the four groups, post-test 1 and post-test 2

Post-test 1

Figure 1 shows the results of the scores on post test 1 and 2. The scores of the post test 1 differ significantly. Group 1 trained in a massed model and scored 686 points, which is significantly lower than the two groups trained by a distributed trainings scenario (group 2 (809 points, p=0.032) and Group 3 (795 points, p=0.036); respectively). All groups score significantly higher than group 4 (474 points, p=0.001).

The scores of group 2 and 3 are equivalent (p= 0.494). Both group 2 and 3 score significantly higher than the non-trained group 4 (p=0.001, p= 0.01 respectively).

Post-test 2

Table 3 and **Figure 1** show that the scores of the groups at post test 2 are significantly different. Two months after their last training group 1 performs worse than immediately after training (546 versus 668). Their scores are lower than those of group 2 (679, p=0.036) and 3 (678, p=0.027). The scores of group 1 are significantly higher than those of group 4 (357, p=0.007). Group 2 and 3 achieve similar scores (679 and 678, p = 0.753), which are lower than their initial scores immediately after their training program (809 and 795). These scores are also significantly higher than the scores of group 4 (p=0.002 an p=0.001 respectively).

Discussion

In our study, distributed training results in higher initial scores and a better retention of psychomotor skills needed for endoscopic surgery on a virtual reality simulator. These results subscribe the findings of earlier studies on technical surgical and psychomotor skills[9;12].

Superiority of distributed training above massed training schedules is known from studies in sports and psychology. Dail et all[21] examined judgments of learning and the long-term retention of a discrete motor task (golf putting) as a function of distributed practice. The results indicated that participants in the distributed practice group performed more proficiently than those in the massed practice group; during both acquisition and retention phases. Lee et all have shown that massed training is superior only in single task training[11]. In their study, a movement timing task was performed. When training a continuous task, (multiple timing moments in one task) instead of a single task (one timing moment only), distributed training is superior. Training psychomotor basic skills must be considered as a form of continuous training. Therefore our results are in line with the results of Lee et all, favouring distributed training above massed training.

All studies show that distributed skills training is to be preferred, although a solid scientific explanation for this is unknown so far. An explanation might be that caused by the development of new or more efficient neuronetworks in the brain during the rest periods, thus enhancing consolidation of newly acquired skills. Walker et all have shown that changes in the brain do take place during rest periods[23]. All 12 subjects trained a finger tapping task and 12 hours later were retested during functional magnetic resonance imaging. When a period of sleep was in between the MRI showed regions of increased activation, in contrary if the there was no sleep in the 12 hour period signal decreases were identified.

Retention of psychomotor skills is reinforced by resting periods, possibly because the brain needs these periods to store the learned skills and to avoid negative effects of tiredness[9,14].

The distributed training schedules of group 2 and group 3 did not show any difference. Authors could not establish arguments for benefits of a schedule of two weeks, almost every day once, or within four weeks with a rest period of two to three days. One might say that as long as there is a resting period, training is more likely to become part of one's palette of internalized skills. The sleep dependency of training motor skills as described above could explain this.

The groups that trained by a distributed schedule, (Group 2 and 3), scored better both directly after the training as well as two months later. These differences are indicative for superiority of distributed training program regarding retention of skills (p=0.0.027 and p=0.007). Moulton et al[12] have shown a significant difference in complex technical surgical skill (performing a microvascular anastomosis) after one month without skills training. Apparently, when training complex tasks, distributed training is even more distinctive to attain retention of skills compared to training basic psychomotor skills. In a study on training psychomotor skills on a virtual reality simulator by Verdaasdonk et al[9], participants' scores did also significantly differ in favour of the distributed trained group. In this study, retention was scored after a period of one week. Although a decrease in performance was seen in both groups, the difference remained significant after a week.

Throughout literature, a decrease in scores is seen after periods without training. Therefore, authors suggest that pre-clinical skills training should immediately be followed by training in the operating theatre.

Conclusion

Distributed training is superior to massed training in acquiring and retaining psychomotor skills for endoscopic surgery on a virtual reality simulator.
The current training programs in the Netherlands are usually based on a two or three day regime, which provides a possibility for massed training only. In contrast, the results of our study show that distributed training should be advised in training psychomotor endoscopic skills. Therefore, in order to train as efficient as possible, training programs should be rescheduled thus redesigned accordingly. Furthermore, residents should be facilitated to execute their newly learned skills preferably in the operating theatre immediately after training.

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Chapter 7

Virtual reality training for endoscopic surgery: voluntary or obligatory?

Abstract

Introduction

Virtual Reality (VR) simulators have been developed to train basic endoscopic surgical skills outside of the OR. An important issue is how to create optimal conditions for integration of these type of simulators in the surgical training curriculum. The willingness of surgical residents to train these skills on a voluntary basis was surveyed.

Methods

Twenty-one surgical residents were given unrestricted access to a VR simulator for a period of four months. After this period, a competitive element was introduced to enhance individual training time spent on the simulator. The overall end-scores for individual residents were announced periodically to the full surgical department, and the ìwinnerî was awarded a prize.

Results

In the first four months of study, only two of the twenty-one residents (9.5%) trained on the simulator, for a total time-span of 163 minutes. After introducing the competitive element the number of trainees increased to seven residents (33%). The amount of training time spent on the simulator increased to 738 minutes.

Conclusions

Free unlimited access to a VR simulator training basic endoscopic skill, without any form of obligation or assessment, did not motivate surgical residents to use the simulator. Introducing a competitive element for enhancing training time had only a marginal effect. The acquisition of expensive devices to train basic psychomotor skills for endoscopic surgery is probably only effective when it is an integrated and mandatory part of the surgical curriculum.

Introduction

Endoscopic surgery requires dedicated skills such as 3-D orientation in a 2-D representation of the operating field and complex instrument handling[8,7,5]. Training of these skills in the operating room (OR) is under pressure due to planning issues and ethical considerations. Virtual Reality (VR) simulators have been developed to train basic endoscopic surgical skills outside of the OR. Several simulators have been validated and found adequate for the transfer of skills from the simulator to the OR[2,6,9,13,14]. However, discussion rises on how to integrate these simulation based training modalities in the surgical training curriculum.

A questionnaire distributed to 245 Dutch surgical residents to explore the perspective of the trainee on this issue. Approximately 75% of residents felt that endoscopic skillsí training outside the OR is useful.[12] In another study, sixty Dutch gynaecology residents responded positively (3.9 on a 5-point Likert scale) with regard to training laparoscopic skills before real surgery[10]. 55% of these 60 residents did not have the opportunity to train laparoscopic skills. However, those that did appeared to train only once or twice a year and 33% did not use available skills trainers voluntarily at all. We hypothesized that insufficient simulator access might be the reason for this contradiction. Therefore, we investigated the willingness of surgical residents to train endoscopic skills on a voluntary basis when VR simulators were indeed readily available. We also evaluated the effect of competitive incentives on the frequency and duration of simulator training.

Materials and methods

Equipment, tasks and scoring system:

This study is performed with the LapSim virtual reality simulator, which uses the Virtual Laparoscopic Interface (VLI) hardware, (Immersion Inc., San Jose, CA, USA) The VLI has an interface with a 2600 MHz hyperthreading processor Pentium IV computer running Windows XP and is equipped with 256 RAM, a GeForce graphics card and a 18-inch TFT monitor. The systems feature LapSim Basic Skills 3.0 software (Surgical Science Ltd, Gˆteburg, Sweden), from the LapSim Basic Skills package, comprising nine tasks.

A training program was designed that included all nine tasks: camera navigation, instrument navigation, coordination, grasping, lifting and grasping, cutting, clipping and cutting, suturing and fine dissection[4].

The computer stores and displays between seven and eleven parameters of performance per task. These parameters are related to time, errors or efficiency of handling.

Tasks can be adjusted to different levels of difficulty. The training program for this study was set at an advanced level with thresholds that are based on the performance of 30 experienced endoscopic surgeons (> 100 endoscopic procedures).

The scoring system is two tiered. First, for any given parameter the system determines whether or not the participant passes or fails the test. Secondly, if a participant passes, a score of between 0% and 100% is attached to his/her performance on that particular parameter. The overall-score per task is determined by the sum-score of the parameters, divided by their number. Hence, an overall-score of 100% can only be obtained by scoring 100% on each of the individual parameters measured during performance of the particular task. An outcome score of 100 points is given to those participants who score a 100% on the task performed. Logically, a score of 85% thus translates into 85 points. A maximum overall score of 900 could be obtained (i.e. 100 points on each of the 9 tasks measured).

Participants

Twenty one surgical residents, ranging from post graduate year one level (PGY1) to post graduate year six level (PGY6), with different endoscopic surgical experience, were given unlimited access to the simulator. Seven residents were at the beginning of their surgical educational program (PGY1 and PGY 2) and therefore inexperienced in endoscopic surgery. Seven residents were in the middle (PGY 3 and PGY 4) and eight residents were at the end (PGY 5 and PGY6) of their surgical educational program.

Setting and Incentives

In the period May 2005- January 2006 a simulator was placed in the general room for surgical residents at the surgical ward of the University Medical Centre in Utrecht. Before the study, residents were instructed on how to operate the simulator, and allocated a personal login number for the simulator. By placing the simulator in the general residents room, it was readily and easily accessible 24 hours a day. The room is secured by a code locked door and accessible for residents only.

During the first four months, there were no additional incentives other than the permanent (24/7) accessibility to the residents for training on the simulator. After these four months, a competitive element was introduced in which the frequency of training was also rewarded (bi-weekly). The overall end-score was calculated every other week by adding this frequency bonus to the highest scores for each task. These overall end-scores for each resident were publicly announced to the complete department of surgery and the ìwinnerî (the resident with the highest score) was awarded a prize.

Questionnaire

After eight months all residents were requested to fill out a questionnaire.
Ten questions concerning their perception of their own experience level in endoscopic procedures, their opinion of the possibility to develop and train endoscopic skills within the current surgical curriculum and their opinion about the application of virtual reality as a means to training endoscopic skills on a 5-point Likert scale were presented. Value 1 was assigned to ìtotally agreeî, value 5 to ìtotally not agreeî. In addition, the residents were asked about their frequency of usage of the simulator. If a participant indicated little usage, he or she was questioned why, and what could motivate increased usage.

Results

In the first four months only two of the twenty-one residents (10%) trained on the simulator, for a total of 163 minutes. One resident was a PGY2, the other one a PGY5. In the second period of four months the number of trainees increased to seven residents (33%, two PGY2, two PGY 3, one PGY5 and two PGY6). The duration of training increased to 738 minutes, thereby constituting a average increase of 23.9 minute per subject. (58%) of training time was performed during night shifts.
All 22 residents (100%) replied to the questionnaire. The total training time, as an accumulation of estimation on individual training time, was 4140 minutes. The actual cumulated training time for all residents was 901 minutes (22 %). Thirteen out of 15 residents who did not train at all (86%) stated that this was due to a lack of time during the day. One resident (7%) stated he had been not interested enough to train and indicated to have alternate priorities. Another resident (7%) stated to be occupied due to an intensive care traineeship and maternity leave.
Residents suggested to enhance use of the VR trainers by incorporating a mandatory VR training into the surgical curriculum (9x), to oblige certain skills level on VR simulator before starting endoscopic surgery in the OR (3x), to implement competitive training with coaching (2x), to diminish working pressure (2x), to have more advanced exercises available on the simulator (3x), to place the VR simulator on other location than in the residents room (1x). Only two stated that more initiative of residents was required to improve outcome.
Figure 1 refers to the perception of residents' own experience level in endoscopic procedures, their opinion of the possibility to develop and train endoscopic skills within the current surgical curriculum and their opinion about the application of virtual reality as a means to training endoscopic skills.

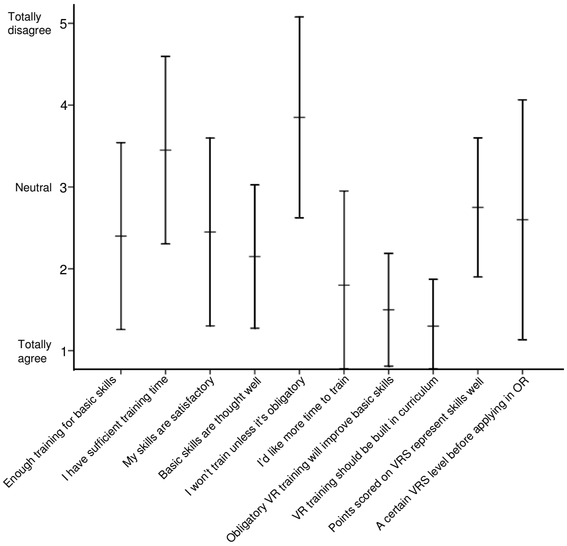

Figure 1 Results of questionnaire
VRS = virtual reality simulator, OR = operating room, VR = virtual reality

In general, the opinion of the residents on their own experience level , on the possibility to develop and train endoscopic skills during their training and on the role of virtual reality varies considerably (SD 0.44-1.39). Their opinion on obligation of VR training to improve endoscopic skills and having VR training as a mandatory part of the basic skills training is most uniform. Residents do not have a marked positive, nor a marked negative opinion on the presented statements on receiving enough training for acquiring basic skills (2.63, SD 1.19), on receiving sufficient training time in the OR to train endoscopic skills (3.47 SD 1.17) and on acquiring a satisfactory level of basic psychomotor skills (2.42, SD 1.16). The same accounts for their opinion on the representation of their training results on the simulator (2.98, SD 0.83); as well as on the statement that thresholds should be reached before training in the OR is allowed (2.47, SD 1.39). There is one statement they do not agree with; I will not train unless it is obligatory. (4.26 SD 1.10).

Discussion

Virtual reality training has the potential to improve and professionalize the training in endoscopic basic psychomotor skills[2,6,9,13,14]. Training results can be showed instantly to demonstrate objective performance and progress of performance assessment. However, one of the main concerns in acquisition of expensive equipment for educational purposes is its effectiveness. While initial enthusiasm about new innovative equipment is usually high among the surgical community, actual usage tends to be disappointing[3]. This study was undertaken to evaluate the aptitude to train on a voluntary basis when a VR simulator was readily available. Free unlimited access to a VR simulator without obligation or assessment in our setting did not seem to motivate surgical residents to use the simulator for improvement of their psychomotor endoscopic skills level. The addition of a competitive element and a desirable prize had only a marginal effect on the frequency and duration of training. We believe that the effort required to provide this incentive is disproportional to its marginal effect.

The majority of residents (86%) stated that ëlack of time due to high working pressureí is the most important reason for not using the simulator. Pursuant to a recent European guideline, as set by the European Commission, a work week for a resident in training is being reduced from 70 hours to 48 hours[11,1]. This may have led to an increase in pressure during working hours with little time available for voluntary training. However, spare time has increased vastly compared to the former curriculum. Residents did not use personal free time for VR simulator training to improve their skills.

The perception of their own experience level in endoscopic procedures and the possibility to develop and train endoscopic skills within the current surgical curriculum was in general neutral. Therefore no conclusions can be drawn from this. There is favorable, uniform opinion on the desirability of integration of skills training into the curriculum. In addition, residents believe skills training ought to be mandatory for marked improvement of their psychomotor skills. Interestingly, the disagreement on the statement of not training unless it is obligatory (4.26, SD 1.10) appears to have no bearing in reality, because our study shows very limited use of the simulator. This incongruence might be caused by “political correctness or by a discrepancy between intentions and actions.

It must be said that our result reflects the quantity of training on a voluntary basis of 22 residents in a single institute only, and might therefore not represent the attitude of national or international surgical residents.

In conclusion, the acquisition of expensive devices to train basic psychomotor skills for endoscopic surgery is probably only effective when it is a mandatory part of the curriculum.

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Submitted

Chapter 8

Will the playstation generation become better endoscopic surgeons?

Abstract

Background and objective

A frequently heard comment is that the current "playstation-generation" would have superior baseline psychomotor skills. However, research has provided inconsistent results on this matter. The aim of this study was to investigate if the "playstation-generation" shows superior baseline psychomotor skills for endoscopic surgery on a virtual reality simulator.

Methods

The 46 study participants were interns (24) of the department of surgery and schoolchildren (12,5) of the first year of a secondary school. Participants were divided into four groups; ten interns with video game experience and ten without, thirteen schoolchildren with video game experience and thirteen without. They performed four tasks twice on a virtual reality simulator for basic endoscopic skills. The one-way analysis of variance (ANOVA) with Post Hoc test Tukey-Bonferroni and the independent student T-test were used to determine differences in mean scores,

Results

Interns with video game experience scored significantly higher on total score (93 versus 74,5; p=0,014) compared to interns without this experience. There was a non significant difference in mean total scores between the group of schoolchildren with and those without video game experience (61,69 versus 55,46, p=0,411). The same accounts for interns with regard to mean scores on efficiency (50,7 versus 38,9; p=0,011) and speed (18,8 versus 14,3; p=0,023) In the group of schoolchildren there was no statistical difference. Efficiency (32,69 versus 27,31; p=0,218); speed (13,92 versus 13,15; p=0,54). The scores concerning precision parameters did not differ for interns (23,5 versus 21,3 p=0,79), nor for schoolchildren (mean 15,08 versus 15; p=0,979).

Conclusion

Our study results did not predict an advantage of video game experience in children with regard to superior psychomotor skills for endoscopic surgery. However, at adult age, a difference in favor of gaming is present. The next generation surgeons might therefore benefit from video game experience during their childhood.

Introduction

Endoscopic surgery requires specific surgical skills because of the fulcrum effect, an unnatural eye-hand co-ordination and the translation of a three-dimensional working field into a two-dimensional monitor[1,2]. It has been shown that the psychomotor skills required for endoscopic surgery can be measured by virtual reality simulators[3-8]. Early studies on psychomotor skills have also demonstrated that video game players have a superior eye-hand co-ordination, visualization skills and have faster reaction times[9,10].
A frequently heard comment at meetings on training surgical skills is that the current "playstation-generation" (e.g. schoolchildren with video game experience) or better the "generation next or generation Z"[11] would definitely have superior baseline psychomotor skills. However, research involving medical students, residents and surgeons has provided inconsistent results on the relation between psychomotor or endoscopic surgical skills and experience with computer games[12-20]. Therefore a study was conducted to investigate the impact of experience in playing video games on the performance of basic endoscopic skills of the "playstation generation" as well as of medical student interns, using a LapSim® Virtual Reality simulator.
The aim of this study was to investigate if the "playstation-generation" shows superior baseline psychomotor skills for endoscopic surgery on a virtual reality simulator.

Materials and methods

Participants

The study was conducted at the skills laboratory of the Department of Surgery of the University Medical Hospital Utrecht, The Netherlands. The 46 study participants were interns (mean age 24 year) of the department of surgery and schoolchildren (mean age 12,5 year) of the first year of a secondary school in Utrecht. The schoolchildren were at a secondary school preparing for A-levels.vel of education in the Netherlands. This level of education is sufficient to apply for medical School. Participants were divided into four groups; ten interns with video game experience and ten without video game experience, thirteen schoolchildren with video game experience and thirteen without. Videogame experience was defined as an average playing time of at least ten hours a week. All schoolchildren attended a one hour lecture on the meaning, usage, usefulness and pitfalls of minimal invasive surgery.
None of the participants has had any prior experience with the virtual reality simulator. All the participants filled out a questionnaire on their non-surgical dexterity skills and microsurgery experience.

Apparatus and tasks

The LapSim® virtual reality simulator uses the Virtual Laparoscopic Interface (VLI) hardware, (Immersion Inc., San Jose, CA, USA) which includes a jig with two endoscopic handles. The VLI has an interface with a 2600 MHz hyperthreading processor Pentium IV computer running Windows XP and is equipped with 256 RAM, a GeForce graphics card and a 18-inch TFT monitor.
The system features LapSim® Basic Skills 2.5 software (Surgical Science Ltd, Göteburg, Sweden), from the LapSim® Basic Skills package, consisting of eight tasks. All of the participants performed four of these basic endoscopic skill tasks. The instrument navigation task, the grasping task, the lifting and grasping task and the clipping and cutting task, as described by van Dongen et all were used for this study[21]. They performed these four tasks twice and therefore a total of eight exercises were performed on the VR simulator. Assessment of skills was based on a total score of 16 parameters and were categorized to score efficiency, precision and speed.

Data analysis

Statistical analysis was performed using SPSS, version 12.0. The one-way analysis of variance (ANOVA) with Post Hoc test Tukey-Bonferroni and the independent student T-test were used to determine differences in mean scores on the simulator between the four groups and on difference in gender. A p-value ≤ 0.05 was considered statistically significant.

Results

Participants

Normal distribution of the data concerning other possible contributors to improving basic psychomotor skills has been tested and confirmed using box plots. Apart from gender, participants were equally distributed per age-group concerning dexterity enhancing surgical and non-surgical skills (**Table 1**).

Comparison within the generations

Interns with video game experience scored significantly higher on total score (mean 93 versus 74,5; p=0,014, **Figure 1**) compared to interns without this experience. There was a non significant difference in total scores between the group of schoolchildren with and those without video game experience, with a higher score for children playing videogames (mean 61,69 versus 55,46, p=0,411, **Figure 1**).

Table 1				
Group	**1 +**	**2 -**	**3+**	**4-**
Male / Female ratio	9 / 1	4 / 6	13 / 0	4 / 9
Age	24.3	24	12.4	12.8
Hours video game / week	1,9	0	8,6	0,46
Camera handling	7	7	0	0
Microsurgery	0	0	0	0
Type blindly	2	1	5	5
Musical instrument	5	4	6	6

Group 1 = student interns , group 2 = student interns , group 3 = schoolchildren , group 4 = schoolchildren
+ = videogame experience, - = no video game experience
M/F = male / female

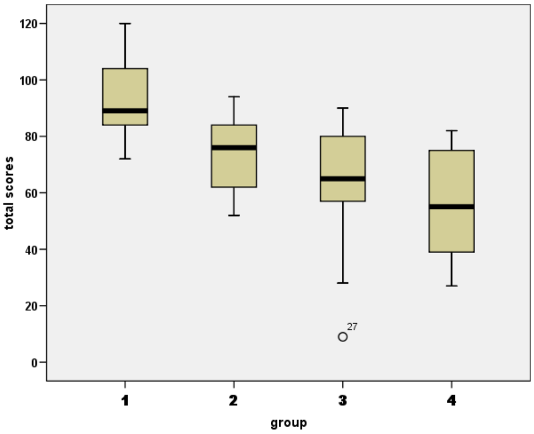

Figure 1 Total scores
group1 versus group 2: p=0.014
group 2 versus group 4: p=0.411

The interns with video games experience also scored significantly higher on efficiency (mean: 50,7 versus 38,9; p=0,011, **Figure 2**) and speed scores (mean: 18,8 versus 14,3; p=0,023, **Figure 3**) compared to interns without video game experience.
The two categories of schoolchildren (group 3 and 4) attained non-significant differences in the score for efficiency and equal scores for speed. (efficiency score mean: 32,69 versus 27,31; p=0,218, **Figure 2** and speed score mean: 13,92 versus 13,15; p=0,54, **Figure 3**).
The scores concerning precision parameters did not differ for interns, nor for schoolchildren (mean 23,5 versus 21,3; p=0.79, respectively mean 15,08 versus 15; p=0,0979, **Figure 4**).

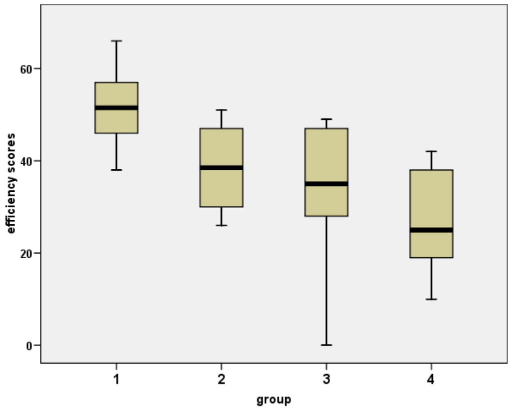

Figure 2 Efficiency scores
group 1 versus group 2: p=0.011
group 3 versus group 4: p=0.218

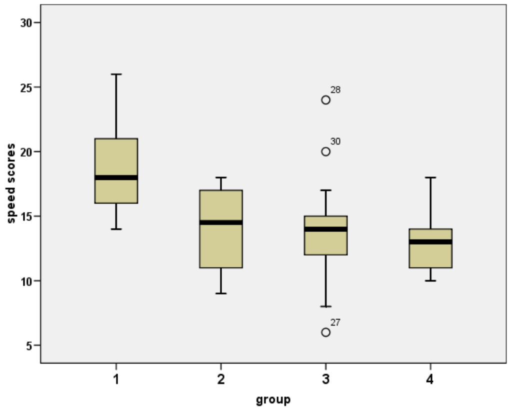

Figure 3 Speed scores
group 1 versus group 2: p=0.023
group 3 versus group 4: p=0.54

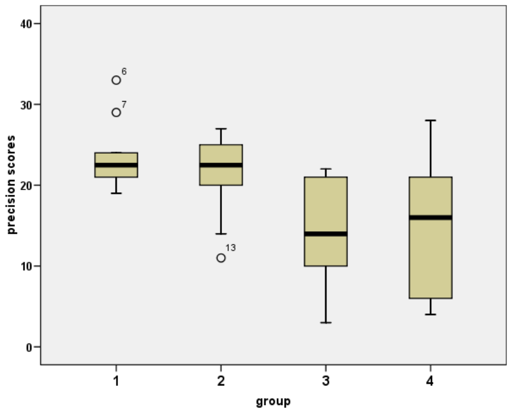

Figure 4 Precision scores
group 1 versus group 2: p=0.79
group 3 versus group 4: p=0.979

Comparison between the two generations

Interns with video game experience score significantly higher than schoolchildren, either with or without video game experience. This is true for the parameters, precision (mean 23,5 versus 15,08 and 15) , speed (mean 18,8 versus 13,92 and 13,15) and efficiency (mean 50,7 versus 32,69 and 27,31) and total scores (mean 93 versus 61,69 and 55,46)

Interns without video game experience attained equal total scores compared to schoolchildren with video game experience (mean 74,5 versus 61,69 p=0,688; **Figure 1**). They do attain higher total scores then schoolchildren without videogame experience, but the difference is not significant (mean 74,5 versus 55,46; p= 0,127 **Figure 1**)

Interns without videogame experience show a trend of scoring higher than schoolchildren without video game experience), although this score is not significantly higher (p=0,127, **Figure 1**).

When comparing both generations in general interns scored significantly better on total score (mean 83,75 versus 58,58; p=0,000, **Figure 5**), as on the categories of efficiency (44,8 versus 30; p=0,001, **Figure 6**), precision (22,4 versus 15,04; p= 0,000, **Figure 6**) and speed (16,55 versus 13,54; p=0,009, **Figure 6**).

Male versus Female

In our group, video gaming experience is strongly linked to the male gender. There was a significant difference between man and women with regard to video game experience in this study. The groups with videogame experience were almost (90% in the interns group), or completely (100% in the schoolchildren group) men only. Nevertheless, the difference in scores for males versus females was not significant (mean 73 versus 63; p=0,15, **Figure 7**).

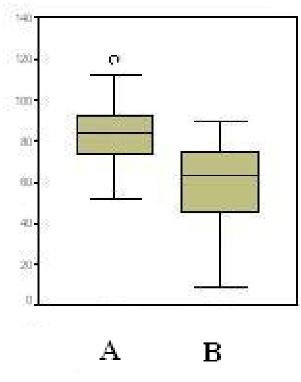

Figure 5 Generations; Total scores
A=interns, B=schoolchildren: P=0.009

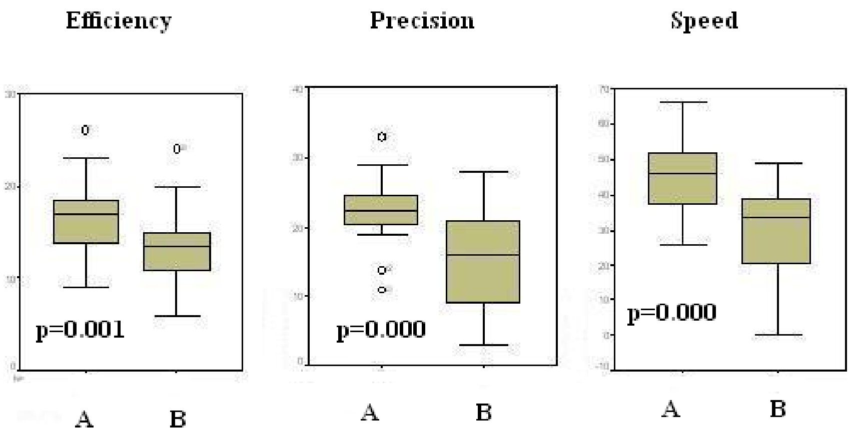

Figure 6 Generations; Efficiency, precision an speed scores
A=interns, B=schoolchildren

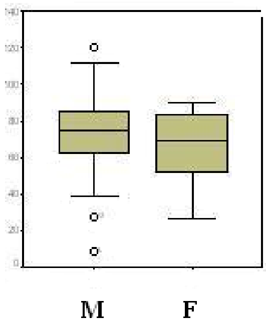

Figure 7 Male versus female
M=male, F=female: P=0.15

Discussion

In the current study, we could not demonstrate significant superior baseline psychomotor skills for endoscopic surgery in schoolchildren with extensive video game experience, although there was a trend towards better performance.

Video game experience did correlate with better psychomotor scores at adult age in a group of interns. Interns with video game experience had higher overall scores and performed better on the efficiency and speed related scores. For total scores, efficiency and speed children with experience attain equal scores as adults without.

These results are consistent with previous investigations regarding videogame experience in adults[13,14,16,17,20,22]. Rosser et al showed that video game players (residents and surgeons) had better overall scores, were faster and made fewer errors in the Rosser Top Gun Laparoscopic Skills and Suturing Program (Top Gun)[17].

They also found a correlation between higher scores in video games and higher scores in the Top Gun program. Moreover, Rosenberg et al also demonstrated a relation between video game performance and time related scores in laparoscopic skills[16]. Kolga Schlickum and Enochsson also show a transfer of skills when training with challenging visual-spatially video games[12,14].

Grantcharov et al did show a correlation, but video game experience was associated with less errors only and no difference was shown in terms of time or unnecessary movement scores[13].

Fewer studies are in contrast to our results. Madan et al reported that video game experience and other non-surgical skills was not associated with better performance in baseline endoscopic skills at al[15]. Sharma et all concluded that, although even psychologists report a relationship between videogames experience and laparoscopic skills, larger studies are needed before video gaming could be accepted as good practise[23].

This study found a statistical significant difference in scores between males and females on a VR trainer. In this group 18 participants were included, of which only seven were male. Due to this small sample size, no firm conclusions can be drawn from this result. Grantcharov et al[13] as well as our results show no difference in overall performance between male and female and therefore we suggest gender is not contributing to differences in endoscopic surgical skills.

Theoretically, a difference in gender with regard to performance might play a role in the results. We cannot investigate this role with our data due to a type 1 or 2 error (90%-100% are men in the groups with video game experience).

The performance scores of the schoolchildren were significantly inferior to the scores of the interns. This could be explained by a the fact that schoolchildren's psychomotor abilities are not fully developed yet. Voelcker-Rehage et al compared the motor performance of a juggling task with both three scarves and three balls in 1206 subjects in different age-groups (6-89 years)[24]. The pre-test result of the juggling performance across the lifespan shows that the age group of 20-24 years perform best. There is an increase in performance from the age of 5-9 years until the age of 20-24 years. After the age of 24 the pre-test performance declines. Additionally schoolchildren seemed to get more easily distracted. while conducting the different tasks. When during an exercise a blood vessel was ripped and started bleeding, they started splashing the blood instead of solving the problem of a ripped blood vessel by clipping the vessel. Other schoolchildren saw the blood at another computer and were easily distracted by this. They watched their schoolmate, playing with a pool of blood, instead of concentrating on their own exercise. This example also shows another possible contributor to the low scores of the schoolchildren. Also the interns seemed to understand the meaning and clinical relevance of the exercises better.

In conclusion, although our study results did not predict an advantage of video game experience in children with regard to superior psychomotor skills for endoscopic surgery at adult age, a difference in favor of gaming seems to be present. The difference in psychomotor development between the age of 12 and 24 might blur the advantage resulting from video game experience derived at a young age. This hypothesis is supported by the fact that gaming children perform as good as non gaming adults with respect to total scores, efficiency and speed. The next generation surgeons might therefore benefit from video game experience during their childhood.

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Chapter 9

Face- and construct validity of virtual reality simulation of laparoscopic gynecologic surgery

Abstract

Objective

To validate virtual reality simulation in assessing laparoscopic skills in gynecology; by establishing the extent of realism of the simulation to the actual task (face validity) and the degree to which the results of the test one uses reflects the subject tested (construct validity).

Study design

Subjects (N=56) were divided in three groups: novices (n=15), intermediates (n=20) and experts (n=21). Participants completed three repetitions of a training program consisting of four basic skills and three gynecologic procedural simulations. The performance was compared between groups using a post hoc t test with the Bonferroni technique. Face validity was determined by using a questionnaire of 27 statements.

Results

Resulting from the questionnaire, the opinion about the realism and training capacities of the tasks was favorable among all groups. The degree of prior laparoscopic experience was reflected in the outcome performance parameters of the tasks. Experts achieved significant better scores on specific parameters.

Conclusion

The results of this study indicates acceptance, and thus face validity of the system among both reference (novice, intermediate) and expert group. There is a significant difference between subjects with different laparoscopic experience and thereby construct validity for the laparoscopic simulator could be established.

Introduction

Laparoscopy is a widely used operation technique in gynecology. In the Netherlands all gynecologists should be able to perform basic laparoscopic procedures (diagnostic laparoscopy, ectopic pregnancy, salphingo-oophorectomy) at the end of their training. The advantages of minimal access surgery have been proven repetitively and comprise less pain, shorter hospital stay and faster recovery [1]. With the growing use of laparoscopy it is important to realize that the laparoscopic technique requires different skills compared to open surgical procedures. It requires distinct psychomotor abilities, hand-eye coordination and depth perception. At present residents-in-training for gynecologist are learning most of the specific laparoscopic skills in the operating room. There is no consensus or agreement on the method with which to learn and measure laparoscopic performance. Virtual reality simulation could provide a safe and objective method to support residents in training, the basic skills of laparoscopy before performing surgery in the operating room.

Virtual reality trainers are widely used in the airline industry and the military [2]. Simulation provides the opportunity to expose trainees to infrequent experienced or risky procedures. A simulator can create a safe, controlled, and standardized environment to practice specific skills and could be able to objectively measure the performance of a subject. Besides training, simulators are capable to asses the skills of a subject in training simultaneously. There is growing interest in the potential role for medical simulation in gynecology [2] and particularly the potential role of the virtual reality [3] because the traditional box trainers and animal models require human monitored evaluation which makes them subjective, expensive and time consuming. In the last few years several basic and more advanced virtual reality laparoscopic simulators were developed and validated [4;5]. The LapSim (Laparoscopic Simulator) surgical simulator is a system designed to simulate basic and advanced laparoscopic tasks in a virtual environment that closely resembles an operative field [4;5].

With increasing interest in simulation programs it is important to investigate the validation of a surgical simulator. Validity is defined as "the property of being true, correct and in conformity with reality". For the surgical simulator this means; does it measure what it is designed to measure? Validation is comprised of a number of principles. To accomplish the different parts of validation, several benchmarks have been developed to asses the validity of a testing instrument. These include face validity, content validity, construct validity, concurrent validity, discriminate validity, and predictive validity [4;6;7].The validation of the virtual reality simulators for training endoscopic surgical skills in surgery has been evaluated repetitively [8-15]. Although some of the training modules on the virtual reality laparoscopic simulators are especially designed to train gynecologists, validation for this surgical speciality has only started recently [16;17].[18] This study focuses on two important types of validity. First, there is the most basic level of validity, face validity e.g. the degree of resemblance between a concept instrument (simulator) and the actual construct (lapaparoscopic procedure), as judged by a specific target population (both references (=novice) and experts). to see if it seems appropriate. Secondly construct validity, e.g. The degree of empirical foundation of a concept instrument, based on theoretical constructs. In practise: often based on the presence of a logical difference in outcome between two research populations, such as experienced surgeons performing better than inexperienced ones on a certain procedure as set up by the instrument. The aim of this study was to investigate face and construct validity of the (LapSim) virtual reality surgical simulator in gynecology.

Materials and Methods

Participants

Gynecologists, residents in training for gynecology and medical students from the University Medical Centre Utrecht were recruited for voluntary participation. The 56 participants had varying experience in laparoscopic surgery. Three groups were formed based on the laparoscopic experience of the subjects. Group one consisted of 15 medical students with no laparoscopic surgical experience (novices), group two of 20 residents in training for gynecologist with some laparoscopic experience (performed 10 to 75 laparoscopic procedures; intermediate) and group three consisted of 21 gynecologists and some senior residents who all performed more than 100 laparoscopic procedures (experts). None of the participants had prior experience with the virtual reality simulator.

Equipment

The LapSim (Laparoscopic Simulator) consist of a 18-inch TFT monitor and a laparoscopic interface module (Immersion Inc., San Jose, CA, USA) with two instruments and a footswitch. The software runs on a dual-processor Pentium IV computer with 256 MB RAM and Geforce graphics card, using Windows XP. The software consists of two modules, the LapSim Basic Skills 2.5 and the LapSim Gyn (Laparoscopic Simulator Gynecology) software (Surgical Science Ltd, Gothenburg, Sweden). The Basic Skills 2.5 package consists of nine different tasks with increasing complexity. The LapSim gyn simulates parts of three procedures: tubal occlusion, salpingectomy in ectopic pregnancy and the final suturing stage of the myomectomy procedure. The system does not possess haptic feedback.

Face validation

All participants filled in a questionnaire after performing the different skills on the simulator. Next to the participant's demographics and laparoscopic experience, the questionnaire consisted of 27 statements about the LapSim. The first 11 were about the realism of the simulator, the second 10 about the training capacities of the simulator. These were presented on a 5-point ordinal answering scale (from not realistic/useless to very realistic/very useful). There was one statement concerning the lack of haptic feedback. Finally, five statements concerning the need for training and assessment by virtual reality were proposed which could be answered with 'agree', 'disagree' or 'do not know'.

Construct Validity

The training module evaluated in this study consists of four basic skills and three gynecologic procedures. The first tasks *camera navigation*, *Instrument navigation* and *the coordination task* provides basic navigational skills for camera and instrument handling as described by Van Dongen et al and Duffy et all[8;14]. The final basic task *clip applying*, is a complex task in which multiple instruments must be used to cut a vessel between two applied clips as described by Larsen et al [17]. After finishing the four basic tasks participants performed three simulations of gynecologic procedures. First the tubal occlusion (sterilization) procedure. In a virtual reality environment both tuba need to be occluded by clips or in a second session, by coagulating and cutting the tuba. One hand navigates the camera and the other manipulates an instrument. Available instruments are a grasper, bipolar grasper, diathermic scissors, a suction/ rinsing device and clip applier. Again performance parameters are measured by the system. The specific task parameters are applied clips, left and right side clip distance, bleeding and blood loss. The second gynecologic procedure is a salpingectomy. In this procedure an ectopic pregnancy has to be dissected from the fallopian tube and surrounding membrane using bipolar graspers and/or a diathermic scissor as described by Larsen et al and Aggarwal et al [16;17]. The last training task is the closure of the uterine wall cavity after a myomectomy. With two needle holders, a needle and thread three sutures have to be correctly placed, tightened and tied. The system measured minimal tissue bite, knot error and ripped stitched. Maximum time in this study was set for five minutes.

After verbal instructions the participants performed three repetitions of this training module composed of the seven different tasks. The first repetition was considered as an familiarization to the virtual reality simulator. The average performance of the second and third repetition were used in the analysis.

Use of statistics

Data were analyzed using the statistical software package SPSS 12.0 (SPSS Inc., Chicago, IL). Analysis of variance (ANOVA) was used with Post hoc analysis using the Bonferroni test to determine the difference in face and construct validity between the three groups. *P*-value < 0.05 was considered statistically significant. Values are presented as means unless stated otherwise.

Results

Face validation

Table 1 shows the mean values of the scores for the first 21 statements. The first 11 statements about the realism of the LapSim had a mean score of 3.29. The lowest scores were given for the realism of the myoma suturing skill (2.43), the tissue reaction on manipulation (2.79) and the appearance of needle and thread (2.87). The training capacities of the LapSim were rated higher (mean 3.86) especially for the simulator in general (4.38) and to train hand-eye coordination (4.46). Some answers showed significant differences between the expert and the two other groups (**Table 1**). The overall scores of the experts were lower compared to the scores of the intermediates and novices. The lack of haptic feedback, was scored as most disturbing with scores of 2.61 from the experts versus 2.50 from the intermediate and novice subjects.
The majority of the subjects agreed that the LapSim virtual reality trainer is an useful instrument to train endoscopic techniques to residents. Especially hand-eye coordination (**Table 2**). Gynecologists were not all convinced that the simulator could measure endoscopic skills for an endoscopic procedure.

Construct validity

The 56 subjects were equally distributed based on level of experience (group 1 n = 15 , group 2 n = 20, group 3 n = 21). The mean age in the groups was: group 1; 25 year, group 2; 32 year and group 3; 42 year. From the 56 participants everyone completed the three repetitions of the seven tasks. The parameters which showed a significant difference between groups are shown in **Table 3**. Comparisons between the expert (group 3) and novice (group 1) subjects demonstrated the most significant difference. For most of the basic skills there was a trend towards better performance on all parameters for group three versus group two and group two versus group one. Only the basic clip applying skill and the gynecologic sterilization module didn't show this trend. The sterilization simulation showed some significant performance parameters. Most difference was found in the ectopic pregnancy procedure. None of the subjects could complete the myoma suturing procedure within the set time limit of five

Table 1 Results questionairy statements; face validity (n=56)					
What do you think about the realism of simulator	Novice	Intermediate	Expert	**Total mean**	p-value < 0.05
(1; not realistic to 5; very realistic)	**group 1** (n=15)	**group 2** (n=20)	**group 3** (n=21)		
the appearance of the instruments	3.86	4.10	3.83	3.94	
the movement of the instruments	3.86	3.70	3.33	3.62	
the freedom of movement of the instruments	3.57	3.45	3.72	3.58	
the function of the instruments	3.71	3.45	3.44	3.52	
the tissue reaction on manipulation	3.14	3.00	2.28	2.79	3<2; p 0.042 3<1; p 0.023
the appearance of organs	3.29	3.15	3.28	3.23	
the appearance of needle and thread (n=47)	2.86	3.35	2.38	2.87	3<2; p 0.021
the sterilisation skill (tuba occlusion)	3.71	3.60	3.11	3.46	
the ectopic pregnancy skill	3.57	3.50	3.22	3.42	
the myoma suturing skill (n=46)	2.43	2.53	2.33	2.43	
the overall ergonomics	3.36	3.15	3.50	3.33	
What do you think about the training capacities ? (1; useless to 5; very useful)					
the simulator in general	4.43	4.60	4.11	4.38	3<2; p 0.034
the simulator to train hand-eye coordination	4.29	4.55	4.50	4.46	
the simulator to train depth perception	3.71	3.75	2.94	3.46	3<2; p 0.020
the skill; camera navigation	3.64	3.85	3.72	3.75	
the skill; instrument navigation	3.93	3.90	4.06	3.96	
the skill; coordination	4.07	4.00	4.00	4.02	
the skill; sterilisation 1 (with clips)	3.93	4.05	3.33	3.77	3<2; p 0.039
the skill; sterilisation 2 (with cutting)	4.00	4.15	3.33	3.83	3<2; p 0.008
the skill; ectopic pregnancy	4.21	3.90	3.50	3.85	3<1 p 0.020
the skill; myoma suturing (n=48)	3.36	3.22	2.81	3.13	
How disturbing is the lack of haptic feedback ?					
(1; very disturbing to 5; totally not disturbing)	2.50	2.50	2.61	2.54	

Table 2 Statements: The LapSim is an usefull instrument to..............					
Statement: the LapSim is an usefull instrument to…	Group	Agree (%)	Disagree (%)	Do not know (%)	Total agree (%)
…train endoscopic techniques to	1	100	0	0	
Residents	2	100	0	0	94
	3	83	6	11	
…train endosopic techniques to	1	86	0	14	
gynecologist	2	70	0	30	79
	3	83	6	11	
…train endoscopic basic skills	1	93	0	7	
	2	100	0	0	98
	3	100	0	0	
… train hand-eye coordination	1	100	0	0	
	2	100	0	0	100
	3	100	0	0	
…measure the skills for an	1	86	7	7	
endoscopic procedure	2	70	5	25	62
	3	33	11	56	

minutes. Five of the 56 subjects (9%) were able to tie one knot, the other subjects none. From these five participants four were from the expert group and one from the intermediate group.

Figure 1 shows the performance parameters time, path length, angular path and tissue damage for the four basic skills together. The more experienced the group the better was the performance. There was a significant difference for path length and angular path between group three and two (P = .028 and P = .022) and between three and one (P = 0.00, and P = 0.00). The ectopic pregnancy module showed the most distinctive difference in performance between the three groups (**Figure 2**). The experts performed best, followed by the intermediates and novices. In this ectopic pregnancy module group one was significant slower than group two (P = .005) and group three (P = 0.00). The total path length and angular path were significant longer in group one versus group three (P = .003 and P = .010). The blood loss was significant more in group one than group two (P = .010) and group three (P = 0.00). The boxplot **Figure 2** also shows that there was less variability in performance in the experts group than the intermediate and novice subjects group.

Table 3 the statistical significant parameters of each task; construct validity

Task with parameter	Group 1 (n=15) Novice	Group 2 (n=20) Intermediate	Group 3 (n=21) Expert	Significant difference ($p < 0.05$)
Camera navigation				
Path length (meter)	4.34	4.04	3.32	3<1 and 3<2
Angular path (degrees)	1720	1556	1223	3<1 and 3<2
Instrument navigation				
Right instrument time (seconds)	37.8	33.7	30.3	3<1
Left instrument time	37.1	33.0	29.1	3<1
Tissue damage (number times)	3.37	2.78	1.91	3<1
Coordination				
Total time	106	104	90	3<1 and 3<2
Instrument misses (%)	47.0	35.8	22.1	3<1
Camera path length	1.68	1.30	1.10	3<1
Camera angular path	859	671	563	3<1
Clip applying				
No significant parameter				
Sterilisation clip				
Total time	79.0	88.8	67.4	3<2
Applied clips (number)	2.07	2.70	2.16	3<2 and 2>1
Right side clip distance (mm)	19.7	15.5	18.6	2<1 and 2<3
Left instrument angular path	191	241	131	3<2
Sterilisation cut				
Bleeding (mililiter/second)	0.11	0.11	0.04	3<2
Ectopic pregnancy				
Total time	384	251	212	3<1 and 2<1
Blood loss (mililiter)	198	113	86	3<1 and 2<1
Unremoved diss tissue (number)	0.60	0.31	0	3<1
Left instrument path length	3.68	2.80	2.13	3<1
Right instrument path length	5.84	4.21	2.73	3<1
Right instrument angular path	1082	778	469	3<1

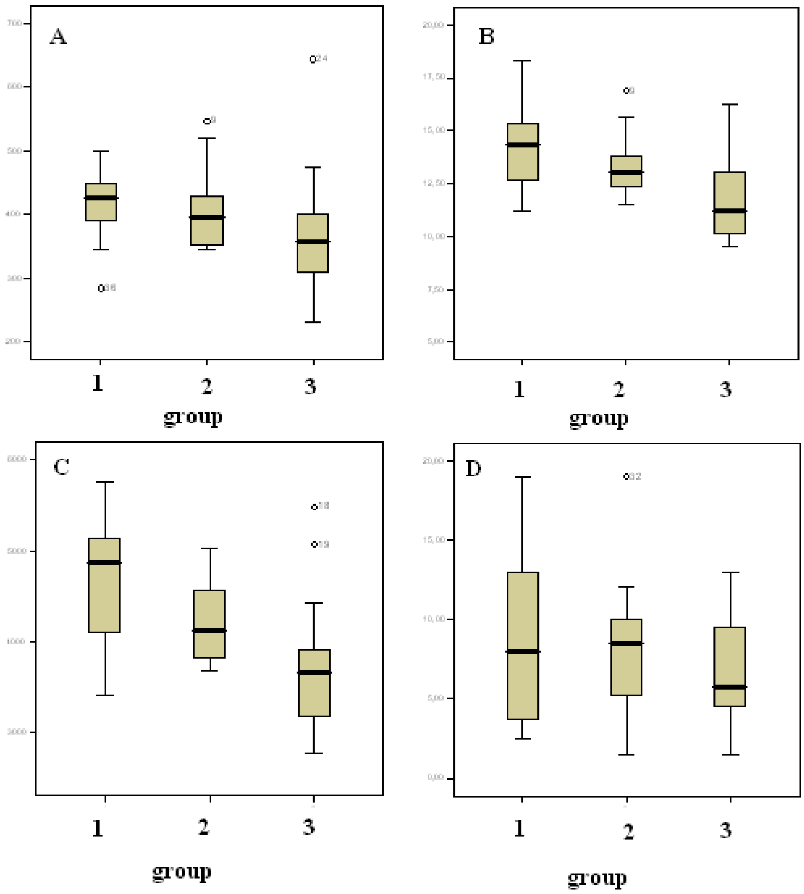

Figure 1 Boxplots of four basic skills together. Parameters time (A, seconds), path length (B, meter), angular path (C, degrees) and tissue damage (D, number of times).

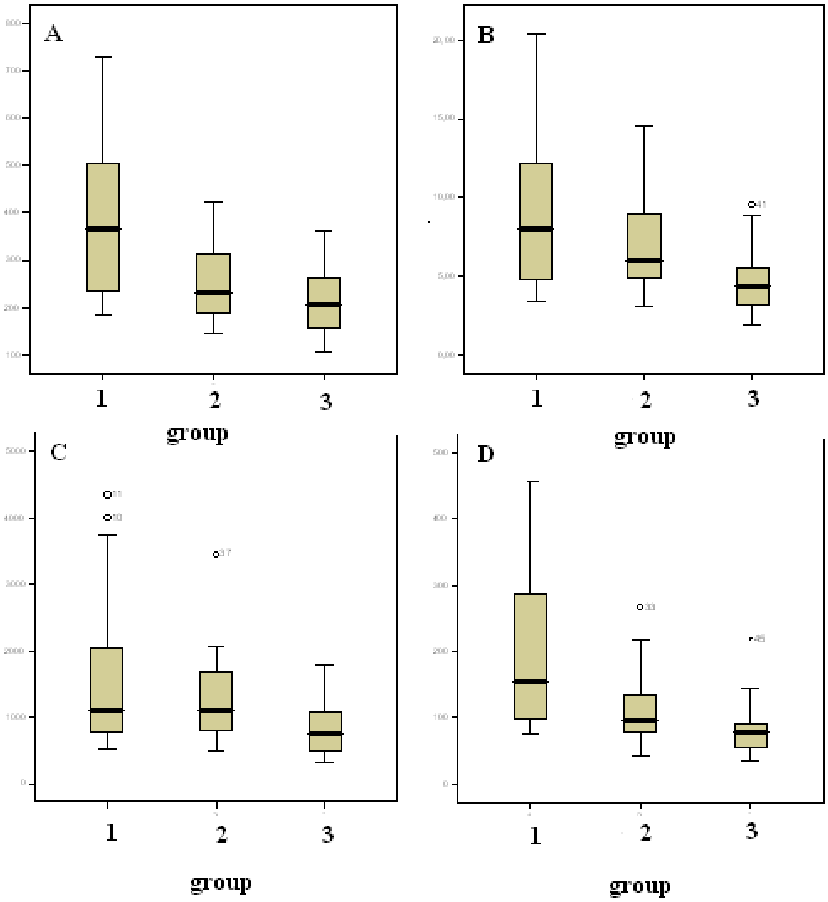

Figure 2 Boxplots of results of the ectopic pregnancy skill. Parameters time (A, seconds), path length (B, meter), angular path (C, degrees) and blood loss (D, ml).

Comment

The questionnaire demonstrated reasonable face validity. The majority of participants believed the LapSim could become a useful tool in training laparoscopic skills to residents and gynecologists. No other studies are known that describe face validity of the LapSim VR simulator for the use in gynecology.

The LapSim was able to differentiate between subjects with varying laparoscopic experience; the performance of the subjects on the virtual reality simulator was proportional to their laparoscopic experience. Twenty out of 82 parameters in different skills were sensitive enough to show a significant difference between the performance of the three groups. Although we could confirm the construct validity of the LapSim, there was a difference in the discriminative properties of the skills. In the basic skills most difference between the groups was found in camera navigation, instrument navigation and coordination. Not all measured parameters are able to show a difference between the groups, this was also found by Woodrum et al [19]. This group used three of the four basic skills we used in this study (coordination, instrument navigation and clip applying). Interestingly, our research confirms their results indicating that time, path length and angular path are the most discriminative parameters. In our study, the coordination skill showed besides time, three other significant parameters (instrument misses, camera path length and camera angular path) and the instrument navigation skill showed another significant parameter (tissue damage instead of path length). In this study the clip applying skill did not show a significant performance parameter, whereas Woodrun et al [19] found three parameters (time, incomplete target areas and blood loss) and Larssen et al [17] found also three parameters (time, path length and angular path) to differentiate significant between the groups. A possible explanation for the smaller difference between the groups in this skill could be the fact that the task is complex. There are some pitfalls that can contribute to a longer performance of the task. Therefore one short familiarization run might not be enough for a reliable measure of the performance of this task.

It can not be excluded that the study is underpowered, because no power calculation was done on for hand

Within the gynecologic procedural simulations the removal of the ectopic pregnancy discriminates the best, as reflected in outcome performance parameters of the different groups. The ectopic pregnancy simulation also scored best by the experts in the questionnaire about the realism and training capacities of the LapSim. The gynecologic suturing skill was not showing a difference among the groups simply because none of the participants could finish this exercise in the available time. Probably it was too complicated, especially within the restricted timeset of five minutes. Further more the graphics of this complicated skill could be improved. Especially the view and fluency of the needle and suture itself. .

It is important to realize that in this study not all performance parameters measured by the LapSim system were able to differentiate between subjects with different levels of experience. This could possibly be explained by the size of the study, or because these parameters might not be valid measures of laparoscopic performance. For procedural tasks one could develop a scoring system which is build on certain clinical relevant performance parameters. In general surgery this was done for the clip and cutting-phase of a laparoscopic cholecystectomy [12].

In the present study the construct validity of the gynecology module is demonstrated. The myoma suturing skill needs to be improved and investigated but the removal of the ectopic pregnancy is a valid and realistic simulation of the VR trainer. This is consistent with the findings of other studies [16;17].

The sterilization simulation showed some significant performance parameters but less than the salpingectomy simulation. In this task on some parameters the novices preformed better than the intermediates. This could be explained by different factors. The sterilisation simulation is not very structured. There is no real parameter to determine if the sterilization is established (clip on the right place? or tuba cut completely through?) and the exercise does not stop automatically. Perhaps it was necessary to give the subjects more instructions about this task.

In the last few years several studies concerning the validation of the basic skills of LapSim for training endoscopic skills have been published by different studies on surgical residents[8;9;11;13;14;19;20] These studies have shown construct validity for the LapSim virtual reality simulator in general surgery. In the field of gynecology Larssen et al showed construct validity for the LapSim simulator[17]. Aggarwal et al [16] showed that virtual reality simulation is usefull in the early part of the learning curve for residents who wish to learn to perform the salpingectomy for ectopic pregnancy. An overview of the use of virtual reality trainers in gynecology is recently given by Hart R et al. In concordance with our opinion, they conclude that virtual reality training will become an essential part of clinical training in the near future[21].

In conclusion the findings of this study are one of the first steps of confirming that virtual reality laparoscopic simulators have great promise in gynecological training. It is an objective and constant system which can measure a trainee's skill level. All the participants in our study thought it was an useful instrument to train eye-hand coordination and almost all thought it was an useful instrument to train endoscopic skills. Face and construct validity in gynecology are established for this simulator. Further research should be done on the predictive validity of the simulator, to show if training on the simulator predicts better performance in the operating theater.

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Chapter 10

Summary and general conclusions

Samenvatting in het Nederlands

Samenvatting in het Tilburgs

Dankwoord

Curriculum vitae auctoris

Endoscopic surgery demands different specific psychomotor skills than open surgery. Virtual reality simulation training has the potential to be a valuable tool in training these skills, because simulation provides the opportunity to train psychomotor skills in a safe environment. In addition to training, virtual reality simulators are capable to objectively assess the skills of a subject in training. In contrast to traditional box trainers and animal models that require human monitored evaluation resulting in subjective assessment. The LapSim virtual reality simulator is a system designed to develop and assess basic psychomotor skills and advanced laparoscopic tasks in a virtual environment[1;2]. As discussed in the introduction, prior to implementation of these simulation based training modalities into the surgical training curriculum some questions are to be answered.

What are the expectations and desires of surgical residents on endoscopic training programs in teaching hospitals in the Netherlands?

In *Chapter 2* a survey of the expectations and desires of surgical residents on endoscopic training programs in teaching hospitals in the Netherlands is described. Residents' expectations against actual training programs offered were contrasted. Residents support the endorsement of a certified, well- endorsed endoscopic training curriculum in line with the demands of Dutch Healthcare Inspection and guidelines of the surgical training community[3;4]. Apparently surgeons still allow residents to perform endoscopic surgery without having participated in such a training program. Only 24,8% of the subjects have had instruction in handling the endoscopic equipment safely and properly. Almost all residents expect to be able to perform basic endoscopic skills autonomously on completion of their surgical residency, yet 18.2% of residents expect to be sufficiently prepared for advanced procedures. This supports the rationale for implementing a uniform endoscopic training curriculum.

Does the LapSim virtual reality simulator show construct validity?

In Chapter 3 and *Chapter 4* construct validity for the LapSim virtual reality simulator is established. It is demonstrated that the simulator discriminates between participants of different endoscopic surgical experience. Subjects were divided into groups subject to level of experience. A scoring system including parameters such as speed, accuracy and efficiency was developed and used to test the endoscopic surgery skills of the different groups. Experienced surgeons performed significantly better than novices, therewith proving construct validity for the LapSim. Furthermore *Chapter 4* looks at the learning curve for basic endoscopic skills of two groups with different experience in endoscopic surgery. Although there was an initial "familiarization curve" with the simulator for all levels of experience; thereafter novices showed a steeper learning curve than experts, which in turn proves that the simulator can discriminate between different levels of experience. Therefore, it is both a valuable training and assessment tool.

Is it possible to determine the number of repetitions needed for a novice to reach expert levels?

In addition, in *Chapter 4* it is demonstrated that the number of repetitions of the modules in a VR simulator is not an indicator for efficiency levels. Novices had not achieved expert level after 15 sessions, whilst having improved their score and experts were still improving after 15 sessions. Therefore a training program ought to contain reference points based on expert scores rather than being fixed in number of sessions. Is it possible to reach consensus on the settings of these exercise configurations and training programs?

In *Chapter 5* a European multicenter validated training program was designed in line with a general consensus amongst members of a large international team with extended experience in virtual reality simulation. To achieve this, a consensus meeting with eight European teams, all very experienced in using the VR simulator was organized. Construct validity of the training program was tested using 20 experts and 60 novices. Consensus was achieved on training designs, exercise configuration and examination. Practically all exercises (seven out of eight) showed construct validity. Therefore a proficiency based training program can be offered to training centres that use this simulator for training basic psychomotor skills in endoscopic surgery.

What is the effect of distributed and massed training on the initial development and retention of psychomotor skills on a virtual reality simulator?

Chapter 6 investigates the difference between distributed and massed training on the initial development and retention of psychomotor skills on a virtual reality simulator. Four groups of medical students lacking any experience in endoscopic training were created. Two groups trained in a distributed fashion, one group trained in a massed fashion and the last group not at all (control group). Distributed training resulted in higher scores and a better retention of relevant psychomotor skills. These results support the findings of earlier studies on technical surgical and psychomotor skills[2;5;6]. Current training programs in the Netherlands are usually based on a two or three day regime, which provides a possibility for massed training only. Our study however, clearly shows that distributed training yields better results in psychomotor endoscopic skills. Therefore, in order to train as efficient as possible, training should contain multiple sessions in time.

Are surgical residents willing to train endoscopic skills on a voluntary basis when VR simulators are indeed readily available?

Chapter 7 shows that free unlimited access to a VR simulator training basic endoscopic skill, without any form of obligation or assessment, does not motivate surgical residents to use the simulator at all.

What is the effect of competitive incentives on the frequency and duration of simulator training?

In *Chapter 7* the introduction of a competitive element is investigated. It increased voluntary training slightly but it only appealed to a third of the residents as a motivator. Therefore, the acquisition of expensive devices to train basic psychomotor skills for endoscopic surgery should only be considered when introduced as an integrated and mandatory part of the surgical curriculum.

Will the "playstation-generation" become better endoscopic surgeon?

Chapter 8 evaluates the assumption that the "playstation-generation" would have superior baseline psychomotor skills. A comparison was made between interns of the department of surgery (24 year old) with and without videogame experience and schoolchildren (12,5 year old) with and without videogame experience. Interns performed significantly better than schoolchildren, irrespective of their video game experience. This could be explained by the fact that schoolchildren's psychomotor abilities are not fully developed. At adult age, a difference in favor of gaming is present. In schoolchildren a statistically significant advantage of video game experience could not be shown, although there appeared to be a slight benefit. The next generation surgeons might therefore benefit from video game experience during their childhood.

Does the LapSim virtual reality simulator show face and construct validity in gynecology?

In *Chapter 9* face and construct validity for the laparoscopic skills in gynaecology is established. The three different groups (novices, intermediates and experts) all were positive about dimensions such as realism and training capabilities (face validity). In addition, scores were consistent with the experience levels of the group, i.e. experts performed significantly better than intermediates and in turn intermediates better than novices (construct validity).

General conclusions

There is an important role for virtual reality training and assessment in training psychomotor endoscopic skills. At this moment residents feel confident in performing basic endoscopic skills at the end of their surgical training. However, endoscopic surgery should not be allowed prior to completing a certified, objective training program at the start of training. Both residents and surgeons feel it is important to train and assess endoscopic skills prior to performing endoscopic surgery. Residents do not demonstrate an intention to train voluntary and surgeons still appear to allow residents to perform endoscopic surgery without any training or assessment.

The LapSim© virtual reality simulator is a valuable training and assessment device for endoscopic psychomotor skills.

Our research in this field has shown that there is not a defined number of "sessions" that would allow anyone to achieve "expert status". Residents show different performance patterns and different training needs. Therefore, it is rather the achievement of certain proficiency levels that is relevant in training. Lastly, distributed training is shown to be more effective than massed training. Training programs should be modified to contain proficiency levels rather than number of sessions as well as distributed rather than massed.

A virtual reality simulator has shown to be highly supplementary in training psychomotor skills for residents with no or limited endoscopic experience. However, to be effective, it is imperative for a training program to be validated, objectively assessed, mandatory, trained distributed and proficiency based. Residents should be able to execute their newly acquired skills in the operating theatre as soon as practically possible after training.

Future perspectives

An important next step is to establish predictive validity of a simulator[1;7]. Do the skills learned in a simulator transfer to the operating room? Several studies have shown very encouraging results. The real time performance was improved in the group trained with virtual reality trainers[7-12]. However some care should be taken in interpreting these studies. They either use groups with different background (surgical versus non-surgical residents), observers who were not blinded, no randomization or have small sample sizes. VR training does reduce operating time, errors and unnecessary movements during laparoscopic cholecystectomy. Understandably, ethical considerations have caused VR training to be introduced as another tool or even replacement in standard laparoscopic training. To date, cost effectiveness is still to be proven and further research on transfer of psychomotor skills ought to be done.

The next generation simulators are focusing on procedural skills instead of training psychomotor skills only. A complete procedure, for instance a laparoscopic cholecystectomy is simulated. These simulators are in development, though still require substantial improvement to simulate a surgical procedure credible.
It now is possible to import three-dimensional images into VR software[2;13]. In the future it might therefore be possible to import images of CT-scans or MRI's into a virtual reality trainer. Training such a reconstruction of a real operation, including anatomical variations would be a major improvement.
Clearly this thesis has been limited to psychomotor skills, but VR training is certainly not limited to that arena alone. Since the introduction of endoscopic surgery as a routine technique into surgical practice it is known that a skillfully performed operation is only 25% dexterity and 75% decision making[14]. Computers and VR simulation can be used in training and assessing a host of other relevant capabilities necessary during operations. Knowledge of a procedure, patho-physiology, anatomy, indication for operations and problem solving are equally relevant and should therefore find their way into VR training as well.

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Eind jaren '80 werd de endoscopische chirurgie (kijkoperatie) geïntroduceerd als chirurgische routine techniek in de algemene chirurgische praktijk.
Bij endoscopische chirurgie wordt een aantal kleine incisies geplaatst, in plaats van één grote incisie. Via deze incisies worden de instrumenten door middel van trocars geïntroduceerd, Trocars zijn speciaal ontworpen buisjes, die deze techniek mogelijk maken.
Een speciale camera (endoscoop), visualiseert het werkgebied op een monitor. De endoscopische chirurgie minimaliseert het trauma aan het lichaam. Dit heeft voor de patiënt onder meer de volgende voordelen: minder pijn, kortere ziekenhuisopname, kleinere littekens en snellere terugkeer naar dagelijkse fysieke activiteiten.
Een kijkoperatie vereist echter andere specifieke psychomotore vaardigheden dan open chirurgie. Virtual reality simulatie training kan een waardevol trainingsinstrument zijn om deze vaardigheden aan te leren. Simulatie biedt namelijk de mogelijkheid om deze vaardigheden te trainen in een veilige omgeving, zonder dat hierbij patiënten risico lopen. Naast training biedt een simulator ook de mogelijkheid om de vaardigheden van de betreffende chirurg objectief te beoordelen. Dit in tegenstelling tot andere trainingsmodellen, zoals een box-trainer of dierenmodel, waarbij de beoordeling altijd door een persoon gedaan zal moeten worden en dus een subjectieve component in zich heeft.
De LapSim virtual reality simulator is een systeem dat is ontworpen om psychomotore basisvaardigheden, noodzakelijk voor het beoefenen van endoscopische chirurgie te trainen en te beoordelen in een virtuele omgeving. Alvorens een dergelijk trainingsinstrument in een chirurgisch curriculum te implementeren, dient eerst een aantal vragen beantwoord te worden.

Wat zijn de verwachtingen en wensen van chirurgen in opleiding met betrekking tot trainingsprogramma's voor endoscopische chirurgie in de opleidingsziekenhuizen in Nederland?

In hoofdstuk 2 wordt een onderzoek over de verwachtingen en wensen van chirurgen in opleiding met betrekking tot de trainingsprogramma's van endoscopische chirurgie in Nederland beschreven. Deze werden vergeleken met de feitelijke stand van zaken. Chirurgen in opleiding steunen de noodzaak van een gecertificeerd goed onderbouwd onderschreven opleidingsleerplan voor endoscopische chirurgie, overeenkomstig de eisen van de Nederlandse Inspectie van de Gezondheidszorg en de richtlijnen van de Nederlandse Vereniging voor Heelkunde. Wel is gebleken dat er nog steeds chirurgen zijn die chirurgen in opleiding, onder supervisie, kijkoperaties laten doen, zonder dat de laatsen aan een dergelijk trainingsprogramma hebben deelgenomen. Slechts 24,8% heeft instructies gehad over het veilig gebruiken van instrumentarium voor kijkoperaties. Bijna alle chirurgen in opleiding verwachten aan het eind van hun opleiding in staat te zijn standaard kijkoperaties zelfstandig uit te kunnen voeren. Slechts 18.2% verwacht goed voorbereid te zijn op het uitvoeren van meer complexe ingrepen door middel van een kijkoperatie.

Kan de LapSim virtual reality simulator experts van beginners onderscheiden?

In hoofstuk 3 en 4 wordt de zogenaamde "construct validity" voor de LapSim virtual reality simulator aangetoond. Dit betekent dat de simulator onderscheid kan maken tussen mensen met verschillend ervaringsniveau op het gebied van kijkoperaties. Dit is belangrijk omdat hiermee wordt aangetoond dat de simulator ook meet wat er moet gemeten worden. Hiertoe zijn proefpersonen ingedeeld in groepen op basis van hun ervaring. Een scoringssysteem gebaseerd op de uitkomsten van de simulator werd ontwikkeld. Deze uitkomsten omvatten parameters zoals snelheid, accuratesse en efficiëntie. Ervaren chirurgen presteerde significant beter dan proefpersonen zonder ervaring op het gebied van kijkoperaties. Tevens werd in hoofdstuk 4 gekeken naar de leercurven van twee groepen met verschillend ervaringsniveau. Beide groepen moesten eerst wennen aan de simulator, maar daarna was de leercurve van proefpersonen zonder ervaring op het gebied van kijkoperaties veel steiler dan die van experts. Hiermee wordt ook aangetoond dat de simulator in staat is een verschillend ervaringsniveau aan te tonen. Daarmee is het dus een waardevol training- en beoordelingsinstrument.

Is het mogelijke het aantal herhalingen van oefeningen te bepalen, dat nodig is om het niveau van experts te behalen?

Hoofstuk 4 laat zien dat dit ons niet gelukt is. Beginners hadden na 15 herhalingen nog niet het niveau van experts behaald. Ook de experts lijken zich nog te verbeteren na 15 herhalingen. Het lijkt daarom beter om een niveau te bepalen dat bereikt moet worden, in plaats van een vast aantal herhalingen verplicht te stellen.

Kan er consensus worden bereikt over de instellingen van de configuraties voor de oefeningen en een trainingsprogramma?

In Hoofdstuk 5 werd een Europees multicenter gevalideerd trainingsprogramma opgesteld overeenkomstig een algemene consensus onder leden van een internationaal team met uitgebreide ervaring in virtual reality simulatie. Om dit te bereiken, werd een consensusvergadering met acht Europese teams georganiseerd.

Construct validity van het trainingsprogramma werd aangetoond door 20 experts 60 beginners het programma te laten testen. Consensus werd bereikt op het gebied van trainingsontwerp, configuratie van de oefeningen en het examen. Praktisch alle getoonde oefeningen (zeven van de acht) laten "construct validity" zien. Daarom kan hiermee een trainingsprogramma aan opleidingscentra worden aangeboden met eindpunten gebaseerd op vaardigheid.

Wat is het verschil tussen verdeelde en gegroepeerde training op de ontwikkeling en op het behoud van vaardigheden?

Hoofdstuk 6 onderzoekt het verschil tussen verdeelde (vaak en kort) en gegroepeerde training (soms en lang) op de aanvankelijke ontwikkeling en behoud van psychomotorische vaardigheden op een virtual realitiy simulator. Er werden vier groepen van medische studenten met dezelfde ervaring op het gebied van endoscopische chirurgie gecreëerd. Er werden twee groepen getraind volgens een verdeeld schema, één groep volgens een gegroepeerd schema en één groep trainde helemaal niet (controlegroep). De verdeelde training resulteerde in hogere scores en een beter behoud van relevante psychomotorische vaardigheden. Deze resultaten steunen de bevindingen van vroegere studies over technische chirurgische en psychomotorische vaardigheden. De huidige trainingsprogramma's in Nederland zijn meestal in twee of drie opeenvolgende dagen gepland en dus gegroepeerd. Onze studie toont duidelijk aan dat de verdeelde opleidingsopbrengsten in betere psychomotorische endoscopische vaardigheden resulteert. Dus, om zo efficiënt mogelijk op te leiden, zou de training ook zo aangeboden moeten worden.

Zijn chirurgen in opleiding bereid om endoscopische vaardigheden op vrijwillige basis te trainen wanneer de VR simulator makkelijk beschikbaar is?

Hoofdstuk 7 toont aan dat vrije onbeperkte toegang tot een VR simulator voor het trainen van basis endoscopische vaardigheden, zonder enige vorm van verplichting of beoordeling, chirurgen in opleiding niet motiveert om deze te gebruiken.

Wat is het effect van het toevoegen van een competitief element op de frequentie en de duur van het gebruik van de simulator?

In hoofdstuk 7 wordt de introductie van een competitief element onderzocht. Er werd minimale toename gezien van vrijwillige training. Slechts door een derde van de chirurgen in opleiding werd er vrijwillig getraind. Daarom zou de aanschaf van dure apparaten om fundamentele psychomotorische vaardigheden voor endoscopische chirurgie te trainen slechts moeten worden overwogen wanneer deze worden geïntroduceerd als geïntegreerd, en verplicht onderdeel van een chirurgische opleiding.

Zal de „playstation-generatie" betere endoscopische chirurgen leveren?

Hoofdstuk 8 evalueert de veronderstelling dat de „playstation-generatie" superieure psychomotorische vaardigheden zou hebben. Een vergelijking werd gemaakt tussen co-assistenten van de afdeling chirurgie (24 jarigen) met en zonder ervaring met videospelletjes en schoolkinderen (12.5 jarigen) met en zonder ervaring met videospelletjes. De co-assistenten presteerden beduidend beter dan schoolkinderen, ongeacht hun ervaring met videospelletjes. Dit zou kunnen worden verklaard door het feit dat de psychomotorische capaciteiten van schoolkinderen nog niet volledig zijn ontwikkeld. Op volwassen leeftijd, is een verschil ten gunste van ervaring met videospelletjes aanwezig. Bij de groep van schoolkinderen kan een statistisch significant voordeel van ervaring met videospelletjes niet worden aangetoond, hoewel er wel een klein voordeel lijkt te zijn. De volgende generatie chirurgen zou wellicht van ervaring met videospelletjes tijdens hun kinderjaren kunnen profiteren.

Laat de LapSim virtual reality simulator face- en construct validity zien bij gynaecologen?

Hoofdstuk 9 bewijst face- en construct validity voor de LapSim virtual reality simulator bij gynaecologen. De drie verschillende groepen (beginners, intermediate, experts) waren allen positief over het realisme en de trainingsmogelijkheden (face-validity). Bovendien waren de scores verenigbaar met de ervaringsniveaus van de groep, d.w.z. experts scoren significant beter dan intermediates en intermediates scoren weer beter dan beginners (construct validity).

Algemene conclusies

Een virtual reality simulator is een belangrijke toegevoegde waarde in het trainen van psychomotore vaardigheden voor endoscopische chirurgie. Om hier zo effectief mogelijk mee te kunnen trainen is het noodzakelijk dat het trainingsprogramma gevalideerd is, objectief gescoord wordt, verplicht is en aangeboden wordt als verdeelde training en op basis van expert waardes het minimaal te behalen niveau wordt afgesproken.

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"Meej en kèèk-ooperaasie? "

"Wè ge wilt dòkter,´k hèb pènt in menen bèùk,

èn gij zèèt hier de naajert"!

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Veel mensen die mij gedurende de periode dat dit proefschrift tot stand is gekomen, bewust of onbewust, hebben geholpen ben ik mijn dank verschuldigd. Zonder anderen tekort te willen doen, is er een aantal personen, die ik met name(n) wil noemen.

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The author of this thesis, Koen Willem van Dongen, was born in Utrecht on April 12, 1976. He graduated high school at the Stedelijk Gymnasium in Utrecht in 1994 and matriculated to medical school at the University of Amsterdam. In 1998 he worked as a research fellow in the field of pediatrics at the Tygerberg Hospital, University of Stellenbosch, Capetown, South-Africa under Prof. Dr. C.J. de Groot and Prof. Dr. P.B. Hesseling. In August 2003 he graduated for his medical training and in January 2004 he started the work of this thesis as a research resident at the Department of Surgery, University Medical Centre Utrecht under Dr. I.A.M.J. Broeders and Prof. Dr. Chr. van der Werken. In 2005 he started as a resident at the Emergency Department of the University Medical Centre (Dr. E.J.M.M. Verleisdonk and Prof. Dr. L.P.H. Leenen). In 2006 he started his surgical training at the University Medical Centre Utrecht (Prof. Dr. I.H.M. Borel Rinkes). Koen continued his surgical training in 2008 in the Twee Steden Hospital in Tilburg (Dr. S.E. Kranendonk), which he will finish in December 2011. During this period the research for this thesis continued under the supervision of Prof. Dr. I.A.M.J. Broeders, Dr. M.P. Schijven and Prof. Dr. Chr. van der Werken.