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Validation of a video game made for training laparoscopic skills

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Chapter 8

Discussion, conclusions, and future perspectives

Ever since Richard Satava made the link between video games, and, the then upcoming, laparoscopic techniques – something he somewhat jokingly called the coming of the age of the “Nintendo surgeon”¹ – a lot has changed in the field of laparoscopic surgery and training. Although expected, little did Satava then know that training laparoscopy with advanced, virtual reality simulators would already become commonplace in laparoscopic surgery². And, probably, neither did he expect that a positive correlation between playing video games and basic laparoscopic skills would actually be established in scientific literature, giving rise to a very peculiar sub specialism in both the serious games and laparoscopic simulator businesses.

In chapter 2, we’ve seen that the amount of observational studies on video game experience and baseline laparoscopic skills, and controlled experiments addressing the positive effects of actual video game training, are gradually increasing. After this literature review, new papers on this subject – all but one supporting our hypotheses – kept on appearing in the same, increasing trend (figure 1)³⁻⁹. Although the amount of papers is still somewhat limited compared to other fields of research, the link between video games and laparoscopy appears to have caught attention in both scientific and popular literature. The age of the Nintendo surgeon has truly come.

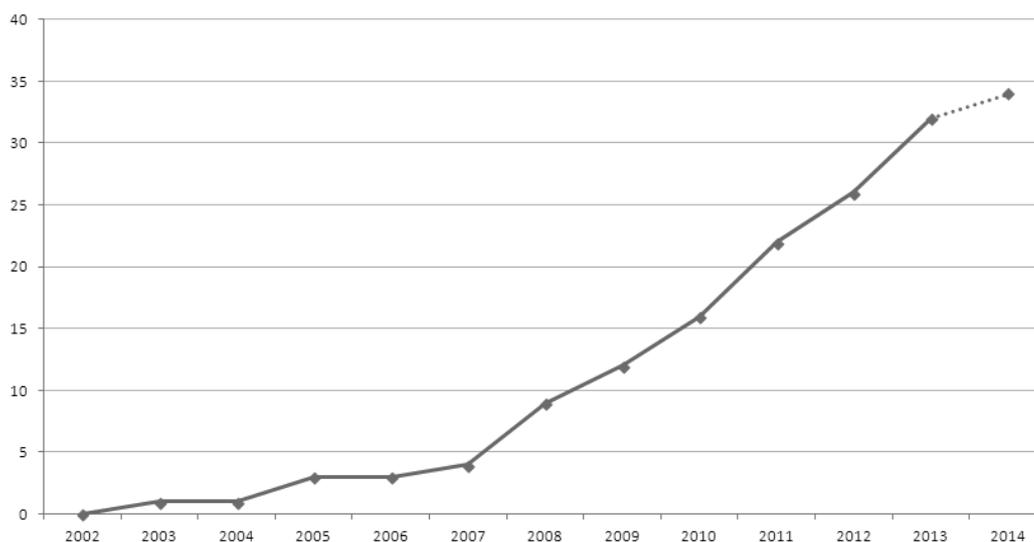


Figure 1: graph showing the cumulative amount of scientific papers addressing the link between playing video games and laparoscopic skills (n.b.: 2014 is an interim score)

As discussed in chapter 2, both existing video game experience and recent video game training can result in significantly shorter operating times and fewer errors (on a simulator). In all of these studies, already existing, non-specific video games have been used for improving laparoscopic skill. And, with the single exception of one study of Bokhari et al., who used a single-handed, custom-made Wii Remote controller add-on for playing an existing video game ¹⁰, only traditional video game input methods were tested. This makes the game described in this thesis, *Underground*, a unique addition to all existing research in the field. Not only did developer Grendel Games create a Wii U video game, specifically aimed at training basic laparoscopic skills, but the umbrella organization, Cutting Edge, also managed to develop a convenient, cheap, and precise laparoscopic input device, based on Nintendo's existing Wii Remote motion tracking device. The idea behind this concept, as discussed in chapter 3, is that a combination of specifically designed hard- and software – closely resembling laparoscopic instruments, but deliberately not mimicking a laparoscopic intervention – has even more effect on laparoscopic basic skills than a traditional video game. By making such a game fun, cheap, and easily accessible, Cutting Edge hopes to develop a good addition to existing virtual reality simulator training.

The developed hardware, and its basic, driver software, were subjected to several test validity studies, as described in chapter 4 and 5. Chapter 4 describes a face validity study, which was conducted with the final hardware, and a near-final version of the video game software. After playing the game, surgeons with experience with laparoscopic surgery, were asked to fill in a questionnaire. The results showed that the custom-made controllers look, feel, and move like real laparoscopic instruments on an acceptable level. Of course, the video game hardware differs from actual instruments; the controllers are quite cumbersome, and lack tactile feedback. But given the fact that the *Underground* hardware is cheap, precise, doesn't require any calibration, and still gets fairly high face validity score, this is accepted. Most importantly, a large majority of laparoscopic experts believe that *Underground* can be a useful tool for training basic laparoscopic skills, such as eye hand coordination, depth perception, inverse movements, and ambidexterity.

When testing the construct and concurrent validity of the controller add-ons, 3D printed prototypes of the hardware were used. In the discussion of chapter 5, we therefore pleaded for a repeated validation study with the final version of the hardware. However, the final hardware hardly differs from the used prototype. The only addition is a small, built-in cog that

provides some mechanical resistance when one opens and/or closes the handle of the instrument. This modification was added after feedback of the experts in the construct/concurrent validity study, which were also asked to fill in a face validity questionnaire after the experiment. (The results of this unpublished face validity study were used as a pilot for the actual face validity study in chapter 4.) Because the changes to the final hardware were only minimal, the construct and concurrent validity studies were not repeated. This experiment showed a strong correlation between a standard skills test (FLS peg transfer test) and the Underground hardware, which means that skills trained on the Underground game correspond to those needed to perform a task in a laparoscopic box trainer. Based on this research, however, it is impossible to claim a direct link to actual laparoscopic surgery.

The effect of playing video games on one's basic laparoscopic skills can roughly be split into two: a short, warm-up effect and a long term effect. As part of experimental validation, we researched the warm-up effect of Underground in chapter 6. We found that laparoscopic experts who played with the first levels of Underground for 15 minutes show a significant decrease in operating time. This study, however, was performed in an experimental setting in which laparoscopic skill was measured by means of a box trainer. Therefore, these results cannot be fully extrapolated to the clinical setting and further research is needed. Still, with these results we suggest that laparoscopic surgeons could benefit from a pre-operative warm-up with Underground.

Finally, chapter 7 looks at the adverse effects of Nintendo's games and hardware in general. Basically, this chapter has nothing to do with the link between video games and laparoscopy. But for the development of a video game with custom-made hardware, it is good to put all possible adverse effects at a glance. Think of it as a sort of risk assessment. Based on the data in this chapter, no big, general problems are to be expected with the Underground hardware. However, given the fact that both motion based video games, such as the Wii, and laparoscopic surgery¹¹ have a reasonable chance of giving rise to various musculoskeletal symptoms, it is to be expected that strenuous practice with Underground may lead to complaints of the upper extremities, neck, and back. Although there are currently no reported cases of musculoskeletal complaints after playing Underground, it is wise to take a 10 to 15 minute break every hour, as is advised in Nintendo's Wii health & safety information¹².

Limitations of this thesis

This thesis lacks a decent content validity study

The Work Group for Evaluation and Implementation of Simulators and Skills Training Programmes of the European Association for Endoscopic Surgery (EAES) defines content validity as “the level to which the system covers the subject matter of the real activity”¹³. This is in contrast to face validity, in which one examines the “resemblance between the system under study and the real activity”.

Underground is a serious game that is aimed at training actual laparoscopic skills, which are to be used in operations on real patients. Although the system itself (the hardware) seems to possess decent face validity, as described in chapter 4, the actual medical content is in absolutely no way comparable to any surgical intervention, making the content validity of the game extremely low¹⁴. The player does not learn anatomy, nor does it gain procedural knowledge. This, however, is done deliberately. If the game itself was to be replaced by a simulated operation in a virtual abdomen, it would no longer be a serious game, but a mere simulator that runs on a video game console¹⁵.

This is why the content validity of Underground was not studied in a separate paper. Testing it for properties as correctness of the anatomy or procedure, tissue feeling, and appropriate physical responses of the patient would be completely useless, simply because those properties were left out of the game on purpose.

However, the hypothesis that Underground is unsuitable for training anatomy and procedural knowledge was tested in a small pilot. This was done by including these two topics on the questionnaire which was used for the face validity study described in chapter 4. These data were not reported in the final paper. In total, 26 expert laparoscopic surgeons participated. The usefulness of Underground for training anatomy scored a median of 1.5 out of 10 (interquartile range 3.3), and training procedural skills and knowledge scored a median of 4.75 out of 10 (interquartile range 5.6). Although not a properly designed study, this pilot shows that Underground does not contain appropriate medical content. As mentioned above, we do not see any value in proving this foreseen lack of content validity any further than this.

The long-term effect of Underground on one's basic laparoscopic skills

It has been shown that virtual reality laparoscopic simulators are cost- and time-effective in training one's basic laparoscopic skills ^{2,16,17}. To benefit from these positive effects, surgical trainees have to spend a certain amount of time training with these machines, which can either be expressed as the amount of hours spent training or the number of repetitions made ¹⁸. Training to pre-set proficiency levels on a laparoscopic simulator has been shown to result in significantly less errors and shorter operation time during actual laparoscopic interventions ^{2,17}. As discussed, in addition to this long-term effect, a short-term (or warm-up) effect has been described as well ^{10,19-22}.

Ideally, the long-term effect of strenuous exercise with the Underground game and hardware on surgical trainees' laparoscopic basic skills should have been covered in this thesis. However, due to a number of limitations, such an experiment was deemed not feasible. First of all, during the course of our studies, the game and its hardware were still in development. Because of Nintendo's strict rules and development structure, it is impossible to run an unfinished version of the game on a normal, commercially available video game console. The experiments in this thesis were therefore performed on special Wii and Wii U developer kits. Not only are these systems expensive, but they are also supplied in very small numbers, and should be closely supervised by the responsible developer. This made it impossible to deploy a certain amount of consoles for a long period of time during the course of our study.

For an ideal study of the long-term effects of the game, a good, single-blind, randomized controlled trial needs to be set up. Because surgical trainees throughout the North of the Netherlands get their experience in different ways (different simulators, different supervisors with their own specialties, and different responsibilities per hospital), there is a large number of confounders which should be corrected. This can be overcome by either increasing sample size or hypothesize larger differences. Since there is no standardized method for assessing basic laparoscopic skills ²³, the latter can be quite challenging, and will probably give rise to some discussion. In the complete North of the Netherlands, only ten new surgical trainees are allowed to start each year ²⁴, a number that is expected to decline in the following years. A power analysis shows we need around 100 subjects for this kind of study. Given the above information, performing such a trial would take too much time and financial resources to be feasible during the period that this thesis was established.

Future perspectives

“More research is needed”

As with all science in general, one experiment is not enough to prove a hypothesis. Studies should be reproduced to decrease the chance of false positive outcomes. Preferably, these should be carried out by an independent, external third party, as this will make the validation of the game more reliable. At the time of writing, the Underground game and hardware are aimed for a release at the end of 2014, and will be commercially available. Independent third parties, with access to sufficient surgical trainees and financial resources, are encouraged to set up their own (validation) studies for the game.

Further uses of the Underground hard- and software

The development of the Underground hardware and its underlying controller software has taken several years. Various prototypes have been rejected and redeveloped, and the software needed a lot of tweaking before an acceptable laparoscopic input device was created. Eventually, the previously described design was chosen and mass produced. The hardware was developed specifically for control of the Underground video game software. However, since the hardware itself has already been released commercially, and has been validated with a rudimentary version of the game made for testing the hardware, it could also be used to serve other purposes. Not only could it be used to easily create another game for training basic laparoscopic skills, but since the input device closely resembles real laparoscopic instruments, one could also use it to develop an actual laparoscopic simulator with appropriate medical content. The main goal was to create a cheap and fun serious game for training basic laparoscopic skills, which could easily be used at home. But since the hardware has been finished and will be distributed this year, it would now be relatively easy to create a traditional simulator for the Wii U – e.g. with a cholecystectomy or appendectomy module – that could be used at home as well. The Wii U is graphically, relatively powerful platform, that can easily display graphics comparable to modern-day simulators. Of course, such a new program needs its own validation studies, with a good evaluation of its medical content in particular.

Not only the Underground hardware, but also the video game software itself could theoretically be used for other purposes than training basic laparoscopic skills (or entertainment). A good example is thoracoscopy, which bears a lot of similarities to laparoscopy²⁵. As with laparoscopy, during a thoracoscopic procedure an endoscope and long

instruments are inserted in a bodily cavity (in this case the thorax instead of the abdomen) for diagnostic and therapeutic purposes. Consequently, skills needed to perform this procedure – such as eye–hand coordination, the ability to handle inverted movements, depth perception, and ambidexterity – are comparable to laparoscopic surgery. It is therefore not unimaginable that the Underground video game could also be used to train these skills in thoracoscopic surgeons as well. In contrast to laparoscopy, as described in chapter 2, no scientific literature on the effects of playing video games on one’s thoracoscopic skills could be found on PubMed. Though it seems quite logical, we cannot claim that Underground is able to contribute to one’s basic thoracoscopic skills training based on the results presented in this thesis, which only focused at laparoscopic skills training. To do so, extra studies to validate the controllers for training thoracoscopic skills are needed.

Another example is arthroscopy, a minimally invasive surgical method to inspect and treat joints from the inside. Movements made during arthroscopy are in many ways similar to laparoscopy, but only on a smaller scale. Existing simulators, such as the VirtaMed ArthroS¹⁵, do have some very basic video game elements built-in, like grabbing stars with an arthroscopic grasper in a virtual reality space. Interestingly, no scientific literature on the effects of playing video games on arthroscopic basic skills could be found on PubMed. However, one could easily imagine that there could be a positive effect between these two as well. Again, separate studies, including renewed construct and concurrent validity experiments, are needed before one can state that Underground could be used for training basic arthroscopic skills as well. Also, one must keep in mind that the Underground hardware is made to look like laparoscopic instruments, not arthroscopic instruments. Theoretically, it is possible to develop a similar system, but with smaller tools that resemble arthroscopic instruments, but due to the weight of the Wii Remote (about 150 gram including batteries), this could turn out quite challenging.

Using Underground for measuring basic laparoscopic skills

The goal of Underground is to be an addition to laparoscopic skills training, and not to be a skills measuring tool. Players should therefore not be judged by their scores. Of course, by proving its face, construct, and concurrent validity, the Underground hardware is validated to measure laparoscopic skill. However, one should bear in mind that this was achieved in special test level, designed in such a way that it only tests the players’ basic laparoscopic skills. In the final version of the game, players still need these skills to successfully beat the

various levels. But, to do so, other skills, such as multitasking abilities, situational awareness, and a certain level of intelligence, are needed too. Hence, the final score is not a pure reflection of basic laparoscopic skills.

Outsiders have often suggested that surgeons should use this game to test surgical residents before they apply for a surgical traineeship. This way, poor scoring residents could be excluded from training, thus, theoretically, improving the average basic skill of future surgeons beforehand. In our opinion, this is not how Underground should be used. First of all, a onetime score on a video game does not reflect future skills, nor does it predict one's learning curves. Secondly, although there is a high correlation with an existing, extensively validated test, the predictive value ($r = 0.812$, $r^2 = 0,66$) of the used level does not equal 1. This means that the test used as a gold standard for basic laparoscopic skills, the FLS peg transfer test, gives a much more reliable idea of a person's skills. Finally, one should not forget that Underground is "just a video game". And it is my, completely non-evidence based, opinion that it would be absolutely ridiculous if someone was rejected such a career in surgery, simply based on a video game. Underground may be a "serious" game, but that doesn't automatically purport that it could be used for a wide array of serious goals.

General conclusions and recommendations

- There is increasing evidence that traditional video games can be used to train basic laparoscopic skills.
- Underground is the first video game that has custom-made hard- and software specifically made for laparoscopic training.
- The Underground hardware and its basic driver software possess solid face, construct, and concurrent validity.
- Since Underground is not a traditional simulator, the validity of its medical content was not tested.
- Although clinical studies have not yet been performed, data from an experimental setting shows that Underground could be used as a pre-operative warm-up.
- Underground could be used to train basic laparoscopic skills in addition to the regular curriculum.
- Underground should not be used for measuring basic laparoscopic skills.
- Underground could, theoretically, be used to train basic thoracoscopic or arthroscopic skills, but it is not yet validated for such purposes.
- As long as gaming technology develops and new ways of gameplay emerge, new video game related health problems will arise.
- When playing a Nintendo game, it is wise to take a 10 to 15 minute break every hour, and watch out where you play motion games.
- More research is needed to assess the long-term effect of playing the Underground video game on the basic laparoscopic skills of surgical residents.

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