Serious games in surgical education
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INTRODUCTION

General Introduction and Thesis Outline
RISE OF THE GAMES

On the fourth of July 2002, the United States Army launched America’s Army, a massive multiplayer online videogame simulating combat experiences. It was designed originally as “strategic communication platform” for the army to reach out to American youngsters. The game was played for over 40 million hours by 2.4 million registered users between July 2002 and November 2003. Because the game encompassed realistic simulations of army training, field commanders soon started to use it as training and selection tool for recruiting new soldiers. This example perfectly illustrates the impact that well-designed serious games can have on society. Serious games can be defined as the application of (digital) games to impose users skills, knowledge or attitudes useful in reality. In games, players are motivated by challenge, narrative, rules and competition to actively display a particular behaviour. That games are able to trigger a player’s intrinsic motivation is of particular use to medicine, has been illustrated by Re-mission (HopeLab, Palo Alto, CA, 2006), a freely available online videogame for teenage leukaemia patients, in which they travel the blood vessels to destroy malignant cells. A randomized controlled trial shows an increase in self-determination and drug adherence in patients playing the videogame, whereas these individuals are usually exceptionally difficult to motivate to adhere to medical treatment regimen.

Homo ludens

Using games to enhance skills acquisition is not a new phenomenon. Czar Peter the Great was known to build simulation armies to try out different military scenarios and strategies. In the 90s, educational videogames were introduced in high school – edutainment programs –, unfortunately with little success. As the videogame industry developed into a multibillion-dollar industry and computer technology became powerful enough to create complex simulations, the possibilities for creating useful and purposeful serious games have increased. User groups have changed dramatically too. The common perception of average gamers being overweight anti-social teenage boys spending their days in their parents’ basement killing off monsters is long overdue. The average gamer to date is 30 years old, 68% of all gamers are above 18 years old and about 47% of them is female. About 77% of gamers play at least one hour a week, and 36% play games on their smart phone.

In The Netherlands, serious games are seen as an interesting growth market. The Dutch game industry is one of the largest in Europe, equalling England and France in scale (330 companies with approximately 3000 employees). In serious gaming, The Netherlands is one of the biggest markets on a global scale (70 companies). For approximately 54% of the consumers recently surveyed by PriceWaterhouseCoopers in the Netherlands, video games are part of their everyday life. To explore serious games for healthcare purposes,
Dutch government funding agency Agentschap NL funded the Patient Safety project (project ‘Patientveiligheid’, reference PID 101060). This spearheaded development of three serious games aimed to improve patient safety: Airway Angels (Grendel Games inc., Leeuwarden), Medialis (Little Chicken, inc., Amsterdam) and the Situation Awareness Game (Weirdbeard, Amsterdam).

**GAMES: LEARNING THROUGH CHALLENGE AND FUN**

**The Flow**

In well-designed games, the *gameplay* captivates the player. It keeps a player motivated and engaged throughout the game and ideally, longing for more after he or she has quit playing. Gameplay comprises of the interaction between the player and a series of challenges imposed by the game, following specific rules. Games thereby seek to create a positive experience and effect in players. Games are most effective when the player enters a state of *flow*\(^ {10}\). In this state of mind, players get completely absorbed in the challenges presented to them, ignoring all surroundings and focus solely on playing. *Flow* results from an optimal balance between the game’s challenges and the player’s abilities, illustrated by Csiksentmihalyi’s flow channel (Figure 1)\(^ {11}\). Factors important for generating flow experience within the gameplay are clearly defined goals, immediate and appropriate feedback, playfulness, usability and speed. Above all, players must sense that the challenges in the game match their abilities\(^ {10}\). Flow results in increased learning, exploratory behaviour, positive attitudes towards the subject and a sense of behavioural control\(^ {10,12,13}\).

\[\text{Figure 1. The flow channel for optimum experience in goal-driven activities}^{11}.\]
Fidelity
Games are ideal for problem-based learning, as long as gameplay and educational goals are sufficiently balanced\textsuperscript{10,14}. Individuals learn from experiences through abstract conceptualization and formation of hypotheses, subsequently refining these in later experiences\textsuperscript{15}. Once challenges, rules and actions in the gameplay sufficiently cohere with real-life situations, transfer of skills to reality can occur\textsuperscript{10}. This is referred to as fidelity of the game. In the past, a lot of effort has been put in creating simulations that bear high physical fidelity to reality (i.e. degree to which the physical appearance replicates the real task), however it has become clear that functional fidelity is most important to skills transfer (i.e. degree to which the game replicates specific cues on which decisions in reality are based)\textsuperscript{16,17}. As long as problem-solving in the game follows the same rules as in real life, contexts and graphical appearance in the serious game are secondary to the learning result, and can be adjusted to optimize the player’s immersion and flow.

Although game-based learning could theoretically be highly effective to train specific medical skills, evidence concerning the effectiveness of game-based training remains limited. Akl\textsuperscript{18} performed an extensive systematic review of the medical literature, describing just two randomized controlled trials applying game-based learning. The game-based learning intervention in both cases showed significant improvement in terms of knowledge outcome compared to the control groups\textsuperscript{18}. Before serious games can be reliably applied in medical training, extensive research is required on the validity of serious games as instrument for education and measurement. Customary to all novel instructional instruments in medical training, validity research ultimately determines the instrument’s ability to improve skills in reality\textsuperscript{19–21}.

GAMES IN SURGICAL CURRICULA: SERIOUSLY?

Competency
Patient safety and quality of care movements, backed by the public, healthcare insurance institutions and the government, demand for a safer, more transparent healthcare system based on the principle of accountability. Only professionals that have proven competent should perform specific procedures on patients. To achieve competency in one specific procedure, trainees must become proficient in skills relevant to this activity. These skills do not only include the ‘technical’ dexterity skills, but also cognitive skills, procedural knowledge, judgment, decision-making, leadership, communication and teamwork\textsuperscript{22}. The competency-based curricula that have recently been implemented in surgical residency training distinguish seven different roles that the surgical professional must master within his or her activities. These roles are based on the CanMEDS
Introduction

Dreyfus et al.\textsuperscript{25} describe a pragmatic model for stages of skills acquisition, distinguishing novice, advanced beginner, competent, proficient, and expert stages (Table 1)\textsuperscript{25}. Novices require conscious processing to execute a procedure, leading to slow execution, unnecessary actions and susceptibility to error. Novices follow strictly rule-based decision paths. Experts perform it seemingly effortless, intuitive and fast, and are far less susceptible to errors and mental strain\textsuperscript{26}. They make superior decisions, are able to respond to emerging task demands and perform at any moment with little preparation\textsuperscript{27}.

### Skills training outside the operating room

Achieving an expert level in complex tasks requires prolonged deliberate practice. This is more than mere repetition, which in itself leads to arrested development over time. In deliberate practice, trainees require a well-defined goal, motivation to improve, feedback and ample opportunities to repeat and refine their performance\textsuperscript{28}. Surgical postgraduate curricula aim to create professionals who are competent, preferably proficient in essential surgical procedures, within approximately 1200 hours of operation time. Even though including the time performing non-essential procedures approximately doubles this number, it can be considered rather little\textsuperscript{29,30}. Simulation and serious gaming could play a significant role in training and assessing performance in individual procedures or activities, limiting the number of ‘flying hours’ required inside the surgical theatre\textsuperscript{29,31}. Ideally, objective measurement of skills and progress within simulators and serious games could lead to a system of accreditation and awarded responsibility. From this perspective, serious games and simulators should not be regarded as two different entities, but rather as two extremities from the same continuum of virtual reality-based training.

Virtual reality (VR) simulators have been evaluated extensively for use of surgical training and skills measurement\textsuperscript{32}. Originally developed for visuospatial skills training and dexterity for minimally invasive surgery (MIS), VR simulators are able to produce standardized, reproducible virtual surgical procedures. Their range encompasses basic task

<table>
<thead>
<tr>
<th>Level of skills acquisition</th>
<th>Description</th>
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<tbody>
<tr>
<td>Novice</td>
<td>Follows rules for specific situations. These rules are not conditional.</td>
</tr>
<tr>
<td>Advanced Beginner</td>
<td>Begins to create and identify conditional rules. Decisions still follow rules.</td>
</tr>
<tr>
<td>Competent</td>
<td>Learns organizing principles. Information sorting by relevance is initiated.</td>
</tr>
<tr>
<td>Proficient</td>
<td>Uses pattern recognition to assess what to do. Uses rules to determine how to do this.</td>
</tr>
<tr>
<td>Expert</td>
<td>No analysis or planning. Pattern recognition extends to plan as well as action.</td>
</tr>
</tbody>
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Table 1. Dreyfus’ model for levels of skills acquisition. A finishing general surgery resident requires at least the level of competence in essential procedures\textsuperscript{29}. |
exercises (e.g. knot-tying or artery clipping) to complete MIS procedures with distinct patient scenarios. Surgical residents training on VR simulators work more efficient and with fewer errors than residents trained with non-VR training. Simulators are able to give high fidelity procedural training, measure skills progression and deliver direct feedback to the trainee. They are thus effective stand-alone training instruments and are incorporated in the residency training curricula of many Western countries, including The Netherlands.

**Integrating VR in competency-based training**

Apart from basic laparoscopic dexterity training, VR simulation has not been widely incorporated into surgical curricula. Necessary financial investments and lack of manpower form practical impediments in many hospitals. Next, the lack of structured, proficiency-based training curricula hinders the integration of simulation in the competency-based surgical training curriculum. VR simulators do not focus on training cognitive, procedural and social skills, creating a discrepancy with the end-terms of the curriculum. Finally, VR simulators are frequently not seen as very motivating teaching instruments by the trainees themselves. Observational studies show that simulators are simply not used by surgical trainees when they are not included as an obligatory part of the curriculum.

In order to make virtual reality the ‘standard’ in competency-based surgical residency training curricula, these challenges have to be met. Applications with a greater focus on cognitive, procedural and communicational skills should be explored. Applications should become more challenging and immersive in order to motivate the trainees to keep practicing outside the OR. Design and technology derived from videogames could very well assist the development of comprehensive VR-enhanced procedural training. The broad range of possibilities in videogame design makes training in cognitive, procedural and communicational skills come within reach. Finally, the main focus in gameplay is to attract the player to continue playing the game. Well-balanced serious games could therefore bridge the gap between VR training and the competency-based surgical residency curriculum.

**OUTLINE OF THIS THESIS**

The aim of this thesis is two-fold. The first aim is to investigate the validity of serious games as training instruments for the surgical curricula. The second aim was to explore new VR-based training solutions that have a greater focus on cognitive, procedural and communicational skills.
Chapter 1 provides an overview of serious games currently developed or under development, relating to training medical professionals. Chapter 2 provides an overview of the professional activities in the surgical curriculum that have the highest priority according to educators.

The first part investigates the possibility to improve surgical trainees’ situational awareness in the operating room using serious games. Chapter 3 provides an overview of the literature regarding teaching methods that showed to be of value in improving situational awareness. Chapter 4 describes the face validity among educators and trainees regarding serious game development for training of non-routine events, aimed to improve situational awareness. Chapter 5 describes its ability to discriminate between different levels of proficiency (construct validity). Chapter 6 describes its ability to predict improvement of trainees’ performance in the operation room (predictive validity).

The second part investigates new perspectives for the use of virtual reality training to support skills training in surgery. Chapter 7 evaluates the validity of a serious game, aimed at teaching knowledge and decision-making of surgical trainees before starting to operate. Chapter 8 discusses the application of simulation training to increase the level of proficiency with camera navigation in MIS for novice surgical trainees. Chapter 9 discusses the construction of a comprehensive, VR-based curriculum for laparoscopic colorectal surgery.

The Synthesis discusses the practical implementation of the serious games and VR simulators described in this thesis. Chapter 10 provides a practical framework for clinicians and educators to evaluate the effectiveness of a serious game. The General Discussion provides perspectives of the construction of a new proficiency-based training curriculum for surgery, in which advancements of VR- and game-based learning instruments are integrated.
REFERENCES


19 Schijven MP, Jakimowicz JJ. Validation of virtual reality simulators: Key to the successful integration of a novel teaching technology into minimal access surgery. Minim Invasive Ther Allied Technol 2005; 14: 244–246.

Introduction


