Chapter 10
How *Serious Games* Will Improve Healthcare

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Abstract Games have the potential to attract large numbers of players and bring to them a specific understanding, skill, or attitude. The classic image of videogaming—socially deprived youngsters killing mystical monsters in their parents' basement—has evolved into a highly social, everyday activity that attracts all age groups to play games in the family living room. *Serious games*, therefore, are increasingly recognized as methods to promote health, treat patients, and train healthcare professionals. Whereas the technological developments in software, platforms, and wearable sensors are moving at high speed, the number of potential applications is rising and so is their use. This chapter aims to give an overview of underlying game mechanisms, main healthcare-related purposes, and the evidence supporting their effectiveness. We conclude that although the field is maturing in terms of diversification and evidence, more high-quality trials are needed to gain insight into the effectiveness of individual games as well as methods to improve transparency for individual users and clinicians.

Keywords Videogame • Education • Medical • Smartphone • Telemedicine • Mobile health • Rehabilitation • Wearable technology

10.1 Introduction

In 2002, the United States Army launched *America's Army*, a massive multiplayer online videogame simulating combat situations. The army originally designed it to be a "strategic communication platform" that would reach out to American

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youngsters. The game was played for over 40 million hours by 2.4 million registered users between July 2002 and November 2003 (Davis 2004). Because it encompassed highly realistic combat simulations, field commanders soon started to use it as a training and selection tool for new recruits (Zyda 2005).

This example perfectly illustrates the impact that well-designed *serious games may* have. Serious games can be defined as the application of (digital) games to improve users' skills, knowledge, or attitudes in real life (Michael and Chen 2006). In games, players are motivated by challenges, narrative, rules, and competitions to actively display a particular behavior or solve a problem. That games are able to trigger a player's intrinsic motivation can be of particular use and significance in the field of healthcare. This has been proven by the serious game *Re-mission* (HopeLab, Palo Alto, CA, 2006), a freely available online videogame designed to help teenage leukemia patients fight their disease. In this game, players virtually travel the blood vessels and combat malignant cells. A randomized controlled trial shows an increase in self-determination and drug adherence in patients playing the videogame, whereas these individuals are typically exceptionally difficult to motivate to adhere to medical treatment regimens (Kato et al. 2008).

Developments in the serious game industry have progressed rapidly in the past decade. Adaptation in healthcare, however, has proved to be slow. As with any healthcare innovation, the major concerns are safety and efficacy against costs for development and maintenance. However, the field may well have bypassed the initial peaks and disillusionments that many tech hypes experience. This chapter aims to give an overview of serious games applied to the field of medicine, evidence, and future issues to be resolved.

10.1.1 Homo Ludens

Using games to enhance skills acquisition is not a new phenomenon. The Russian Czar Peter the Great was known to build simulation armies to try out different military scenarios and strategies (Konstam 1993). In the 1990s, the first educational videogames were introduced in high schools, sometimes referred to as "edutainment" programs—mostly with little success (Susi et al. 2007). As the videogame industry developed into a multibillion-dollar industry and computers became powerful enough to create complex simulations, the possibilities for creating more immersive and purposeful serious games have increased greatly. New generations of serious games differ from edutainment in that they first and foremost attempt to attract and immerse the player into the gameplay while simultaneously incorporating purposeful content in a subtle, stealthy way (Susi et al. 2007; Sharp 2012).

User groups and their behavior 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 gone. The average gamer to date is 35-years-old: 73% of all gamers are over 18-years-old and about 41% of them are female. About 77% of gamers play at least 1 h per week, 48% play games socially, and 36% play games on their smartphones (Entertainment Software Association 2016).

10.2 Learning Through Challenge and Fun

10.2.1 Flow Experiences

In well-designed games, interaction with the gameplay captivates the player. Series of causally linked challenges keep a player motivated and engaged throughout the game and, ideally, longing for more after he or she has quit playing. Gameplay depends on the interaction between the player and a series of challenges presented by the game, following specific (predictable or sometimes unpredictable) rules. Good games evoke emotions and surprise, creating a positive experience in players. Games are most effective when the player enters a state of *flow* (Kiili 2005). In this state of mind, players become completely absorbed in the challenges presented to them, ignoring all surroundings and focusing solely on playing. Flow experience (Fig. 10.1) results from an optimal balance between the game's challenges and the player's abilities as illustrated by Csiksentmihalyi's flow channel (Csikszentmihalyi 1975). Various factors are recognized to generate flow experience, such as clearly defined goals, immediate and appropriate feedback, playfulness, surprise, usability, and speed. Above all, players must sense that the challenges in the game match their abilities as well as a level of control to avoid them from opting-out (Kiili 2005). A player absorbed in a state of *flow* will learn more from the game, explore further, display a more positive attitude toward the subject and feel more in control (Kiili 2005; Schüler 2007; Skadberg and Kimmel 2004).

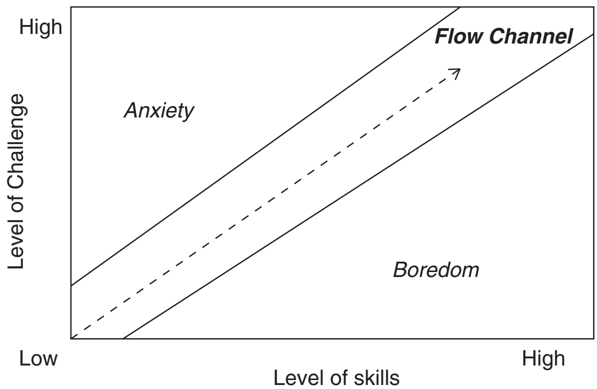

Fig. 10.1 Csikszentmihalyi's *flow* channel shows the relation between challenges and player skills in order to create an optimum experience in goal-driven activities (Schüler 2007)

10.3 Physical and Functional Fidelity

Games are ideal for problem-based learning as long as gameplay and educational goals are sufficiently balanced (Kiili 2005; Rollings and Adams 2003). Individuals learn from gaming experiences through abstract conceptualization and forming hypotheses, subsequently refining them in later experiences (Kolb 1984). If challenges, rules, and actions in the gameplay sufficiently cohere with real-life situations, the transfer of knowledge and skills to reality will occur (Kiili 2005). This is referred to as a game's *fidelity*. In the past, a lot of effort has been put into creating simulations that bare high *physical* fidelity to reality (i.e., the degree to which the physical appearance replicates the real task), whereas it was thought that only perfect physical recreation of the task leads to learning. Therefore, much effort was put into creating *simulators* in medical education, such as the virtual reality simulators in laparoscopic surgery. However, it has become clear that for a game (or simulator) to lead to skills transfer, its *functional* fidelity is most important. This refers to the degree to which the instrument replicates specific cues on which decisions in reality are based (Maran and Glavin 2003; Alexander et al. 2005). As long as problem-solving in a serious game follows the same rules as the real-life situation it is meant to support, the game's contexts and graphical appearance are secondary to the learning result and can be adjusted to optimize the player's immersion and flow.

10.4 Games for Health

The earliest and most obvious goal for use of serious games in healthcare is to change individuals' behavior in order to promote health. These "health games" can be specifically designed to promote healthy behavior, but may also be commercial games that serve general goals. These games fall in a wide range, including action or sports games, played on platforms that can detect motion (e.g., Nintendo Wii™ or Kinect™), but can also include actions, role-playing, or puzzle games with an element of strategy on mobile phones such as *Pokémon Go*™ (Niantic I 2016). Health games were originally developed mostly for the younger generations as it was believed to be most in line with their digital style of learning. Nowadays, they come in many forms for all generations and cater to specific interests.

Systematic literature reviews summarize a large number of potential applications for games in health education, promotion, and management (Table 10.1). They are applied to promote physical fitness (*Exergames*), for cognitive training (*Brain* games), to promote knowledge and self-management in chronic diseases and conditions (including asthma, diabetes, and obesity), and to reduce psychological conditions and stress related to treatment (e.g., low self-esteem, anxiety, and pain). Recently, Charlier et al. performed a systematic review of serious games directed specifically at improving adolescents' health behavior and self-management in the context of chronic illness. They included nine randomized

Table 10.1 Summary of systematic reviews on the effectiveness of games for health

Article	Game purpose	No. of articles	No. of games	Study types included	Meta-analysis	Conclusions
Charlier et al. (2016)	Health education and self-management in adolescents	9	7	RCTs only	Yes	Significant positive effect of serious games on health education and self-management in adolescents.
Kueider et al. (2012)	Cognitive training in older adults	8	22	RCTs, cohort studies	No	Videogames appear to be an effective means of enhancing reaction time, processing speed, executive function, and global cognition in older adults. Low-quality evidence.
Primack et al. (2012)	Promoting health and/or improving health outcomes	38	NR	RCTs only	No	Potential health-related benefits of serious games. Low-quality evidence.
Guy et al. (2011)	Combat childhood obesity	34	21	All	No	Action videogames use can elicit light to moderate physical activity among youth and increase nutrition-related knowledge. Evidence remains limited.
DeShazo et al. (2010)	Diabetes education	9	8	RCT, cohort	No	Games hold great potential as an alternative modality for diabetes education. Games described are exclusively for children. Evidence remains limited.

(continued)

Table 10.1 (continued)

Article	Game purpose	No. of articles	No. of games	Study types included	Meta-analysis	Conclusions
Adams (2010)	Healthcare in general	51	12	All	No	May be used for health education and training. Evidence remains limited.
Papastergiou (2009)	Health education and physical education	34	NR	All	No	Games may positively influence young people's knowledge, skills, attitudes and behavior in relation to health and physical exercise. Evidence remains limited.

NR = not reported, RCT = randomized controlled trial

controlled trials in a meta-analysis in which seven serious games were applied for the management of asthma: Asthma Command (Rubin et al. 1986; Homer et al. 2000); Watch, Discover, Think, and Act (Bartholomew et al. 2000; Shegog et al. 2001); Wee Willie Wheezie (Huss et al. 2003); The Asthma Files (McPherson 2006); juvenile diabetes (DiaBetNet) (Kumar et al. 2004); Packy and Marlon (Brown et al. 1997): and leukemia (Re-mission) (Kato et al. 2008). Results show a combined significant effect size of 0.361 (Hedges' gu, 95% confidence interval 0.098–0.624) on improving knowledge of the game groups versus the control groups that received mostly written knowledge. On improving self-management behavior, the effect size was 0.361 in favor of the game group (Hedges' gu, 95% CI 0.122–0.497) versus control groups that did not receive any education (Charlier et al. 2016). This study is the first to prove that serious games can improve the treatment of chronic disease in adolescents at the highest level of evidence (Grade A recommendation, level 1a).

10.5 Rehabilitation

Because of the strong motivation and immersion that videogames exert on their players, clinicians see them as interesting adjuncts to conventional physical rehabilitation in patients suffering from injury or disability. The spectrum varies from complex immersive virtual reality systems (van Kerckhoven et al. 2014) to commercially available games played on off-the-shelf game consoles (Saposnik et al. 2016). Rapid developments in motion detection systems in these consoles will make these games easily accessible for large groups of patients in need for rehabilitation on a global scale.

Saposnik et al. published a systematic review of the medical literature on the effectiveness of virtual reality (VR) rehabilitation systems (including both immersive VR systems and commercial videogames) for recovery of upper extremity motor function after stroke (Saposnik et al. 2011). The authors describe 12 clinical trials and observational studies in which technology was applied to detect movement through cameras and motion detection software or wearable devices with motion sensors. Limb function is then improved by through VR exercises ($n = 9$) or (commercial) videogames ($n = 3$). Data from five RCTs were pooled in a meta-analysis that showed a significant effect in favor of VR rehabilitation (OR 4.86, 95% CI 1.31–18.3, $p < 0.02$). The authors view the lack of trials *combining* VR with conventional therapy as a major shortcoming in current clinical practice (Saposnik et al. 2011).

Apart from rehabilitation in chronic conditions (e.g., cerebral palsy, multiple sclerosis, stroke, and Parkinson's disease), evidence is accumulating that also short- and medium-term rehabilitation after trauma or orthopedic surgery is achievable using serious games (Fig. 10.2). Rehabilitation after burn injury using videogames was shown to be equally effective as standard therapy, whereas videogame play even resulted in less pain experienced (Parry et al. 2015). This may be the result of a higher level of motivation and/or immersion, which perfectly exemplifies the major benefit of videogames in this context. Videogames have great potential as (adjuncts to) rehabilitation therapy in terms of cost reduction and effectiveness. The rapid advances in VR and wearable technology are likely to boost their application in the foreseeable future.

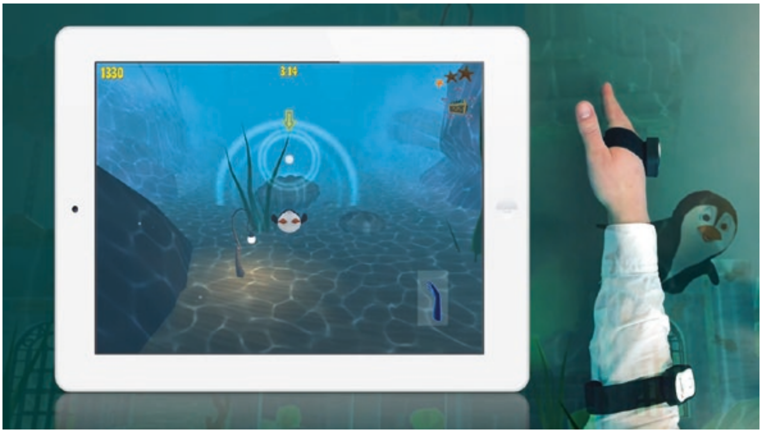

Fig. 10.2 In *Revalidate*™ (Motek (Amsterdam, The Netherlands)), in cooperation with Virtual play (Utrecht, The Netherlands), a player trains his or her wrist function after trauma or surgery. The controller attached to the player's hand measures its posture, allowing the player to control the turtle in the game to follow a specific course and score points. By introducing a fun and challenging aspect to rehabilitation, the producers hope to improve patients' functional outcome after trauma

10.6 Crowdsourcing Science

Online multiplayer gaming communities often spend a vast number of hours playing one single game—often in a social context (Entertainment Software Association 2016). The scientific community has been trying to capitalize on this phenomenon, attempting to use these massive amounts of human brainpower to solve complex or large-scale problems for healthcare-related purposes such as unraveling complex three-dimensional structures of specific proteins, DNA, and RNA. *Foldit* was developed by the University of Washington's Center for Game Science to allow non-scientists help unfold protein structures (Cooper et al. 2010). In the serious game, players can improve their scores by optimizing a given protein's structure or reducing the amount of intrinsic energy required, which is computed by a structure prediction model. One protein is presented at a time, allowing multiple players to attempt to solve the puzzle, automatically checking each other's efforts. *Foldit* has over 300,000 registered users who already delivered over 5400 protein recipes (Khatib et al. 2011). The players' efforts have resulted in real-world improvements in computational enzyme design (Eiben et al. 2012). In a survey dispersed by the developers, players give the game's competitive elements, social interaction through chat and web community, as well as the possibility to unravel scientific problems as main reasons to participate (Cooper et al. 2010).

Eyewire, developed by the Brain & Cognitive Sciences Department of the Massachusetts Institute of Technology, is a multiplayer online puzzle game that involves over 100,000 "citizen neuroscientists" in unraveling the structures of the mammalian retina. A dataset containing 3D electron micrographs of a mouse retina is chopped into little puzzle pieces and the players have to color subsets of individual neurons. The scoring system rewards agreements between players coloring the same neurons. Using this approach, "real" scientists were then able to reconstruct a connectivity model of the mouse retina (Kim et al. 2014). Other scientific problems addressed by crowdsourcing games are DNA multiple sequence alignment (*Phylo*) (Kawrykow et al. 2012), RNA structure design (*EteRNA*) (Lee et al. 2014), gene–disease associations (*Dizeez*) (Loguercio et al. 2013), and issues related to quantum physics (*Quantum Moves*) (Sørensen et al. 2016).

10.7 The Gaming Doctor

In the last decade, the availability of serious games developed to train or educate health professionals has increased rapidly. As Wang et al. (2016) showed in a systematic review, the number has increased from 4 in 2007 (including two different genres) to 42 in 2014 (including eight different genres) (Wang et al. 2016). The scope has widened from merely surgically oriented simulation games to almost all disciplines: internal medicine, neurology, geriatrics, intensive care, emergency medicine, general surgery, urology, obstetrics, pediatrics, pharmacy, nursing, pathology, and preclinical medical education. Game types include simulations, quizzes, puzzles, adventure games, and board games. The following three examples of educational serious games

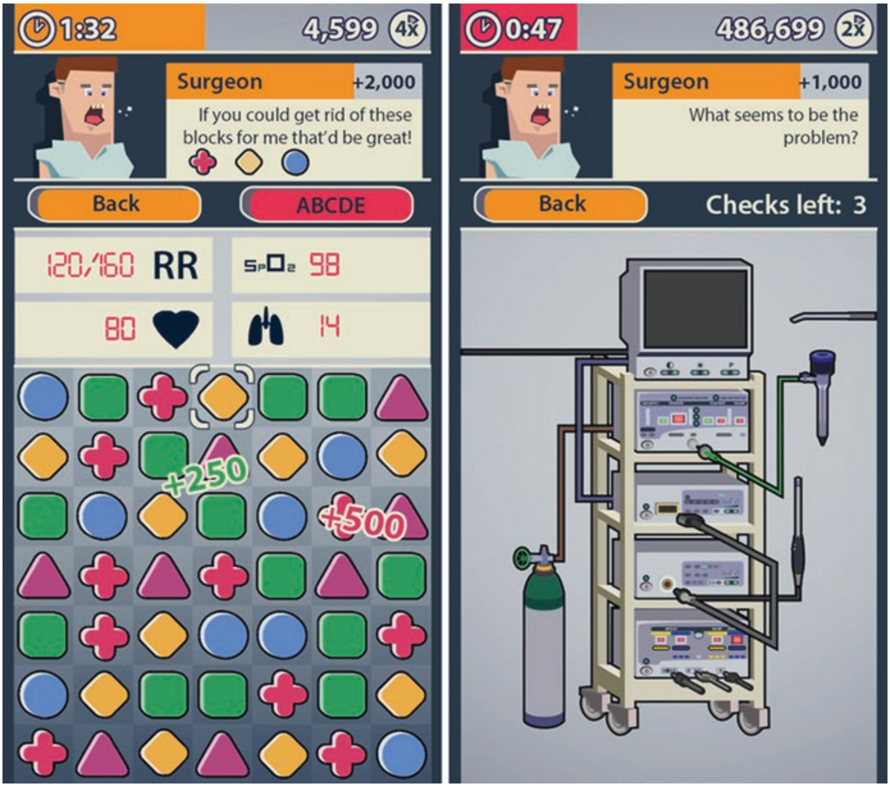

Fig. 10.3 In *Dr. Game: Surgeon Trouble*™ (Weirdbeard, Co., Amsterdam, The Netherlands), the trainee plays an amusing game on their smartphone (*left*) in which sudden changes may occur resembling equipment-related problems during laparoscopic surgery. The player has to solve the problem in a pop-up screen (*right*). The player learns surgical problem-solving skills while playing an amusing game (©Weirdbeard Co.)

give insight into the wide range of goals and design features. *GeriatriX*™ is a management simulation game aimed at teaching medical students how to deal with cases in geriatric medicine in which cost consciousness, end-of-life decisions, and psychosocial factors play a significant part (Lagro et al. 2014). *Dr. Game, Surgeon Trouble*™, is a simple arcade-type game (resembling *Bejewled*), in which equipment-related malfunctions typical to laparoscopic surgery are concealed (Fig. 10.3). The purpose of the game is to train the surgeon's situational awareness in a subtle, stealthy way while they play an amusing arcade game (Graafland et al. 2014a). In the serious game *Underground*™, the player has to build and manage an underground society of trolls using Nintendo Wii™ controllers adjusted to resemble laparoscopic surgical instruments (Fig. 10.4). While playing a game that has seemingly little to do with surgery itself, one acquires dexterity skills that can be translated to real-life laparoscopic surgery (Jalink et al. 2014a). All three serious games were the product of a collaboration of medical educators and game designers.

Fig. 10.4 In *Underground*™ (Grendel Games, Leeuwarden, The Netherlands), the trainee controls an underground society of trolls with two handles (depicted *left* and *right*) that resemble laparoscopic surgical instruments attached to a Nintendo Wii™ game console. While playing a game that has seemingly nothing to do with surgery, the player develops complex laparoscopic dexterity skills (©Grendel Games) https://www.undergroundthegame.com/

Healthcare professionals will only accept games as tool for training or treatment if their effectiveness has been scientifically scrutinized. In their systematic review, Wang et al. found that 33/42 serious games were subjected to (at least) one study evaluating their efficacy as teaching intervention (Wang et al. 2016). They found a high heterogeneity in study design, with mainly positive results (only 11% of the studies found a negative result). Moreover, overall study quality was low (10.5 out of 18 points on the MERSQI score (Reed et al. 2008)). This more or less coincides with earlier systematic reviews, showing similar study quality and a limited amount of randomized controlled trials (Graafland et al. 2012; Akl et al. 2013). To answer the question of whether serious games are effective in general, one can merely conclude that there is sufficient evidence that *some* serious games have a significant effect on learning outcomes for healthcare professionals (level 2, Grade B). However, these studies did not research skills transfer to real-life (clinical) performance. Moreover, evidence of long-term learning retention is limited (Wang et al. 2016; Graafland et al. 2012; Akl et al. 2013).

10.8 Games in Official Medical Programs: *Seriously*?

10.8.1 Validity

It needs to be emphasized that the overall effect of serious games in clinical education or health promotion for individuals must not be confused with the effectiveness of individual games (Schijven and Jakimowicz 2005). Because of the heterogeneity in

Table 10.2 Validity of research process

Validity type	Description	Criteria for achievement
Content validity	The degree to which a game content adequately covers the dimensions of the medical construct it aims to educate (or is associated with).	Uniform and positive evaluation of game content and associated testing parameters by expert medical specialist panel.
Face validity	Degree of resemblance between medical constructs featured in gameplay and in reality, as assessed by novices (trainees) and experts (referents).	Uniform and positive evaluation of the game as a valuable learning environment among novice and expert medical specialists.
Construct validity	Inherent difference in outcomes of experts and novices on gameplay outcome parameters.	Outcome differences considered to be of significance between players being of different medical specialist levels of skill.
Concurrent validity	Concordance of study results using a concept instrument (e.g., game) and study results on an established instrument or method, believed to measure the same medical theoretical construct.	Outcome parameters show correlation considered to be significant between game and an alternative, established training method.
Predictive validity	The degree of concordance of a concept instrument (e.g., game) outcome and task performance in reality based on a validated scoring system.	Metrics show correlation considered to be significant between outcome parameters of a game and performance results on the medical construct featured in the game in real life after performers are trained using the game.

Adapted from Graafland et al. (2012)

design aspects, target groups, and purposes, every newly developed game will require a *separate* evaluation process—the gravity of which should be in accordance with the game's application. For instance, when applied to treating a sick patient or assessing a surgeon before he or she will perform a real-life operation, a game's assessment system should be more rigorously tested than when used as an adjunct to promote fruit and vegetable consumption in 5-year-old, otherwise healthy individuals. Consensus on the level of evidence required for specific games is an ongoing topic of discussion (Graafland et al. 2014b). However, there is a general need for *systematic* assessment strategies to prevent false and incomplete claims of effectiveness.

A useful concept in this systematic approach is *validity*. Validity research is a stepwise approach to evaluate various aspects of an instrument's resemblance to a real-life skill or performance parameter. The highest form of validity is *predictive validity*—an instrument's ability to improve skills in reality (Schijven and Jakimowicz 2005; Gallagher et al. 2003; Youngblood and Dev 2005). Table 10.2 shows the steps in the classical validity research processes applied most widely, although the concept itself is the subject of ongoing debate (Cook et al. 2014).

For example, one cohort study compared the speed and movement efficiency of experienced surgeons playing *Underground*™ to novices ($n = 30$) and found their result to be significantly faster (111%), thus proving its effectiveness in measuring competence on this specific skill (Jalink et al. 2014a). A second cohort study found that 97% of 34 pediatrics residents found the *Bronx Jeopardy*™ quiz game an easy-to-use and effective learning tool through a questionnaire (Jirasevijinda and Brown 2010), proving the likelihood that residents are likely to accept it as a training modality. However, the study setup and research purpose leads to the conclusion that *Underground*™ can be regarded as a more reliable or valid training instrument than *Bronx Jeopardy*™. In the first case, the game shows to have clear *construct* validity, whereas the second shows to have reasonable *face* validity.

10.9 Games in Skills Training Outside the Operating Room

Achieving an expert level in complex medical 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 opportunity to repeat and refine their performance (Ericsson 2006). Surgical postgraduate curricula aim to create professionals who are *competent*, and preferably *proficient*, in essential surgical procedures within approximately 1200 h of operating time. Even though including the time performing non-essential procedures approximately doubles this number, it can be considered rather limited (Bell 2009; Chung 2005). 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 (Bell 2009; Smith et al. 2009). Ideally, the 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 VR-enhanced training.

Virtual reality simulations have been developed and evaluated extensively for use in medical training (Dawe et al. 2014; Cook et al. 2011). Well-known examples include the minimally invasive surgical (MIS) simulators, developed for improving visuospatial skills and dexterity. Simulators are able to produce standardized, reproducible virtual surgical procedures. Their range encompasses basic task exercises (e.g., knot-tying or artery clipping) to complete MIS procedures with distinct patient scenarios (Schreuder et al. 2011). Surgical residents training on VR simulators work more efficiently and make fewer errors than residents not trained using VR simulators (Gurusamy et al. 2008; Ahlberg et al. 2007; Larsen et al. 2009). Simulators are able to give high-fidelity procedural training, measure skills progression, and deliver direct feedback to the trainee (Lamata de la Orden 2004). Thus, they are effective stand-alone training instruments and incorporated in residency training curricula in many developed countries (Dutch Society for Endoscopic Surgery 2009; Hamming et al. 2009).

However, apart from basic dexterity training for various surgical procedures and crew resource management in emergency situations, the integration of virtual reality (VR)-enhanced simulation in medical and surgical training curricula has been rather limited (Zevin et al. 2014). Lack of financial investments and manpower form practical hurdles in many hospitals. Next, the lack of structured, proficiency-based training curricula hinders the integration of simulation in the competency-based training curricula (Zevin et al. 2014; Schijven and Bemelman 2011). Finally, most commercially available VR simulators are frequently not seen as very motivating by their users (van Dongen et al. 2008; Chang et al. 2007). One can imagine that repeating *peg transfer* in a box trainer will not trigger a busy adult healthcare professional's interest for long.

This is where gamification, serious games, and VR headset solutions—the second wave of VR-enhanced learning—can play a major role. First, gamifying existing VR simulators, such as adding competitions and leaderboards, significantly increases its use by trainees (Verdaasdonk et al. 2009). Second, the design features and game mechanisms discussed above will assist the development of immersive, challenging educational instruments, tailored to a trainee's specific level and requirements (Dankbaar et al. 2014). Third, a new generation of VR head-mounted displays and systems capable of overlaying the real world with digital features are coming into play, varying from expensive headsets (e.g., Oculus Rift™, Samsung Gear VR™) and simple cardboard headset boxes holding a smartphone (Google Cardboard™) (Allaway 2015). These have great potential for creating complex and blended simulations in medical postgraduate education.

10.10 Financial and Ethical Aspects

Various financial reimbursement strategies have been applied in medical serious games in recent years. The most common model is where one or more health institutions present as the sponsor of a game, making the investment necessary for its production. The sponsor then distributes the game among patients or trainees (e.g. Dr. Game, Surgeon Trouble™). The main disadvantage of this strategy is that the sponsor may ultimately lose its interest or budget in the long run, threatening the game's development or maintenance.

A second model is when the game designer himself makes the investment for production and distributes the game to clients (e.g. Underground™). This model will naturally lead to better, high-quality products on the long term, but requires a significant investment from -often-small design companies. The designer runs the risk of the game failing to produce the desired effectiveness or popularity. Furthermore, designers often do not have the time or the budget to conduct scientific research.

A third model is when a non-profit organization (university, hospital or governmental organization) produces the game for free use to the public (e.g. Foldit™, Re-Mission™). This model is mostly applied when the use of the game has a common public interest and/or charitable objective.

In order for the medical serious game market to become more mature and independent on the long term, more rigid reimbursement models should be implemented. Opportunities lie in involving the main stakeholders in the development process, such as health insurance companies, patient organizations and (inter-)national federations charged with training and education of medical professionals.

From an ethical perspective, it is important that serious games do not lead to injuries or exacerbate diseases to their clients. Jalink et al. (2014b) published a systematic review on injuries caused by using the Nintendo game system. Apart from bizarre injuries such as haemothorax by falling from a couch during gameplay, most injuries described are relatively mild and non-specific. The authors conclude that videogames do not appear to be a serious health threat. However, when specific serious games are designed to treat specific patients, rigorous testing and/or FDA approval may be necessary before introduction to the market.

10.11 Discussion

Many tech hypes experience a period of disillusionment after an initial period of rapid growth, whereas the field of serious games in healthcare may be well have bypassed this stage. The field has diversified substantially and evidence on the effectiveness of serious games is mounting among a variety of applications and target groups. The technological advances continue to stride forward. For example, the use of optical head-mounted displays can significantly enhance the level of immersion and fidelity of serious games in the near future. Wearable sensors combined with motion detection software are already altering the field of rehabilitation. Applications that may render a virtual reality "layer" over the real world (*augmented reality*) are available in smart visors (Hololens™, Google Glass™, Vuzix™, etc.) but also on smartphones (Layar™). Combined with videogames, augmented reality will lead to holistic, immersive, diversified experiences that can be used to educate patients and professionals (Schreinemacher et al. 2014).

Although the future perspective for serious games is hopeful, there is still a multitude of challenges to be overcome before they will become common clinical applications. First, healthcare professionals are—for good reasons—hard to convince of the (cost-)effectiveness of new technologies. In contrast, the gaming industry is pushing for rapid adaptation from a business point of view. Although game designers and early medical adapters are starting to understand the importance of testing and validating new serious games, the evidence still remains rather thin. The systematic reviews discussed in this chapter all conclude that the quality of present clinical studies is moderate at best. There is a lack of randomized clinical trials and there are few negative studies, indicating some form of publication bias. Second, no evidence has been produced on the cost-effectiveness of game-enhanced therapies and training. In the age of cost reductions in healthcare across many developed countries, this potential benefit of videogames requires more emphasis. Third, our understanding on *what* motivates individuals to interact with a game remains very limited. It is important to know what aspects trigger specific user groups in order to predict the long-term effectiveness of games. In this context, so-called *super-users*, players that spend an unusual amount of time and effort playing digital applications, are thought to blur outcome statistics (van Mierlo et al. 2012).

Next to these scientific hurdles, practical issues need to be overcome as well. For example, most "mainstream" clinicians and patients remain simply unaware of the existence of relevant games let alone of the evidence supporting their use. Relevant information on games and mHealth applications is often hard to find in disorganized app stores and claims of effectiveness are hard to judge. This will cause caution and possibly even distrust among clinicians. Moreover, most clinicians are currently unequipped to judge the validity of serious games.

The establishment of scientific conferences and journals directed at serious games for healthcare purposes, such as Games for Health Journal (Baranowski n.d.), BMJ innovations (Jha n.d.), and JMIR Serious Games (Eysenbach n.d.), have greatly enhanced their visibility and awareness on importance to both the public and healthcare professionals. Efforts have been made to construct validation frameworks, to guide users in seeking the information necessary to judge a game's purpose, and effectiveness (Graafland et al. 2014b). To gain clinical exposure and reduce our dependency on disorganized app stores, we recommend some form of a publicly available library for medical serious games and comparable digital applications. Full transparency of serious games' benefits and limitations to both the public and healthcare professionals will ultimately facilitate their adaptation in treatment protocols and training curricula.

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