Review of General Psychology
2010, Vol. 14, No. 2, 113–121

1089-2680/10/$12.00 DOI: 10.1037/a0019441

Video Games in Health Care: Closing the Gap

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Although a great deal of media attention has been given to the negative effects of playing video games, relatively less attention has been paid to the positive effects of engaging in this activity. Video games in health care provide ample examples of innovative ways to use existing commercial games for health improvement or surgical training. Tailor-made games help patients be more adherent to treatment regimens and train doctors how to manage patients in different clinical situations. In this review, examples in the scientific literature of commercially available and tailor-made games used for education and training with patients and medical students and doctors are summarized. There is a history of using video games with patients from the early days of gaming in the 1980s, and this has evolved into a focus on making tailor-made games for different disease groups, which have been evaluated in scientific trials more recently. Commercial video games have been of interest regarding their impact on surgical skill. More recently, some basic computer games have been developed and evaluated that train doctors in clinical skills. The studies presented in this article represent a body of work outlining positive effects of playing video games in the area of health care.

Keywords: video games, interventions, technology, health

Despite the existence of effective medicines, advanced medical technology, and hospitals staffed by highly trained and educated health care professionals, human beings do not always behave in ways that take advantage of what health care has to offer. A majority of patients do not comply with the treatment regimes that could save their lives (Partridge, Kato, & DeMichele, 2009). Similarly, doctors make mistakes to such an extent that medical errors can be counted among the leading causes of death in the United States (Institute of Medicine, 2001; Kohn, Corrigan, & Donaldson, 1999). The solutions to these problems are clearly complex, yet psychological and behavioral factors play a prominent role. An innovative tool that is being used more and more to address the psychological and behavioral barriers to optimal health care is the video game.

Most people think of video games as entertainment. There is a growing interest, however, in video games as a means to educate and train people (Durkin, 2010). *Serious games* is a term that has been used to describe video games that have been designed specifically for training and education (Annetta, 2010). The field of medicine has a history of embracing games as a means to engage patients behaviorally to improve their health outcomes. There are early reports of case studies using video games with patients experiencing diseases or physical disabilities (Krichevets, Sirotkina, Yevsevecheva, & Zeldin, 1994; Szer, 1983). We are now seeing more video games evaluated in the literature that are developed and used explicitly for health education and training. Games are now being evaluated in randomized trials with the scientific rigor applied to pharmaceutical therapies (Kato, Cole, Bradlyn, & Pollock, 2008). It is interesting that examples of video game applications in health care consist not only of serious games that are designed specifically training and education purposes, but also of commercially available off-the-shelf games that are repurposed to meet certain behavioral goals in health care.

As deduced from the review that follows, the use of video games to train medical professionals is only in its infancy compared with the depth to which the medium has been explored with patients. This use of games has grown out of the tradition of training physicians with simulations. It has gone from a focus on learning with cadavers and mannequins to the use of computer-generated 3-D interactive software to teach technical skills in medicine. This is the first review to evaluate the state-of-the-art research on video games and their impact on health by evaluating the effect they have had on training medical professionals to provide high-quality health care as well as their impact on patient health.

In this review, psychological theories of play that may explain the effectiveness of games in health care are explored. A history of video games and health is also described, with a focus on studies of video games aimed at improving the health of patients and then on video games that are used to train and educate medical students and doctors. The use of commercial games and tailor-made games for behavioral health or medical training is reviewed. Only games that have been described and evaluated in peer-reviewed publications are presented in this article.

Theories and Mechanisms

Video games have been used strategically to affect a number of issues in health among patients. The main mechanism for action often cited is their ability to increase motivation. Engaging a patient's motivation is frequently necessary in health care because patients are often required to undergo procedures or engage in behaviors that are painful and aversive on the one hand (e.g., undergoing chemotherapy) or boring and mundane on the other (e.g., taking pills, exercising on a regular basis). These procedures

I thank Chris Ferguson and the comments of three anonymous reviewers for their extremely helpful editorial advice.

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and behaviors are often necessary to maintain and improve health or even to cure the patient's disease. The focus of attention on an engaging distraction is also thought to be a key factor in explaining how individuals manage aversive symptoms through video game play. The repetitive nature of video game play is thought to be a key mechanism that promotes learning in games as well (Rosas et al., 2003).

What seems clear is that these mechanisms are usually activated in games within the context of play. To understand how games can engage and affect patients and doctors, it is important to understand how theorists have conceptualized play.

Play usually has the following attributes: (a) It is usually voluntary; (b) it is intrinsically motivating, that is, it is pleasurable for its own sake and is not dependent on external rewards; (c) it involves some level of active, often physical, engagement; and (d) it is distinct from other behavior by having a make-believe quality (Rieber, 1996, p. 44).

Psychoanalytic theorists viewed play as a means for children to experience catharsis, or a release of tension and fears in a safe context (Freud, 1968). Play is therefore often conceptualized as a means of stress management. Thus, play as stress management probably has a key role in helping patients manage aversive or shameful aspects of their illness through playing video games.

Symbolic interactionist theorists viewed play among children as a means for them to understand their social world (Mead, 1982). Children's role-playing games (e.g., playing "cops and robbers" or "house") help them understand different social roles that people have in society. Role playing also helps players develop their sense of empathy, or understanding the feelings and viewpoints of different people. Role playing is clearly a means of play that makes simulations in training medical personnel an appealing way to learn. They can act out dangerous scenarios in a simulated environment so that they can try out their professional roles and make mistakes without fear of real-world consequences.

If we thought about video games as play for adults, we could create a research program that examined the relationship between video game play and social skills such as perspective taking and empathy; psychosocial functioning such as self-confidence, happiness, relaxation, and achievement motivation; and cognitive skills such as attention, planning, spatial reasoning, and creativity. Researchers who develop and evaluate the impact of serious games should acknowledge theories of play as a pathway to learning, not just among children, but among adults as well.

Reviewed Studies

Commercially Available Video Games for Health

Since the early 1980s, there have been reports in the literature of commercially available video games used for therapeutic purposes in different patient populations (Redd et al., 1987; Szer, 1983). Most of the early reports are directed toward children because the average game player was quite young and video games were largely targeted toward this market. As these gamers grew older, video games became more sophisticated and the market broadened for an older audience (Kent, 2001). This is reflected in the broader age range of the target audiences of video games for health more recently as well.

Below, the use of commercially available video games with patients in a pediatric setting is reviewed. These studies represent some of the earliest reports of the use of commercial games in a therapeutic context with patients in the hospital. Also included is a review of a recent report on the use of a video game application for anxiety management with children.

Next, the history of commercial games used for physical therapy and as exercise is reviewed. It is interesting to note that the earliest applications of video games in health occurred because someone clever made an innovative interface so that the typically sedentary games could be used to motivate patients to engage adolescent and adult patients in physical therapy and physical activity. These innovations are needed less and less as modern commercial games and console systems now have innovative hardware interfaces that require the user to be physically active. The application of these games to health is described as well.

Nausea in pediatric cancer. Commercially available video games have been shown to have therapeutic effects on side effects associated with the treatment of cancer. These side effects include nausea, vomiting, anxiety, and pain associated with chemotherapy or radiation treatments. The therapeutic effects of games are attributed to the distraction that games provide that focus attention away from these aversive side effects. In an early report of two experiments (Redd et al., 1987), young patients (age range 11–20 years in Experiment 1; age range 9–18 years in Experiment 2) in pediatric oncology who played a video game for 10 min during chemotherapy induction showed significant decreases in reported nausea compared with control patients. Children assigned to the video game group could choose from 25 different games on an Atari 800 XL computer system. Children in the control group were allowed to play with nondigital books, toys, games, or TV. These results suggest that there is something more engaging and distracting involved in video game play than with nondigital play objects or entertainment.

A similar study (Vasterling, Jenkins, Tope, & Burish, 1993) compared patient groups provided cognitive distraction through video games or standard relaxation training with a control group of young cancer patients. The patients in the video game distraction group and the patients in the relaxation-training group reported less nausea prior to chemotherapy and had lower blood pressure following chemotherapy compared with controls. There were no differences between the distraction and relaxation-training patients, indicating that the treatments were similar in effectiveness. Practically speaking, however, relaxation training requires a trained therapist to administer. The cost, time, and availability of trained professionals make it difficult for many hospitals to take advantage of this technique. In contrast, computer games are less expensive over time, readily available, and considered acceptable therapies by the patients, making them ideal for interventions for conditioned nausea in young patients with cancer.

Anxiety management. The previous studies demonstrating the effective use of video games as distractors for nausea management are classic examples of the early work of using commercially available games as therapy that capitalize on the ability of games to distract patients' attention from aversive symptoms. The study presented below examined the use of commercial games as distractors to help young patients manage their anxiety in a hospital setting. This recent work explored the use of a portable game platform on which the games can be played, which may improve the ease of use and accessibility of this type of adjunct to therapy.

In a study of 112 children (ages 4–12 years) undergoing general anesthesia for elective surgery, patients were assigned to one of three groups: (a) parent present, (b) parent present + oral midazolam (preop sedative), or (c) parent present + a hand-held video game distraction (Patel et al., 2006). The video game distraction consisted of 10 commercial games to play on a Nintendo Gameboy platform (A. Patel, personal communication, November 4, 2009). Patients who did not have a hand-held video game showed significant increases in anxiety from baseline to induction of anesthesia. Patients who played the video games showed no significant increases in anxiety from baseline to induction and reduced anxiety compared with the parent-present group and no difference with the midazolam group during induction of anesthesia. These findings are significant for this population group and procedure because the games and hand-held device represent a low-cost, easy-to-implement, portable, and effective method of anxiety management in a vulnerable population during a critical time of care. Furthermore, the findings have clinical implications because the impact of the video games on anxiety was as effective as a pharmacological intervention for anxiety. Future studies should explore the use of this game platform for anxiety management with young patients in other stressful situations in the hospital (e.g., chemotherapy induction, venipuncture).

Physical therapy and physical fitness. There are early reports in the literature that the mere physical requirements of playing a regular video game (e.g., joystick control, arm reaching) can have therapeutic effects as physical therapy for arm injury (Szer, 1983), Erb's palsy (Krichevets et al., 1994), and traumatic brain injury (Sietsema, Nelson, Mulder, Mervau-Scheidel, & White, 1993). The success of video games as an adjunct to physical therapy can be attributed in large part to the increased engagement and motivation that video games add to typically mundane and repetitive tasks associated with physical therapy. In other words, patients may cooperate more fully with the procedures required in physical therapy when the procedures are combined with or are part of an entertaining game.

Racing games have been used in combination with physical exercise equipment for physical therapy for different patient groups. For example, in one study, racing games were used with manual wheelchair interface called GameWheels with 35 patients with spinal cord injury (O'Connor et al., 2000). The interface turned the wheelchair into a virtual joystick in which users could control game play through the movement of their wheelchairs wheels on the rollers of the interface. Players were motivated to maneuver their wheelchairs on the device in order to play popular racing games (e.g., *Need for Speed II* and *Power Boat Racer*). The results showed that patients using these devices were able to reach fitness goals as indicated by results of a submaximal oxygen consumption test (VO_2/kg) and heart rate monitoring. Unfortunately, this study did not include a control group of patients who were asked to engage in the activity with the device without a video game interface. This would have helped to more precisely define the causal effects of the video game in achieving the observed results.

In a more recent study, a commercially available video game *Need for Speed* was used in conjunction with an add-on exercise hand crank device (ergometer) called the GameCycle to control movements in the games (Widman, McDonald, & Abresch, 2006). Patients were adolescents with spina bifida, a congenital malformation of the spinal cord. These patients had mobility impairments associated with their disease that did not allow them to participate in most mainstream sports. The game intervention focused on an area of physical activity for the patient population that they could engage in and combined it with the video game play to improve their motivation to engage in physical activity. The 4-month home-based video game–exercise intervention showed that most patients were able to reach levels of intensity training consistent with guidelines set forth by the American College of Sports Medicine for the general population (i.e., at least 50% of VO_2 reserve or 50% of heart rate reserve). Patients in the study who did not meet this standard had the highest baseline strength values and reported that the intervention was not physically challenging. Closer inspection of this group revealed that these patients were already physically fit. This suggests that the intervention was effective for patients who needed it the most. Subjective ratings of the intervention also revealed that virtually all patients found exercising on the GameCycle to be easy, enjoyable, and physically challenging. A similar study comparing a standard ergometer with the GameCycle (ergometer combined with a video game) found that wheelchair athletes who exercised with the GameCycle and accompanying video games showed increased intensity of training compared with controls (Fitzgerald & Cooper, 2004). An interesting finding was that each group's reported perceptions of exertion levels did not differ.

The studies above demonstrate that video games have the potential to positively influence physical activity in populations of medical patients, especially those with physical impairments. In recent years, a new generation of commercial games has been developed that explicitly requires mainstream audience of users to be physically active as part of game play. Although studies have linked video game play with obesity (Vandewater, Shim, & Caplovitz, 2004), video games that accompany wireless video game console systems (e.g., the Nintendo Wii) and certain accessories (e.g., the dance pad with *Dance Dance Revolution*) have been shown to significantly increase energy expenditure among players (Graves, Stratton, Ridgers, & Cable, 2008; Lanningham-Foster et al., 2006). Although the energy expenditure may not be as great as engaging in an authentic version of the sports simulated in the games (e.g., boxing, tennis, and bowling), these video games provide alternative activities for individuals concerned about video games as a sedentary activity. In fact, these games are among the most popular video games on the market. The Nintendo Wii *Fit* game, in which players engage in strength, balance, and aerobic activities, has topped the charts as the best-selling console game (Orry, 2009). *Dance Dance Revolution* was a chart-topper as well (Konami Digital Entertainment—America, 2005).

The use of commercially available video games to increase physical activity challenges a prevailing assumption that playing video games is a sedentary activity. The positive effects of these games stand in contrast to concerns that excessive gaming is related to negative outcomes such as repetitive stress injuries (Mirman & Bonian, 1992). In most of these studies, specialists supervised the therapeutic use of the games. In addition, the patients were probably engaged in the games in a way that was representative of average players of games who do not play in excess to the point of physical injury.

Tailor-Made Games for Health

As the general popularity of video games grew and it was clear that video games could be used to engage patients in their care, video games were made specifically to address issues in health care. These games built on past research that showed that video games were effective as a distraction for pain, nausea, and anxiety. They also built on past research evidence that video games were powerful motivators for people to engage in active behaviors. Whereas commercial games were used to increase compliance in physical therapy, the new tailor-made games were used to increase compliance with other treatment directives by delivering health-related information, modeling positive health behaviors, and providing opportunities for players to vicariously practice engaging in positive health behaviors for specific patient groups.

Burn pain. Building on the power of commercial video games to distract patients and provide a means of pain management, a team of researchers and game designers developed a virtual reality game for burn patients called *SnowWorld*. In this game, players are immersed in a virtual reality world where they fly through an icy landscape of a canyon, cold river, and waterfall through gently falling snow. As they navigate their way through the canyon, they can shoot snowballs at snowmen, penguins, igloos, and robots. In contrast to games used for physical therapy and exercise, this game was designed specifically to minimize body motion during gameplay to enable wound care (debridement) by nurses (Hoffman et al., 2008). This was possible because players controlled their movements and activities in the game (such as throwing snowballs) by manipulating a fixed joystick. Studies of this intervention showed that it was effective in reducing pain perception among 11 burn patients in a pretest–posttest evaluation (Hoffman et al., 2008). One randomized controlled trial of the virtual reality intervention showed a 20% reduction in subjective reports of pain when compared with standard analgesic interventions (Sharar et al., 2007). Although it is not clear from the design of the evaluative studies of the game if the "cool" (temperature-wise) imagery of the game induced an extra level of pain tolerance, it does seem clear patients who felt themselves "present" in the cool world of the game reported feeling less pain. Furthermore, it was surmised that the increased reports of the virtual reality intervention as being "fun" also contributed to greater compliance with the painful procedures involved with treating burns such as burn debridement. Finally, the results of this work suggest that virtually immersive games may also have therapeutic effects in other patient populations with pain management needs.

Diabetes. One classic video game for health is *Packy and Marlon*, which was originally made for the Super Nintendo game console system. The game is aimed at children with diabetes. The characters in the game are two elephants that are at a diabetes summer camp. They have to get rid of a gang of marauding rats that are keeping the campers from healthy food and diabetic supplies. To win, players have to successfully manage their insulin levels and food intake while keeping their characters' glucose levels within an acceptable range. This game was evaluated in a randomized trial in which participants in the treatment group played the game for 6 months (Brown et al., 1997). By the end of the study, patients who had access to the game showed greater perceived self-efficacy for diabetes self-management, increased communication with parents about diabetes, and improved daily diabetes self-management behaviors (e.g., monitoring blood glucose levels regularly, taking insulin as needed, eating the right foods). More impressive, in terms of objective health outcomes, the treatment group had a 77% decrease in diabetes-related emergency and urgent care clinical visits compared with controls. These findings have clinical significance because they show that an interactive video game can have an effect on important health behaviors in children with a chronic illness.

Asthma. *Bronkie the Bronchiasaurus* is a video game on the Super Nintendo Entertainment System platform that was made for young children with asthma. The game is set in prehistoric times and the world is covered in dust. A fan that usually keeps the dust at bay has broken. Players help the two in-game characters, Bronkie and Trakie, keep their asthma at bay by avoiding triggers such as dust and smoke while they go on their quest. There are some textual question-and-answer inserts in the game along the way that need to be answered correctly in order to proceed. A series of studies on the game found that patients' asthma-related self-concepts, social support, knowledge, self-care behaviors, and self-efficacy improved after playing the game compared with a control group (Lieberman, 2001). These findings contribute to our knowledge about what video games can do to affect important health beliefs and practices among young children.

The interactive game *SpiroGame* was developed for use with a device that measures and gives a readout of breathing function for spirometry. Spirometry is a measure of lung function, and it is used with patients who have diseases associated with compromised lung functioning such as asthma or cystic fibrosis. Spirometry is often difficult to perform with young children because it depends highly on patient cooperation and effort during the procedure; however, spirometry conducted with the measuring device paired with the *SpiroGame* was shown to promote the successful measurement of lung functioning in preschool children (Vilozni, Barker, Jellouschek, Heimann, & Blau, 2001). The game teaches 3- to 6-year-old children to differentiate between inhalation and exhalation and to control their breathing. Children controlled an animated caterpillar through their breathing. The caterpillar crawls to an apple over a period of 30 s as long as the child's breathing reaches targets predetermined by a computer algorithm. Another minigame teaches children how to do a breathing test by pairing attainment of certain breathing targets with the movement of an animated bee flying from flower to flower. These games are good examples of how interactive technology can be used not only to motivate behaviors, but also to train and to obtain higher than expected performance of target behaviors from a group of very young children.

Bladder and bowel dysfunction. Video games, in particular those that employ biofeedback to control gameplay, have been used successfully to treat patients with pediatric voiding dysfunction or irritable bowel syndrome (IBS).

Pediatric voiding dysfunction is diagnosed in children who do not empty their bladder normally and experience bedwetting and daywetting. Treatments include pharmacological interventions along with behavioral treatments that include dietary management, a timed voiding schedule, and muscle training of pelvic floor muscle groups that are involved in urinary continence. Biofeedback, an effective treatment modality to train the pelvic floor muscles among these patients (Pfister, Dacher, & Gaucher, 1999), is often a part of treatment. Similar to other interventions that involve behavior change, the success of biofeedback depends on patient motivation and compliance with the program. Children are generally not interested in dealing with the embarrassing topic of incontinence, and they also have difficulty remaining focused on the task of biofeedback training. Biofeedback combined with a game interface was used to increase interest and motivation to engage the therapy. In this method, sensors are placed by a nurse on the child's perineum to detect pelvic floor muscle activity. Leads from the sensors connect to a port on the computer in which electrical activity from the sensors is transformed through algorithms to relate to actions in the game. The games used to treat pediatric voiding dysfunction were PC-based games of golf, spaceships, baseball, basketball, and a safari adventure. For example, in the golf game used in this study, pelvic floor contractions determined the distance a golf ball traveled. In the basketball game, accuracy of shooting a basketball through a hoop was related to the patient's ability to relax the pelvic floor muscles. Studies of these biofeedback games showed improvements in symptoms and high levels of treatment compliance through self-report and objective measures (Herndon, Decambre, & McKenna, 2001; McKenna, Herndon, Connery, & Ferrer, 1999). In addition, the biofeedback computer game program proved to be useful in children with pediatric voiding dysfunction as young as 4 years old (Herndon et al., 2001), a group previously thought to be too young for biofeedback muscle training because of limited ability to cooperate and motivation to engage in it (De Paepe et al., 2000).

A computer biofeedback game was also designed for patients with IBS, a gastrointestinal disorder characterized by abdominal pain, bloating, constipation, and diarrhea. Symptoms are controlled through medication and behavior management such as diet and stress management techniques. A biofeedback game that was developed for patients with IBS was designed to teach stress management through deep relaxation exercises (Leahy, Clayman, Mason, Lloyd, & Epstein, 1998). Biofeedback sensors connected to the patients' fingers measured electrodermal activity, or microchanges in the skin's sweat response. The patient was able to control the animated representation of bowel movement through changes in their electrodermal conductivity that the biofeedback sensors detected when the patient engaged in mental and physical relaxation techniques. The patients were able to control their movement in an animation of the gut (intestines) to the extent that they were able to relax. A study of 40 patients with IBS who were refractory to conventional treatment showed that four half-hour biofeedback sessions resulted in reports among half of the patients that the technique helped them control their symptoms. Patients also showed significant reductions in global and bowel-specific symptom scores. In long-term follow-up of the patients, 64% of the patients reported that they continued to use the techniques they had learned. The advantage of using this biofeedback game to teach stress management over interpersonal therapy is that it does not require the assistance and guidance of trained therapists because it can be self-administered. The game was probably also motivating and useful for this group because it allowed the users to deal with managing embarrassing aspects of their disease in a private manner.

Pediatric cancer. *Re-Mission* is a game made for adolescents and young adults with cancer. The goal of the game is to improve treatment in this often "hard-to-reach" age group of patients. In the game, players control a nanobot named Roxxi. Roxxi flies through the body of different cancer patients to destroy cancer cells and tumors with chemotherapy and radiation. She also combats side effects of treatment such as pain, nausea, infection, and constipation. Information is provided visually through animations and direct interactions with environments. In a randomized trial (Kato et al., 2008) with 374 patients between the ages of 12 and 29 at 34 medical centers in the United States, Canada, and Australia, patients who played *Re-Mission* were compared with patients who played a control game, *Indiana Jones and the Emperor's Tomb*. Patients who played *Re-Mission* over the 3 months of the study maintained higher levels of chemotherapy in their blood and took their prophylactic antibiotic medication more frequently as prescribed than patients in the control group. Patients who played *Re-Mission* also showed greater increases in knowledge about cancer and self-efficacy to manage their cancer than patients in the control group. The research showed that a tailor-made video game for young people with cancer can have an impact on important health behaviors that are related to survival outcomes.

The evidence supports the use of tailor-made games for specific medical goals. These games vary widely in terms of their content and the platforms on which they are delivered, yet they all harness the power to focus, engage, and motivate players in an activity. They go beyond the strengths of commercial games in their ability to increase specific knowledge about self-care and disease. They are also useful because they can help patients manage embarrassing aspects of certain illnesses in a private way. They can help patients develop specific skills needed to manage illnesses in a cost-effective, easily distributed way. In addition, even though video game reviewers may find that these games for health do not meet their standards for graphics and gameplay (Atriou, 2009; Stahl, 2009), their intended users give them high ratings of acceptability and find them engaging (Kato & Beale, 2006; Lieberman, 1997).

Commercially Available Video Games in Medical Education

Video games and video game technology have long been used to improve patient safety and patient care through their use as tools to teach doctors. Commercial games have been explored as a means to improve surgical skills, and tailor-made games for medical students have been used to teach clinical skills. Research on these games is reviewed below.

Surgical skills. The relationship between video game play and surgical skills has been a focus of attention in particular because skills in playing certain video games are also crucial in performing surgery (e.g., visual spatial performance, eye–hand coordination, fine motor control, and reaction time). Studies have focused on how video game play may enhance some of these skills in a normal population. There is evidence that individuals who are avid video game players show enhanced visual attention skills (Green & Bavelier, 2003) and visual memory (Ferguson, Cruz, & Rueda, 2008). There is also causal evidence that nonplayers trained on video games show improved visual skills (Green & Bavelier, 2003, 2007). Other research has shown, however, that avid video game players do not differ from nonplayers in their visual processing strategies but merely have faster response times to visual attention tasks (Castel, Pratt, & Drummond, 2005).

Studies with physicians that have examined the relationship of video game play to actual surgical skills such as targeting and grasping objects and suturing have also shown a great deal of evidence of a positive association. One study that compared the surgical skills of avid video game players (>3 hr/week) with their less avid counterparts found that the avid players made 37% fewer errors and were 27% faster in completing a simulated laparoscopic procedure and suturing (Rosser et al., 2007). Physicians in this study were also asked to play three video games in the lab: *Super Monkey Ball 2*, *Star Wars Racer Revenge*, and *Silent Scope*. The physicians' skill in playing these video games and their past experience playing games explained a significant amount of variance in their performance on the simulated laparoscopic procedure. A number of similar studies have been carried out that also show that physicians who play video games or are skilful at playing games make fewer errors in performing laparoscopy (Grantcharov, Bardram, Funch-Jensen, & Rosenberg, 2003), are faster at achieving proficiency on certain tasks in a laparoscopic simulator (Shane, Pettitt, Morgenthal, & Smith, 2008), and are more efficient in screening and faster in examining during simulated gastroscopy (Enochsson et al., 2004).

One study with mixed findings showed that medical students with previous video game experience had enhanced skills in maneuvering safely in a sinus surgery simulator. Their advantage, however, did not hold as the demands and realism of the sinus surgery simulator increased at higher levels (Glaser, Hall, Uribe, & Fried, 2005). There are also studies that did not find an association between video gameplay experience or skills and robotic surgical performance (Hagen, Wagner, Inan, & Morel, 2009; Harper et al., 2007) or endoscopy (Westman et al., 2006).

Taken together, the above studies are compelling, yet they merely show a correlation between video game experience or skill and surgical skills. They do not demonstrate the causal relationship that playing games will lead one to be more skillful in surgery. A handful of studies have more recently tested this causal claim. One study that found that video game skills were indeed associated with laparoscopic skill among novice surgeons also examined more closely the causal role of playing games on laparoscopic surgery skills (Rosenberg, Landsittel, & Averch, 2005). In this small study, participants were randomly assigned to a control group or a gaming group. The control group ($n = 6$) was asked to refrain from playing any video games for 2 weeks and the game group ($n = 5$) was asked to play any type of video game for 2 weeks. At the end of this time period, members of both the treatment and control groups returned to the lab for assessment of their laparoscopic skills. Surgeons in the gaming group played games for 6.2 hr on average during the 2 weeks and surgeons in the control group reported that they did not play any games. No difference was found in laparoscopic skills between these two groups at follow-up; however, this was not surprising given the small sample size, the low level of intensity of the gaming intervention, and the lack of control over the types of video games played.

More recently, another study examined the causal effect of playing games on virtual surgical endoscopy skills with a relatively more scientifically rigorous research design. In this study (Schlickum, Hedman, Enochsson, Kjellin, & Felländer-Tsai, 2009), medical students were randomly assigned to one of three groups. For a total of 5 weeks, one group of participants ($n = 15$) underwent systematic training with the video game *Half-Life*, a 3-D first-person shooter game; another group underwent training with a 2-D non–first-person shooter game called *Chessmaster*. These two groups were asked to play between 30 and 60 min a day, 5 days a week, for 5 weeks. The control group participants were asked to refrain from playing any video games at all for 5 weeks. At follow-up, both video game training groups showed significant improvements on the MIST-VR simulator, whereas those in the control group showed none at all. Only the *Half-Life* group showed improvements on another surgical endoscopy task on the GI Mentor simulator. The enhanced skills shown by the *Half-Life* group were thought to be due to the high visual spatial skill demands of this game and its visual similarity to endoscopy. This suggests that the content and demands of video games are important for a transfer to surgical skills to occur. Overall, this study is the most scientifically sound study to date that provides evidence that playing certain video games can improve surgical skills.

In sum, the research suggests that playing video games certainly does not make surgical skills worse. In some cases, it has no effect at all but, overall, both the correlational studies and the more scientifically grounded controlled study suggest that playing certain video games do improve surgical skill.

Tailor-Made Games in Medical Education

There are surprisingly few reports in the literature of tailor-made video games used to teach clinical skills. There are even fewer reports of evaluations of these games. In addition, it is often up for debate whether or not the software used in these areas is actually a video game or merely taking advantage of video game technology such as 3-D modeling software and game software engines in simulation scenarios.

Cancer care. The *Oncology Game* was developed for medical students to help them appreciate the multidisciplinary aspects of oncology patient management, increase their knowledge of general principles in cancer care, and promote teamwork skills in solving clinical problems. The PC-based game was designed so that two teams of two students played the game at a time. Sixteen patient scenarios were developed for the game. Treatment plans for the patients required the involvement of two or three of the following cancer specialties: medical oncology, radiation oncology, and surgical oncology. At the start of the game, each student on a team is randomly assigned two patients. Teams work together to advance their patients through the game through surgery and medical and radiation oncology clinics in the best order to obtain the best treatment. Players are presented with questions on general oncology along the way. If they give a correct answer, they can proceed to the next clinic automatically. If they are incorrect, they must rely on the roll of the die to proceed to the clinic. The goal of the game is for each team to complete the treatment of four patients in order. A study was conducted to evaluate the effect of the game on medical student knowledge and their appreciation of the multidisciplinary nature of cancer management (Fukuchi, Offutt, Sacks, & Mann, 2000). Pre- and posttest evaluation of 16 students who played the game over a 3-week period showed that students who played two or more rounds of the game answered significantly more questions correctly on a 16-item true–false questionnaire about 16 different types of cancers represented in the game.

Students gave highly favorable subjective ratings of improvements in their understanding of principles in cancer treatment, their knowledge of cancer, and their appreciation of the multidisciplinary nature of cancer through playing the game.

Breast health. The same group that developed the interactive, computer-assisted board game for cancer above (the *Oncology Game*) also created a similar game that simulated the outpatient evaluation and management of patients presenting with breast problems. In this game, each player is responsible for managing four in-game patients. Patients are introduced when players roll a virtual die and drag the patient icon to a specified location so that the patient chart can be reviewed. A history of the patient is provided, and the player can advance the patient across the board to a number of locations for a mammography, ultrasound, or other procedure (biopsy, fine needle aspiration, etc.). Players may continue until they feel prepared to make a management decision. They have a choice of five decisions to make. If they make the correct decision, the patient is considered successfully managed and removed from the board. If they make an incorrect decision, they lose a turn. The goal of the game is to be the first to successfully manage all four patients. The 33 students who played the game showed significant improvement from pre- to posttest on a 10-item true–false test on breast problem management. They also gave the game favorable ratings for usefulness and appeal (Mann et al., 2002).

The *Oncology Game* and the game for breast health may be quite simple in their approach and design, but they are remarkable in medical education because they openly combine play with learning. The findings are intriguing and promising, but controlled outcomes studies are needed to more fully determine the causal role that this approach to educating doctors has on learning and ultimately on clinical practice.

Simulations. There are reports of other games to teach clinical skills in the literature, but they are only descriptive reports of these games. They are mentioned here because they show strong promise and potential for affecting health outcomes. Both of these games are simulation-based, and it is unclear from their descriptions what, if any, game mechanics they use to engage the player in the scenarios depicted.

Burn Center is a training module simulation that teaches triage and resuscitation in a simulated mass casualty disaster scenario with 40 patients (Kurenov, Cance, Noel, & Mozingo, 2009). *Pulse!!* is simulation software that replicates the National Naval Medical Center at Bethesda, Maryland. It is aimed at both civilian and military medical students and professionals. A report in the medical literature says that it offers an "epistemic framework for optimizing cognitive and psychomotor skills in clinical practices" (Johnston & Whatley, 2006, p. 240). Despite the apparent sophistication of these games and their aims, no evaluation of the efficacy of these tools to affect clinical practice exists in the literature. Evaluating the efficacy of games such as *Burn Center* and *Pulse!!* presents a rich opportunity for future research, and the findings will further our knowledge about what video games can do to improve clinical skills.

Discussion

The research evaluated and reviewed here demonstrates that video games can positively affect health behaviors and outcomes. The use of commercial and tailor-made games to improve the health of patients shows that a great deal of innovation and creativity has gone into making this medium work in effective ways for patients. On the other hand, the use of games for medical education is just in its infancy, and the full potential of serious game applications in this area has yet to be seen. Overall, however, the findings outlined here suggest that video game design and video game technologies have important applications beyond entertainment.

The efficacy of games to change important health behaviors and improve knowledge suggests that the strengths of these tools should be seriously considered when designing interventions in health care. The findings also suggest that play and entertainment can be effective foundations for serious interventions in health care. The work outlined in this article shows that games can have indirect clinical implication because they can promote quality in care through improving surgical skills of doctors and their clinical skills involved in patient care. They have direct clinical implications because video games can help improve patient participation in important diagnostic tasks, enhance patient knowledge about their disease, and increase patient adherence to aversive yet lifesaving treatments.

One thing to keep in mind when considering the overview of studies presented in this article is the possibility that there was a bias to publish studies with positive results, otherwise known as the "file drawer problem" (Rosenthal, 1979). In general, the file drawer problem is a bias to focus on the positive results over negative or inconclusive results. Thus, some writers may have failed to submit their studies with negative or inconclusive results of the effects of video games on health. Similarly, editors and reviewers may have had a tendency to publish evaluations of video games for health that show positive results and not publish studies with negative or inconclusive results. This bias should be kept in mind, although it may be less of a concern with video game studies given that there is a strong interest in general to focus on the negative effects of video games on outcomes (Ferguson, 2007, 2010).

One other drawback is that I did not a review of all the games that have been developed for health, only the games for health that have been described in the scientific literature. As is apparent from general searches on the Internet, other games for health do exist. These games for health may not appear in the scientific literature because of the file drawer problem, lack of funds or expertise available to conduct an evaluation, or purely a commercial interest in developing the games. Whatever the reason, our knowledge and understanding of what video games can and cannot do to affect health can only move forward if we make these investigations a priority, disseminate the findings, and build on them.

In the future, more research studies that clearly outline a causal link between playing video games for health, health care, and outcomes should be conducted. This can be done if researchers conduct randomized controlled trials on these games. Furthermore, efforts should be made to include sample sizes with sufficient power to detect differences between the treatment and control groups. This is often difficult when actual populations of potential participants are small as with certain disease groups or in certain specialties in medicine. It is also difficult because making video games can be an expensive endeavor. For many, the cost of a randomized trial following game production can be a challenging goal. Finally, studies should focus on outcomes that are objective and have clinical relevance. Self-reports of likeability should be paired with objective data, such as amount of time spent playing the game. Also, measures of surgical skill should be demonstrated not only on simulations, but also with real patients where possible.

In conclusion, conversations and debates about the value of video games should include evidence about video games and health. In addition, the field of medical education and training can look to the impressive innovation and activity shown with video games and patient health for inspiration in designing their own educational interventions. The time has come for treatment plans to explore the use of video games as adjuncts to therapy to help patients take full advantage of advances in treatments. Medical curricula designers also should consider including video games as teaching tools so that our wealth of health care resources can be delivered safely and effectively.

References

Annetta, L. (2010). The "I's" have it: A framework for serious educational game design. *Review of General Psychology, 14,* 105–112.

Atriou (2009). *Bronkie Health Hero*. EVERYGAME. Available from http://everygame.wordpress.com/2009/03/27/bronkie-health-hero/

Brown, S. J., Lieberman, D. A., Gemeny, B. A., Fan, Y. C., Wilson, D. M., & Pasta, D. J. (1997). Educational video game for juvenile diabetes: Results of a controlled trial. *Medical Informatics, 22,* 77–89.

Castel, A., Pratt, J., & Drummond, E. (2005). The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica, 119,* 217–230.

De Paepe, H., Renson, C., Van Laecke, E., Raes, A., van de Walle, J., & Hoebeke, P. (2000). Pelvic-floor therapy and toilet training in young children with dysfunctional voiding and obstipation. *British Journal of Urology International, 85,* 889–893.

Durkin, K. (2010). Video games and young people with developmental disorders. *Review of General Psychology, 14,* 122–140.

Enochsson, L., Isaksson, B., Tour, R., Kjellin, A., Hedman, L., Wredmark, T., & Tsai-Felländer, L. (2004). Visuospatial skills and computer game experience influence the performance of virtual endoscopy. *Journal of Gastrointestinal Surgery, 8,* 874–880.

Ferguson, C. (2007). Evidence for publication bias in video game violence effects literature: A meta-analytic review. *Aggression and Violent Behavior, 12,* 470–482.

Ferguson, C. J. (2010). Blazing angels or resident evil? Can violent video games be a force for good? *Review of General Psychology, 14,* 68–81.

Ferguson, C. J., Cruz, A., & Rueda, S. (2008). Gender, video game playing habits and visual memory tasks. *Sex Roles: A Journal of Research, 58,* 279–286.

Fitzgerald, S., & Cooper, R. (2004). The GAME(Cycle) exercise system: Comparison with standard ergometry. *Journal of Spinal Cord Medicine, 27,* 453–459.

Freud, A. (1968). Acting out. *International Journal of Psycho-Analysis, 49,* 165–170.

Fukuchi, S., Offutt, L., Sacks, J., & Mann, B. (2000). Teaching a multidisciplinary approach to cancer treatment during surgical clerkship via an interactive board game. *The American Journal of Surgery, 179,* 337–340.

Glaser, A. Y., Hall, C. B., Uribe, S. J., & Fried, M. P. (2005). The effects of previously acquired skills on sinus surgery simulator performance. *Otolaryngology—Head and Neck Surgery, 133,* 525–530.

Grantcharov, T., Bardram, L., Funch-Jensen, P., & Rosenberg, J. (2003). Impact of hand dominance, gender, and experience with computer games on performance in virtual reality laparoscopy. *Surgical Endoscopy, 17,* 1082–1085.

Graves, L., Stratton, G., Ridgers, N., & Cable, N. (2008). Energy expenditure in adolescents playing new generation computer games. *British Journal of Sports Medicine, 42,* 592–594.

Green, C. S., & Bavelier, D. (2003, May 29). Action video game modifies visual selective attention. *Nature, 423,* 534–537.

Green, C. S., & Bavelier, D. (2007). Action-video-game experience alters the spatial resolution of vision. *Psychological Science, 18,* 88–94.

Hagen, M., Wagner, O., Inan, I., & Morel, P. (2009). Impact of IQ, computer-gaming skills, general dexterity, and laparoscopic experience on performance with the da Vinci surgical system. *International Journal of Medical Robotics, 5,* 327–331.

Harper, J., Kaiser, S., Ebrahimi, K., Lamberton, G., Hadley, H., Ruckle, H., & Baldwin, D. D. (2007). Prior video game exposure does not enhance robotic surgical performance. *Journal of Endourology, 21,* 1207–1210.

Herndon, C., Decambre, M., & McKenna, P. (2001). Interactive computer games for treatment of pelvic floor dysfunction. *The Journal of Urology, 166,* 1893–1898.

Hoffman, H. G., Patterson, D. R., Seibel, E., Soltani, M., Jewett-Leahy, L., & Sharar, S. R. (2008). Virtual reality pain control during burn wound debridement in the hydrotank. *Clinical Journal of Pain, 24,* 299–304.

Institute of Medicine. (2001). *Crossing the quality chasm: A new health system for the 21st century.* Washington, DC: National Academies Press.

Johnston, C., & Whatley, D. (2006). *Pulse!!*—A virtual learning space project. *Studies in Health Technology and Informatics, 119,* 240–242.

Kato, P. M., & Beale, I. L. (2006). Factors affecting acceptability to young cancer patients of a psychoeducational video game about cancer. *Journal of Pediatric Oncology Nursing, 23,* 269–275.

Kato, P. M., Cole, S. W., Bradlyn, A. S., & Pollock, B. (2008). A video game improves behavioral outcomes in adolescents and young adults with cancer: A randomized trial. *Pediatrics, 122,* e305–e317.

Kent, S. L. (2001). *The ultimate history of video games: From* Pong *to* Pokemon*, the story behind the craze that touched our lives and changed the world.* Roseville, CA: Three Rivers Press.

Kohn, K., Corrigan, J., & Donaldson, M. (1999). *To err is human: Building a safer health system.* Washington, DC: National Academies Press.

Konami Digital Entertainment—America. (2005). Dance Dance Revolution *goes "platinum" in North America as sales of the landmark music game surpass the one million mark in 2004:* DDR *phenomenon explodes as more than 2.5 million units have been sold across all platforms since its introduction into the North America marketplace.* Retrieved from http://www.gamezone.com/news/01_31_05_03_33PM.htm

Krichevets, A., Sirotkina, E., Yevsevecheva, I., & Zeldin, L. (1994). Computer games as a means of movement rehabilitation. *Disability and Rehabilitation: An International Multidisciplinary Journal, 17,* 100–105.

Kurenov, S., Cance, W., Noel, B., & Mozingo, D. (2009). Game-based mass casualty burn training. *Studies in Health Technology and Informatics, 142,* 142–144.

Lanningham-Foster, L., Jensen, T., Foster, R., Redmond, A., Walker, B., Heinz, D., & Levine, J. A. (2006). Energy expenditure of sedentary screen time compared with active screen time for children. *Pediatrics, 118,* e1831–e1835.

Leahy, A., Clayman, C., Mason, I., Lloyd, G., & Epstein, O. (1998). Computerised biofeedback games: A new method for teaching stress management and its use in irritable bowel syndrome. *Journal of the Royal College of Physicians London, 32,* 552–526.

Lieberman, D. A. (1997). Interactive video games for health promotion: Effects on knowledge, self-efficacy, social support, and health. In R. L. Street, W. R. Gold, & T. Manning (Eds.), *Health promotion and interactive technology: Theoretical applications and future directions* (pp. 103–120). Mahwah, NJ: Erlbaum.

Lieberman, D. A. (2001). Management of chronic pediatric diseases with interactive health games: Theory and research findings. *The Journal of Ambulatory Care Management, 24,* 26–38.

Mann, B., Eidelson, B., Fukuchi, S., Nissman, S., Robertson, S., & Jardines, L. (2002). The development of an interactive game-based tool for learning surgical management algorithms via computer. *The American Journal of Surgery, 183,* 305–308.

McKenna, P. H., Herndon, C. D. A., Connery, S., & Ferrer, F. A. (1999). Pelvic floor muscle retraining for pediatric voiding dysfunction using interactive computer games. *The Journal of Urology, 162,* 1056–1062.

Mead, G. (1982). *The individual and the social self: Unpublished essays by G. H. Mead.* Chicago: University of Chicago Press.

Mirman, M., & Bonian, V. (1992). "Mouse elbow": A new repetitive stress injury. *Journal of the American Osteopath Association, 92,* 701.

O'Connor, T., Cooper, R., Fitzgerald, S., Dvorznak, M., Boninger, M., Van Sickle, D., & Glass, L. (2000). Evaluation of a manual wheelchair interface to computer games. *Neurorehabilitation and Neural Repair, 14,* 21–30.

Orry, J. (2009). *Wii* Fit *the UK's best seller of 2009.* Retrieved from http://www.videogamer.com/wii/mario_kart_wii/news/wii_fit_the_uks_best_seller_of_2009.html

Partridge, A. H., Kato, P. M., & DeMichele, A. (2009). Adherence to oral cancer therapies: Challenges and opportunities. In R. Govindan (Ed.), *American Society of Clinical Oncology 2009 Educational Book* (pp. 124–128). Alexandria, VA: American Society of Clinical Oncology.

Patel, A., Schieble, T., Davidson, M., Tran, M. C. J., Schoenberg, C., Delphin, E., & Bennett, H. (2006). Distraction with a hand-held video game reduces pediatric preoperative anxiety. *Pediatric Anesthesia, 16,* 1019–1027.

Pfister, C., Dacher, J., & Gaucher, S. (1999). The usefulness of a minimal urodynamic evaluation and pelvic floor biofeedback in children with chronic voiding dysfunction. *British Journal of Urology, 84,* 1054–1057.

Redd, W. H., Jacobsen, P. B., DieTrill, M., Dermatis, H., McEvoy, M., & Holland, J. C. (1987). Cognitive–attentional distraction in the control of conditioned nausea in pediatric cancer patients receiving chemotherapy. *Journal of Consulting and Clinical Psychology, 55,* 391–395.

Rieber, L. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *Educational Technology Research and Development, 44,* 43–58.

Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., . . . Salinas, M. (2003). Beyond Nintendo: Design and assessment of educational video games for first and second grade students. *Computers & Education, 40,* 71–94.

Rosenberg, B., Landsittel, D., & Averch, T. (2005). Can video games be used to predict or improve laparoscopic skills? *Journal of Endourology, 19,* 372–376.

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological Bulletin, 86,* 638–641.

Rosser, J., Lynch, P., Caddihy, L., Gentile, D., Klonsky, J., & Merrell, R. (2007). The impact of video games on training surgeons in the 21st century. *Archives of Surgery, 142,* 181–186.

Schlickum, M., Hedman, L., Enochsson, L., Kjellin, A., & Felländer-Tsai, L. (2009). Systematic video game training in surgical novices improves performance in virtual reality endoscopic surgical simulators: A prospective randomized study. *World Journal of Surgery, 33,* 2360–2367.

Shane, M., Pettitt, B., Morgenthal, C., & Smith, C. (2008). Should surgical novices trade their retractors for joysticks? Videogame experience decreases the time needed to acquire surgical skills. *Surgical Endoscopy, 22,* 1294–1297.

Sharar, S., Carrougher, G., Nakamura, D., Hoffman, H., Blough, D., & Patterson, D. (2007). Factors influencing the efficacy of virtual reality distraction analgesia during postburn physical therapy: Preliminary results from 3 ongoing studies. *Archives of Physical Medicine and Rehabilitation, 88,* s43–s49.

Sietsema, J., Nelson, D., Mulder, R., Mervau-Scheidel, D., & White, B. (1993). The use of a game to promote arm reach in persons with traumatic brain injury. *American Journal of Occupational Therapy, 47,* 19–24.

Stahl, E. (2009). *Bronkie the Bronchiasaurus*. *Something awful: The Internet makes you stupid*. Available at http://www.somethingawful.com/d/rom-pit/bronkie-asthma-dinosaur.php

Szer, J. (1983). Video games as physiotherapy. *Medical Journal of Australia, 1,* 401–402.

Vandewater, E., Shim, M., & Caplovitz, A. (2004). Linking obesity and activity level with children's television and video game use. *Journal of Adolescence, 27,* 71–85.

Vasterling, J., Jenkins, R. A., Tope, D. M., & Burish, T. G. (1993). Cognitive distraction and relaxation training for the control of side effects due to cancer chemotherapy. *Journal of Behavioral Medicine, 16,* 65–79.

Vilozni, D., Barker, M., Jellouschek, H., Heimann, G., & Blau, H. (2001). An interactive computer-animated system (*SpiroGame*) facilitates spirometry in preschool children. *American Journal of Respiratory and Critical Care Medicine, 164,* 2200–2205.

Westman, B., Ritter, E. M., Kjellin, A., Törkvist, L., Wredmark, T., Felländer-Tsai, L., & Enochsson, L. (2006). Visuospatial abilities correlate with performance of senior endoscopy specialists in simulated colonoscopy. *Journal of Gastrointestinal Surgery, 10,* 593–599.

Widman, L., McDonald, C., & Abresch, T. (2006). Effectiveness of an upper extremity exercise device integrated with computer gaming for aerobic training in adolescents with spinal cord dysfunction. *Journal of Spinal Cord Medicine, 29,* 363–370.

Received December 28, 2009
Revision received December 28, 2009
Accepted January 16, 2010 ■