The Effect of Videogame Play on Robotic Surgery Skill Acquisition

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THE EFFECT OF VIDEOGAME PLAY ON ROBOTIC SURGERY SKILL ACQUISITION

by

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Modeling and Simulation in the College of Engineering and Computer Science at the University of Central Florida Orlando, Florida

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Major Professor: Charles Hughes
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ABSTRACT

Robotic surgery uses innovative technology to transcend a surgeon’s skills when performing complex procedures. Currently, the only FDA approved robotic system is Intuitive’s da Vinci Surgical System. While this system offers many advantages over other minimally invasive techniques, it also introduces a need for specialized training. Virtual reality simulators have emerged as valuable tools for standardized and objective robotic surgery skill training and assessments. In recent years, the idea of using video game technology in surgical education for laparoscopy has also been explored; however few have attempted to make a connection between video game experience and robotic surgical skills. Thus, the current study aims to examine the performance of video gamers in a virtual reality robotic surgery simulator. Furthermore, the video gamers’ performance was compared to that of medical students, expert robotic surgeons, and “laypeople.” The purpose of this study is to examine the hypothesis that video gamers acquire perceptual and psychomotor skills through video game play, similar to those used by robotic surgeons.

Subjects completed a demographic questionnaire and performed three computer-based perceptual tests: a Flanker compatibility task, a subsidizing task, and a Multiple Object Tracking test. Participants then performed two warm-up exercises on the Mimic dV-Trainer to familiarize themselves with the system and eight trials of two core exercises to test their skills. After completing all trials, participants completed a post-questionnaire regarding their experience with the system.

Expert video gamers (n=40), medical students (n=24), laypeople (n=42) and expert robotic surgeons (n=16) were recruited. Medical students and gamers were significantly faster
than experts in the Flanker Task. The experts were significantly slower than the all other groups in the subsidizing task. Experts scored significantly higher, were significantly more efficient, and were significantly faster than laypeople, medical students, and gamers in the first trial of Ring & Rail 1 and Suture Sponge. In trial eight of Ring & Rail 1, experts scored significantly higher and were more efficient than laypeople. Experts were also significantly faster than all other groups. Experts scored significantly higher than laypeople and gamers in trial Suture Sponge. Experts were significantly more efficient and significantly faster than all other groups.

Contrary to prior literature in laparoscopy, this study was unable to validate enhanced abilities of video gamers in a robotic surgery simulator. This study does further demonstrate that the transfer of skills developed through video game play is relevant to the surgical technique. This may be due to the differences of the systems and how the users interact within them. In a society where video games have become an integral past time, it is important to determine the role that video games play in the perceptual and psychomotor development of users. These findings can be generalized to domains outside of medicine that utilize robotic and computer-controlled systems, speaking to the scope of the gamers’ abilities and pointing to the capacity within these systems.
I would like to dedicate this dissertation to my parents. My entire life I knew that if I could be anything close to the people that you are, I would have something to be proud of. Thank you for always encouraging my sense of inquiry and academic growth. This dissertation is also dedicated to Casey. Your unyielding love and encouragement has carried miles and truly been the support, without which my life would be incomplete. Finally, to my grandparents, thank you for being a continual source of love and encouragement in my life.
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<td>CM</td>
<td>Centimeter</td>
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<tr>
<td>CT</td>
<td>Computed Tomography</td>
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<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
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<td>DOD</td>
<td>Department of Department</td>
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<td>DVSS</td>
<td>Da Vinci Skills Simulator</td>
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<tr>
<td>FDA</td>
<td>Food and Drug Administration</td>
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<td>FIEA</td>
<td>Florida Interactive and Entertainment Academy</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<td>NIH</td>
<td>National Institute of Health</td>
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<tr>
<td>MIS</td>
<td>Minimally Invasive Surgery</td>
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<td>MOT</td>
<td>Multiple Object Tracking</td>
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<td>PICSOR</td>
<td>Pictorial Surface Orientation</td>
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<td>PS2</td>
<td>PlayStation 2</td>
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<td>ROSS</td>
<td>Robotic Surgery Simulator</td>
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<td>SEC</td>
<td>Seconds</td>
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<td>VGE</td>
<td>Video Game Expert</td>
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<td>VR</td>
<td>Virtual Reality</td>
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<td>Visuospatial Perception</td>
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CHAPTER ONE: INTRODUCTION

Surgical Training

The earliest surgical training model, typically characterized as “See One, Do One, Teach One,” was the apprenticeship model developed by William Stewart Halsted. Prior to Halsted’s contribution, no formal apprenticeship program existed for young surgeons. The Halstedian model remained fundamentally unchanged until Dr. Edward Delos Churchill proposed a new framework, which was used as the core of the residency programs in the United States until the twentieth century (Gallagher & O’Sullivan, 2011).

A number of cases have spurred changes in medical training, including the Institute of Medicine’s report To Err is Human; however, the realization that surgical training needed a considerable change came with the introduction of minimally invasive surgery (MIS). While minimally invasive approaches to diagnostic procedures had been used by various specialties since the 1980s, MIS did not come to fruition until the 1990s (Gallagher & O’Sullivan, 2011).

Surgical modalities. Surgery is generally described as fitting into two categories – open and minimally invasive surgery (MIS), the latter of which includes laparoscopic and robotic-assisted procedures. Open surgery is the most fundamental of the surgical types. An incision is made through the skin, muscle, and fascia to enter the surgical space. The incision must be large enough for the surgeon’s hands or tools and for the surgeon to see into the operative space. MIS is facilitated through several small incisions, in which instruments are inserted to perform the surgery in replacement of the surgeon’s hands and traditional instruments. MIS is used in several specialties including general, gynecology, urology, spinal, and orthopedics. In robotic-assisted
surgery, the surgeon’s movements are facilitated through a computer driven system to move the robotic instruments (Figure 1).

Figure 1. An example of incisions in open surgery vs. MIS

The introduction of MIS revolutionized the field of surgery and was quickly adopted into practice. Not long after establishment, laparoscopic procedures were associated with higher complication rates than performing the same procedures via an open technique. The higher complication rates resulted from the substantial perceptual and psychomotor difficulties users face, including reduced degrees of freedom, limited tactile feedback through the 18-inch long surgical instruments, a pixelated 2-D visual screen, and a fulcrum effect incurring strain on visual processing and a proprioceptive-visual conflict (Gallagher & O'Sullivan, 2011).

In 1992, a consensus conference by the American National Institute of Health (NIH) evaluated the use of laparoscopic cholecystectomies for the treatment of gallstones and concluded that, while the procedure was effective, surgeons performing the procedure must be properly trained and credentialed. This resulted in a rapid increase in training courses and
surgical training centers across the country. While the knowledge component of these courses was robust and standardized, the skills training lacked repeated practice and consisted of subjective assessments of performance (Gallagher & O'Sullivan, 2011).

In 1993, Dr. Richard Satava proposed virtual reality simulation as a solution to the disparity in the standard of training and associated costs of training courses. The events in the surgical field, which led to this point, revolutionized the way that physicians train and pushed a national understanding that physicians must begin demonstrating their skills. This notion, combined with reduced training opportunities, limited work hours, and a need for advanced training created a time of critical evaluation in the medical training community (Kuhn, 1962; Gallagher & O'Sullivan, 2011).

The introduction of VR simulators coincided with a drive in the field to move away from the traditional apprenticeship model and towards proficiency-based training, although this has still not yet come to realization. This approach acknowledges that all trainees do not enter training with equivalent knowledge and skills. Thus, a standard time or number of tasks for training will not have an equivalent effect across all learners. The proficiency-based approach requires learners to reach a specified performance benchmark that is based on the performance of experts in the same task (Gallagher et al., 2005).

**Robotic Surgical Systems**

Many robotic systems preceded the current state of medical robotics. In 1961, Unimation, Inc. created an industrial robotic arm with six degrees of freedom to perform labor-intensive manufacturing tasks that were previously performed by humans. In 1978 the Programmable Universal Manipulation Arm (PUMA) applied the technology to medicine to place a needle for a
brain biopsy under CT guidance (Figure 2) (Kwoh, Hou, Jonckheere, & Hayati, 1988). In the 1980s the PROBOT was developed by the Imperial College in London to assist in transurethral prostatectomies (Kalan et al., 2010). Using this system, the surgeon outlines a specific area for resection on a computer generated 3-D model of a prostate, which is executed by the robotic system without further guidance from the surgeon. ROBODOC, developed in 1992 by Integrated Surgical Systems, uses CT data to drill a precise hole in the femoral head for hip arthroplasty (Paul et al., 1992).

Figure 2. The PUMA robot created by Unimation

The Automated Endoscopic System for Optimal Positioning (AESOP) added a new dimension to the field for robotic surgery in 1994 by introducing the first laparoscopic camera holder approved by the FDA (Unger, Unger, & Bass, 1994). The robotic arm was initially developed by Computer Motion for NASA as a robotic arm to be used in space, but found its
role in laparoscopic surgery as a table mounted camera holder (Figure 3). In 1998, Computer Motion leveraged the technology into the ZEUS robot, which consisted of one AESOP camera arm and two robotic arms with four degrees of freedom (Figure 4). Concurrently, the Defense Advanced Research Projects Agency (DARPA) was developing the Green Telepresence System, which would later become the Da Vinci Surgical system (Rininsland, 1993; Kalan et al., 2010). This system evolved from the idea of a surgeon performing surgery from a location remote to the patient, a concept referred to as telesurgery. The intended purpose was to enable a surgeon to treat injured soldiers in a combat environment anywhere in the world. It was soon realized that this application was valuable not only as a military application, but also when the surgeon was separated from the patient by a layer of skin and the license was purchased by Frederick H. Moll to create Intuitive Surgical (Satava, 2002).
The AESOP robot created by Computer Motion

The ZEUS robot created by Computer Motion

Robotic surgery today. While the ability to perform these remote surgeries has not completely come to fruition, the current state of robotic surgery introduced an innovative approach to surgery and a new dimension to the surgical toolbox. The only currently available robotic system that is FDA approved for procedures on humans is Intuitive’s da Vinci Surgical System. This system consists of three main components: the surgeon console, patient cart, and video tower. The surgeon manipulates the master controllers at the surgeon console, which is communicated to the patient cart through a fiber optic cable connection and translated into scaled-down, micro-movements to manipulate tiny instruments. The master controllers allow the
surgeons to move their arms and wrists in a natural manner and to open and close their instruments by opening and closing the controllers in their hands (Figure 5). By facilitating the surgeon’s movements through this technology, the system provides motion amplification, 7-degrees-of-freedom, and tremor damping (Patel et al., 2013; Hubens, Coveliere, Balliu, Ruppert, & Vaneerdeweg, 2003; Blavier, Gaudissart, Cadière, & Nyssen, 2007).

Figure 5. Example of the data flow through the daVinci System

The surgeon’s vision is facilitated using a high-definition endoscope inserted in the abdomen of the patient, which provides a true stereoscopic picture to the surgeon via the 3-D stereo viewer on the surgeon console. Unlike the tactile feedback surgeons receive in laparoscopic procedures, robotic surgeons work completely from visual cues of depth perception.
and a synthetic tactile sensation, which is facilitated by the magnified, 3-D vision. This is quite an advantage over traditional minimally invasive procedures, which are performed using a 2-D image. Since the robotic endoscope is held in place via one of the four robotic arms, the system offers camera stabilization and control also unavailable to surgeons in other minimally invasive methods. The robotic system offers clinical advantages similar to laparoscopy, including faster recovery time with less pain and fewer complications after surgery (Seamon et al., 2008). While the introduction of the robotic system offers many technological advantages to laparoscopic surgery it also introduces a specific need for affordable training and certification to ensure a minimal standard of care for all patients.

**Simulation in Medicine**

Simulation is the act of imitating a thing, state, or process (Simulation, n.d.). Simulation is a method of training that has been used by the aviation field for nearly nine decades. One of the earliest flight simulators for training was the Link Trainer developed in 1929 (Okraski, 2013). The aviation field has adopted simulation as a means of skill acquisition, skill maintenance, and certification. Following suit, many fields have begun using simulation as a means of skills training, with a more recent example being medicine.

The earliest commercial medical simulator was a cardiopulmonary resuscitation trainer, Resusci Annie (Rosen, 2008; Cooper & Taqueti, 2004). Anesthesiologists have used more advanced human-patient simulators since the 1960s (Rosen, 2008). Current uses of simulation can be seen in many aspects of medicine, ranging from standardized patients, mannequins, part-task trainers, and virtual trainers.
Simulation training in robotic surgery. The concept of simulating the operative environment can be seen in many examples. This can range from a basic, non-interactive model to a sophisticated computer simulation. At the most fundamental level, simulation is used in the form of dry or wet lab training. In a dry lab, synthetic materials and manufactured objects are used, while excised tissue is used for wet labs. These trainings are used to practice basic skills. For example, dry labs typically train non-surgical, psychomotor skills (e.g. wrist manipulation and object handling). These are typically meant to help the trainee understand how to use the tool and to acquire correct technique. In a wet lab, the trainees would typically practice basic surgical skills, such as dissection, suturing, or energy techniques (i.e. the use of bipolar or monopolar energy tools for cauterization).

Simulating the operative environment can also be seen in the form of animate and cadaveric training. Animate trainings allow for a similar anatomical setting, with live characteristics (i.e. bleeding or tissue coloration) and cadaveric training is used for precise anatomical markings. While these options offer high fidelity training environments, particularly cadaveric training, they are time consuming and expensive (Wanzel, Matsumoto, Hamstra, & Anastakis, 2002). A solution that has been offered to relinquish the resources needed for robotic training is VR simulation. A number of VR simulators have been developed to support training and skill assessment in robotic surgery.

Virtual reality robotics surgery simulation. Robotic surgery simulators are economical training tools that offer standardized and objective skills assessments. VR simulators have existed in laparoscopy for more than fifteen years and have become available for robotic surgery in the last five years. Surgeons use these simulators to train in virtual environments and complete
various basic tasks to improve surgical performances, reduce learning curves and maintain skills ability. The currently available robotic surgery simulators include: the da Vinci Skills Simulator (dVSS) by Intuitive Surgical Inc., also known as the “Backpack Simulator”; the dV-Trainer from Mimic Technologies Inc., the RoSS by Simulated Surgical Sciences Inc., and the Robotix Mentor from Simbionix (Figure 6). The purpose of these simulators is to train robotic surgeons prior to using the actual robotic system and to allow them to acquire the necessary robotic skills to perform a safe surgery. All of these da Vinci simulators utilize a visual scene that is presented in a computer generated 3D environment, providing challenging tests for practicing dexterity and system operations. Originally, the simulated exercises trained basic robotic skills; however with advances in technology, surgeons can now train for specific procedures (e.g. partial nephrectomy and hysterectomy).
Figure 6. The commercially available robotic surgery simulators

In the dVSS, the trainee sits at and operates the simulated environment using the actual da Vinci surgeon console. The simulator is a custom computer, appended to the surgical console through the actual surgical data port. While the simulator costs approximately $100,000, the surgical console costs $500,000 incurring a total investment of about $600,000. Using this simulator, users can train using the actual hardware they would use during surgery; however, this requires the use of the surgeon console that may be needed to conduct surgeries. Most hospitals may not have a dedicated training console, meaning that users would not have appropriate access to the simulator. The second is a standalone system that utilizes a graphic/gaming computer, connected to a custom desktop viewing and control device that replicates the hardware of the da Vinci surgeon’s console. This system shares similar software with the dVSS, but does not require the use of any actual da Vinci hardware. The cost of this simulator is approximately $100,000. The third is composed of a completely customized replica of the da Vinci surgeon’s console. Internally the simulator contains a graphic computer, a 3D monitor, and commercial Omni Phantom haptic controllers. This simulator uses unique software and costs about $100,000
(Smith, Truong, & Perez, 2014). The Robotix Mentor is a standalone system that uses custom hardware for the master controllers and Sony glasses for the 3D visual system. The system costs about $80,000 (Robotix Mentor, n.d).

**Video Game Technology in Medicine**

In recent years, a new aspect of training has been explored: the role of video game technology in surgical education. The role of serious games for training has been explored by the military for many years and military simulations often contain gaming technologies (Chatham, 2007; Lenoir, 2003; Smith, 2007). Medicine has also adopted this concept for the training of diagnostic skills and physician-patient interactions. An example can be seen in the American College of Physicians’’ Doctors Dilemma, which uses Jeopardy-style questions to challenge residents’ medical knowledge.

**Current videogame research in surgery.** The field of surgery has become increasingly interested in this concept. Previous research has been directed at investigating the effect that video game play can have on surgical skills. Prior studies demonstrated that trainees with prior video game experience perform better on basic laparoscopic tasks in a dry lab and VR training environment (Lynch, Aughwane, & Hammond, 2010). Studies have also investigated using video games as training tools for MIS, many of which found positive training outcomes (Rosser et al., 2012; Badurdeen et al., 2010; Ju, Chang, Buckley, & Wang, 2012; Bokhari et al., 2010; Middleton et al., 2013). For laparoscopic surgery, many of them have shown improvement on skills abilities performing basic laparoscopic simulation procedure (Giannotti et al., 2013; van Dongen, Verleisdonk, Schijven, & Broeders, 2011; Schlickum, Hedman, Enochsson, Kjellin, & Felländer-Tsai, 2009). While many studies have attempted to make a connection between video
game experience and laparoscopic skills development, few have attempted to make this connection with robotic surgical skills (Chien et al., 2013; Harper et al., 2007).

There are several gaps in the existing research. While many of the research studies found positive relationships between video games and basic skills performance, some studies were unable to confirm a relationship with more complex skills. Furthermore, a study by Chien et al. (2013) found that using a video game as a training tool may provide negative training to users. Also, the improvement was well demonstrated on surgical simulators but remained less clear on the actual surgical procedures as shown by Madan et al. (2005) on a porcine model.

The Current Research

The current research aimed to examine the performance of video gamers on a robotic surgery simulator. Furthermore, the video gamers’ performance was compared to the performance of medical students, expert robotic surgeons, and “laypeople.” The purpose of this study was to determine whether video gamers acquire perceptual and psychomotor skills which may prepare them for success in fields other than video gaming, more specifically surgery. This study measured the performance of this population against that of experienced robotic surgeons who regularly perform robotic surgery, but spend little time using video games.
CHAPTER TWO: REVIEW OF LITERATURE

Many fields have aimed to find more innovative ways to create effective and engaging curricula. Game mechanics and technology have come to the forefront as a possible offering for engaging methods of training. Games can offer interesting ways to learn and practice knowledge and skills. Many fields incorporate game mechanics into training, including business and management (Wolfe, 1993). In more recent years, medicine has also begun incorporating game concepts into learning for topics ranging from interacting with or diagnosing patients. In one instance, surgical residents were challenged with topic-specific questions and scenarios to train their clinical reasoning. The residents of this program indicated that they enjoyed the game and preferred it to the didactic lecture (Meterissian, Liberman, & McLeod, 2007).

Video games have also demonstrated the ability to lead to the acquisition of practical skills when combined with virtual reality situations. For example, Fery and Ponserre (2001) used 62 right-handed males with no prior golf experience. The subjects were divided into a control group, two learning groups, and two enjoyment groups. The results showed that the two learning groups improved the most, with all experimental groups improving in their post-test golf scores. The popularity of research surrounding the use of video gaming for effective surgical training has grown recently. Rosser’s Top Gun program aims to train laparoscopic skills through video game mechanics (Rosser et al., 2007; Rosser, Rosser, & Savalgi, 1998; Rosser, Rosser, & Savalgi, 1997).

Impact of Video Games for Surgical Skills Training

Many studies have suggested that video games may act as a kickstarter for skills essential to performing surgery. A literature review was conducted to survey the available literature on the
use of games and gaming populations in surgical training research. Literature on the cognitive abilities of gamers and robotic surgeons was also surveyed. Literature databases such as Pubmed and Google Scholar were surveyed.

**Videogame impact on dry lab and wet labs.** Of the available research, some has evaluated the relation of video game experience to surgical performance in dry or wet lab training. This research is based on either observational attributes or treatments. The observational studies analyze the extent of self-reported video game use via questions on a demographics questionnaire. The research studies that use video gaming as a treatment administer video gaming as a warm-up prior to a surgical training or as a means of training between a pre-test and post-test of surgical skills.

**Observational research.** Rosser (2007) found that surgeons (n=33) who reported previously playing video games at least three hours per week made significantly fewer errors and were significantly faster than non-video game playing surgeons in Top Gun Drills. The results showed that current video game users also performed significantly better than non-video gamers on the Top Gun Drills. In this study, Rosser also demonstrated that certain video games (i.e. Super Monkeyball 2, Silence Scope, and Star Wars Racer Revenge) correlated with laparoscopic skills used in Top Gun. The author suggests that mechanics of video games can have positive effects on skills and are more likely to be mechanisms to improve laparoscopic skills. The results also suggest that the effects of gameplay on skills can be seen even after prolonged non-use. However, the authors did not collect data regarding the time elapsed since the participants stopped participating in regular video game play. In this study, the authors do not distinguish which participants were residents and which were attending surgeons. This distinction is
important because one would expect that an attending would have fewer errors and less gaming experience than a resident, which could affect the results.

Other studies also show improved laparoscopic dry lab performance by trainees with prior video game experience. Adams, Margaron, & Kaplan (2012) found that residents with prior gaming performance performed better on a peg transfer task than those without prior gaming experience.

*Treatment research.* Rosser, Gentile, Hanigan, & Danner (2012) proceeded to take their video game research further with a quasi-experimental design, based on the performance of participants in Rosser’s Top Gun Laparoscopic Skills and Suturing program, which involves various basic drills in a laparoscopic dry box. For this study, participants (n=303) were placed in either an experimental or a control group. The experimental group played three video games (i.e. Star Wars Racer, Silent Scope, and Super Monkey Ball) before completing the Top Gun program, while the control group only performed the Top Gun program. The scores for the experimental and control group were significantly different for the cobra rope and suturing tasks. The video game training group was also significantly faster for the suturing task. The groups were not significantly different for any of the other tasks. The participants performed the Bean Drop task several hours after training, which could indicate that the warm-up effect had worn off.

In another study, medical students and junior doctors (n=19) performed three tasks in a laparoscopic box trainer. The first task was to use two graspers to stack twelve sugar cubes as high as possible. The second was to remove as many fingers as possible off of a glove within four minutes, while also cutting within designated lines. The third was to thread as many mints
as possible onto a shoelace in ten minutes. The subjects then completed three mini games, with similar skill sets, using the Wii console: Pose Mii, Shooting Range, and Charge! The composite Wii score correlated strongly with the laparoscopic trainer score. The individual score on each of the games also correlated positively with the laparoscopic scores. The participants in the top tertile of the Wii scores performed significantly better on laparoscopic skills than those in the bottom two tertiles. These results also indicate an overlap between video game use and skills used for basic laparoscopic exercises. The authors suggest that the Wii controller and the movements in a 3-D space offer a similar model of laparoscopy surgery, which may explain the correlation. The authors also suggest that video games, which incorporate mechanics similar to those used in laparoscopic tasks, may play a role in acquisition of perceptual skills for laparoscopy (i.e. visuospatial, motor, and attentional skills). (Badurdeen et al., 2010).

In another study, 42 participants performed a pre-test consisting of a suturing task and a bead transfer task in a laparoscopic box trainer. The participants were then randomized to play either Time Crisis 2 on the Playstation 2 (PS2) or a strategy game called BoomBloxx on the Nintendo Wii. All participants then completed a post-test consisting of the same box trainer tasks. The authors found that both groups improved significantly from pre-test to post-test on the bead transfer task; however, there was no significant difference in improvements between the two groups. Neither group improved significantly in the suturing task. In fact, 18% and 15% respectively of participants in the Wii and PS2 groups performed worse. This study also demonstrates the possibility of games having a positive impact on basic laparoscopic skills; however, the improvements on more complex surgical skills are not clear. An interesting point of this study is that the PS2 and Wii groups improved with no significant differences between them.
Contrary to Badurdeen, et al. (2010), the authors suggest that the type of game controller may not necessarily be a critical factor to surgical training. One critique of this study is that the subjects trained with the video games for 30 minutes, which may not have been extensive enough (Ju, Chang, Buckley, & Wang, 2012). Many other studies also found improvements in laparoscopic abilities in dry lab using video game training (Adams, Margaron, & Kaplan, 2012).

**Videogame impact on virtual reality training.** Studies have also investigated the impact of prior video game use on ability and surgical skills in a VR simulator, many of which have shown improvements in a laparoscopic setting. Others have also compared the use of video games to laparoscopic simulators as training tools, in terms of the acquisition of laparoscopic skills.

**Observational research.** Grantcharov, Bardram, Funch-Jensen, & Rosenberg (2003) recruited 25 surgeons in training to perform 10 repetitions of six exercises on the MIST-VR laparoscopic simulator. The authors found that surgeons with computer game experience made significantly fewer errors than those without such experience. A weakness of the study is that it does not detail the amount of game play in which the subjects participated.

In a 2013 study, the authors found that gamers scored significantly better for manual parameters (e.g. time for a lifting and grasping task) in a laparoscopic simulator. No difference was found between the gamers and non-gamers on a second trial of the same task after seven days of training. The gamer group did not demonstrate a significant improvement from the first to the second trial of testing for most metrics, except tissue damage and score. When testing the same groups in a fine dissection task, no differences were found in the first or second trial and the gamers did not improve significantly between the first and second trials. The authors explain
that the gamers improved significantly in a task that required manual skills, as opposed to clinical skills. Also, they posit that the gamers may not have improved significantly from one trial to the next because they already have the optimal skills necessary to succeed in the task. (Lehmann et al., 2013).

In another study, the authors tested children aged 8.4 to 12.1 years of age (n=32), residents (n=20), and board certified surgeons (n=14). First, the participants performed a test of stereopsis, which is the process in visual perception leading to perception of depth and 3D dimensions. All participants demonstrated stereopsis. The participants were then tested on their spatial abilities and fine motor skills using the Wechsler Intelligence scale for Children and a peg board task. The subjects then performed LapMentor basic tasks using Xitact/Mentice hardware equipped with realistic instrument handles for manipulation. Residents performed better than the children in the non-age weighted WISC scores. The comparison of performance in the VR tasks showed a trend of the lowest performance in children with low experience in video games, followed by those with high experience, residents and finally surgeons. This study demonstrates that the age of the subject may not necessarily matter for the effect that video games have on “surgical skills” (Rosenthal et al., 2011).

In a 2011 study, 38 undergraduate medical students, sixteen of whom played video games, performed three tasks: an exercise in the ProMIS simulator, a Pictorial Surface Orientation (PicSOr) exercise, and cube comparison, card rotation, and map planning tests. A significant difference was found between gamers and non-gamers in the ProMIS simulator for time and instrument path length metrics. After a regression analysis, video game experience only significantly explained the variations in the path length score. No significant differences were
found between the groups for either the PicSOr or visuospatial tests. No correlations were found between the cognitive or visuospatial tests and the simulator metrics. The authors suggest that no significant differences were found for perceptual or visuospatial abilities because these abilities are in theory innate and unchanged by video game play (Kennedy, Boyle, Traynor, Walsh, & Hill, 2011).

In another study participants were interns at a department of surgery (n=20) and school age children (n=26), both with and without video game experience (defined as at least 10 hours per week). The participants performed four basic skill exercises on the LapSim virtual reality simulator twice, totaling eight times. Interns with videogame experience scored significantly higher on total score compared to interns with no experience. The interns with video game experience also scored significantly higher on efficiency and speed scores when compared with interns who had no experience. Interns with videogame experience scored significantly higher than schoolchildren, both with or without videogame experience. The interns without video game experience actually attained equal overall scores with both groups of school children. When comparing the two generations in general, the interns outperformed the school children in overall score, efficiency, precision, and speed. This study could not demonstrate significant superior baseline psychomotor skills for endoscopic surgery in schoolchildren with extensive video game experience. Video game experience did correlate with better psychomotor scores in the intern group. The authors suggest that a difference was not found for psychomotor skills because the skills may not be fully developed in the school age children yet. Also, the lower simulation performance may have resulted from the children being distracted too easily (van Dongen, Verleisdonk, Schijven, & Broeders, 2011).
Other studies have also found increased abilities in trainees with prior video game experience. Hislop et al. (2006) found that time to complete individual tasks and to complete a whole exercise were highly correlated with hours of video game play per week in an endovascular simulator. Enochosson et al. (2004) found that medical students who reported playing computer games demonstrated increased proficiency and time in an endoscopic virtual reality simulator. Also, the students’ performance significantly correlated with a visuospatial test.

*Treatment research.* Other studies examine video game use as a means of warm-up or training to improve laparoscopic skills. Bokhari et al. (2010) recruited 21 surgical residents to use a game on the Wii console, which closely mimics surgical movements. The investigators used the Wii controllers to create modified joysticks, which limit the participants gaming movements similar to what they would experience in a laparoscopic procedure. This study found that, compared with subjects who trained on a laparoscopic simulator only, Wii trained residents took less time, made fewer errors, and were more proficient with their hand movements when performing a specific laparoscopic task. The authors suggest that incorporating an engaging and easily accessible tool, like a video game, into training could benefit surgical residency programs. The choice of game is important, however, since the value of each game in surgical training is not equivalent. The design of this study aligns with the idea described by Ju, Chang, Buckley, & Wang (2012) which suggested that the type of controller may affect the training for laparoscopic skills. However, since this study used modified game controllers, similar to laparoscopic instruments, it is unclear if the improved training was due to the video game training alone or the experience with the controllers. The authors suggest that the effect of video games as a warm-up, an idea addressed by Rosser (2012), be explored.
Another study found significant improvements, after training using a Wii video game, in measurements relating to a hand-eye coordination task and a bimanual clipping and grasping task in a laparoscopic simulator. In the single-blind, randomized, prospective controlled study participants (n=23) performed a baseline assessment consisting of three tasks on a laparoscopic simulator: eye-hand coordination task, bimanual clipping and grasping, and two handed manipulation task. The subjects were randomized into groups training with a Wii for either two hours, four hours, or not using the Wii at all over the course of 2 weeks. After their last gaming session, all participants then performed the same tasks on the laparoscopic simulator. After transforming the Wii game scores into rank scores, the authors were able to find a moderate correlation with decreased time to complete, faster right hand speed, and decreased right hand total path for the eye-hand coordination task. The authors concluded that, compared to the control group who did not train with the Wii, the video game group significantly improved their performance. The Wii trained group demonstrated significantly higher scores in measurements such as accuracy, time to complete, number of left hand movements, left hand total path, and left hand economy of movement for both tasks. Some limitations of this study include a small sample size and a short duration of video game play. The authors did demonstrate differences after playing for only two hours over the course of two weeks, which is an improvement to the five weeks observed by Schlickum et al. (2009) (Middleton et al., 2013).

In another study, the authors had subjects (n=40) test in two validated endoscopic simulators (MIST-VR and GI Mentor II). Thirty subjects were randomized into two experimental groups, which trained over five weeks using either Chessmaster or Half Life games. These participants were instructed to train with their respective games for at least 30 minutes per day
and no more than 60 minutes per day for five days per week. The subjects were also instructed to not play any other video games over the course of the trial. The remaining ten subjects, those who indicated that they had no prior video game usage, were designated as a control group, which did not play any video games for the five-week trial. The subjects were then tested with the endoscopic simulators under identical testing conditions and with the same test proctor.

When comparing the effect of video game training on performance in the MIST-VR simulator task, the authors found that both the Half-life and Chessmaster groups showed significant improvement in performance between the first and second testing sessions. The control group did not show a significant improvement. The Half-life group also showed significant improvement in the GI-Mentor II task; however the Chessmaster and control groups did not. A significant correlation was also found between previous and present video game play and performance scores in both simulators. The authors suggest that Half-life demonstrated greater training potential because the gaming environment is more visual-spatially loaded, which may indicate an importance of visual similarity of video games in surgical training. Thus, the authors suggest that the video games should have contextual similarity to the surgical task being trained (Schlickum, Hedman, Enochsson, Kjellin, Fellander-Tsai, 2009).

In another study, a group of residents (n=42) performed a pre-test on the LapMentor using three basic laparoscopic tasks and one virtual patient case of a complete cholecystectomy. The group was then randomized to either an experimental group (n=21), which trained with the Nintendo Wii, or a control group (n=21). The experimental group trained with the Wii console for 60 minutes per day and five days per week. The group played three games: Sports Tennis, Table Tennis, and Battle at high altitude. After four weeks, the residents performed a second test.
using the LapMentor. All 42 participants improved significantly from session 1 to session 2. The control group improved significantly in all performance metrics except for accuracy in task 1 and the total number of exposed balls collected in task 3. The Wii group improved significantly in all performance metrics. After comparing the Wii with the control group, the authors found significant differences in the improvement of all performance metrics except the total time for task 2, the total time needed for task 3, and the total number of exposed balls in task 3. Similar to others, the authors suggest that the Wii platform was an analogous training platform for laparoscopic procedures (Badurdeen et al., 2010; Boyle, Kennedy, Traynor, & Hill, 2011). A concern of this study is that the control group also significantly improved over the course of the four weeks; however the authors do not explain this result. One would expect that, without treatment, the control group would not improve significantly. The change in the control group from session 1 to session 2 may be attributed to the standard residency training that all subjects received during that time (Giannotti et al., 2013).

Plerhoples, Zak, Hernandez-Boussard, & Lau (2011) randomized participants (n=40) evenly into an experimental and a control group. The subjects in the experimental group played Super Monkeyball 2 on an Apple iPhone for 10 minutes as a warm-up. The control group had no warm-up. All subjects then performed two tasks in the validated ProMIS simulator: an object placement task and a tissue manipulation task. The results were similar for both exercises. The experimental group demonstrated significantly lower errors in both exercises; however they did not demonstrate improvements over the control group in any other metrics. Overall, the reduction in total errors remained significant. It should be noted that the participants in this study
warmed up for a very short duration of time, which may not have been long enough to show an effect on other metrics.

**Videogame impact on a porcine model.** One study performed by Rosenberg, Landsittel, & Averch (2005) examined the effect of video game training on skills in a porcine model. Eleven subjects performed three video games as a pre-test: Top Spin, Project Gotham Racing 2, and Amped 2. The participants then performed four laparoscopic tasks on a porcine model: object transfer, tracing a figure-of-eight, suture placement, and knot-tying. After being randomized, the experimental group played their choice of video game for two weeks. At the end of the two weeks all participants returned and performed the pre-test video games and porcine tasks. Significant positive correlations were found between the Top Spin video game and the time needed in the object transfer and figure-of-eight laparoscopic tasks. Significant positive correlations were also found between the Amped 2 and time in the object transfer, figure-of-eight, and knot-tying tasks, as well as the number of errors in the knot-tying tasks. Overall, all subjects significantly improved from the first session of laparoscopic tasks to the second for object transfer and knot tying. The training group did not improve more than the control group in the tasks. A limitation to the study is the small sample size. Since the subjects used a video game prior to perform the laparoscopic tasks, the subjects’ performance may have been influenced by a warm-up effect, thus affecting the results. Also, the researchers did not regulate the amount and type of gameplay over the course of two weeks. Similar to other research, the results do suggest that video game training may only influence basic skills as opposed to more complex surgical skills.
Conclusions on Videogames in surgical training. While various studies have verified increased ability of video game experience and other non-surgical skills to increased performance in surgical training, the results are conflicting. Madan et al. (2005) demonstrated significantly better times by students who used chopsticks for baseline laparoscopic tasks in a porcine model. The authors tested other skills such as playing an instrument and sewing, none of which demonstrated any significant differences. The authors suggest that using chopsticks may give users an advantage over the fulcrum effect imposed by laparoscopic instruments.

Madan et al. (2008) further explored the potential influence that non-surgical skills (i.e., using computer games, typing, using chopsticks, and playing a musical instrument) may have on surgical skills. The authors recruited first and second year medical students who participated in these activities and assigned them to either a virtual reality (n=18) or a box trainer (n=33) experimental group. No differences existed in the box trainer group for any of the non-surgical skills participants. Better scores were observed in the groups for the virtual reality tasks; however the differences were not significant. A weakness in this study is the unequal sample size, with a low sample size in the virtual reality group. Also, the virtual reality groups and the box trainer groups did not perform the same tasks. Finally, it is unclear in this study how much non-surgical experience the participants had. It is possible that the participants did not have extensive enough experience in these non-surgical skills to have an effect on their surgical performance.

Boyle, Kennedy, Traynor, & Hill (2011) also found that medical students who trained with the Wii gaming platform did not demonstrate significant improvements in performance in a virtual reality simulation or dry lab. A study by Chien et al. (2013) actually found that, in
comparison to a group using task specific virtual reality training, a control group using video
game training did not perform as well on an actual task using the surgical robot. The authors also
found that using a video game to train actually had a negative impact on the post-training
performance. The authors suggest that playing a PC game might only enhance proficiency in a
specific level of a task. They also state that, for training purposes, a training environment as
similar to the actual environment yields the best learning effect for trainees. In this study, while
the game training group used the same manipulators for their training, they played a 3-D tennis
game as opposed to training actual tasks. This study is also one of the few regarding video game
training on robotic surgery skills, as opposed to laparoscopic.

Harper et al. (2007) also designed an observational study concerning robotic skills
abilities and video game experiences. Participants (n=18) were evaluated on the number of knots
tied in a five-minute trial on the robot. The authors found that on average video game players
tied significantly fewer knots than non-players. However, the authors did find that subjects who
played a sport for at least four years made significantly fewer mechanical errors, broke
significantly fewer sutures, and performed significantly fewer errors overall. The authors suggest
that the results of this study demonstrate that video game use negatively impacts robotic
performance, while playing sports has a positive impact. They suggest that this may result from
video gamers playing games in a 2-D, which may not translate to the 3-D robotic environment.
The authors suggest that the results demonstrate prior skill sets that could translate the robotic
environment and could be used to select candidates for advanced surgical training. A weakness
of this study is the small sample size.
Of the studies that have found positive correlations between video game use and laparoscopy, most concluded that the effects were relevant for basic or manual skills, as opposed to more complex skills (Lehmann et al., 2013). Many studies also found that the type of video game played affected the value of the training. The video game should have mechanical and contextual similarity to be valuable for laparoscopic training (Rosser et al., 2007; Badurdeen et al., 2010; Bokhari et al., 2010; Schlickum, Hedman, Enochsson, Kjellin, Fellander-Tsai, 2009). Similarly, many studies also found that the gaming platform may affect the value of the video game for training. The Wii was found by many to show significant positive effects, which many authors contributed to the similarity of the gaming movements to laparoscopic movements (Badurdeen et al., 2010; Bokhari et al., 2010; Giannotti et al., 2013).

**Perceptual Abilities**

So, what spurred the idea that video games may have positive contributions to surgical skills? The concept may have risen from the similarities of movements or the virtual reality visual scenes, which are akin to what a user might see in a video game. It is certain though that the recent influx of research into the psychomotor and perceptual benefits has perpetuated the belief. In recent years, gaming advocates have aimed to put an end to the ill-received perception of video games. Several studies have been conducted to look at the positive impact that video games may have on various psychomotor, perceptual, and cognitive skills.

**Video gamer skills and attitudes.** It has long been assumed that video gamers have certain preferences and attitudes that frame a defined “video game culture.” Many studies have aimed to examine the skills and attitudes that may be more prevalent in video game players. Much of the early research focused on the negative implications of frequent video game play;
however, recently more research is aimed at shedding a positive light on the outcomes of video gaming.

Brown & Thomas (2008) explain that, while each generation of players and games brings a new gamer disposition, typically this disposition is made of five key attributes. Gamers are *bottom line oriented*. They understand that in order to improve, they must use the implicit and explicit rules for assessment. For a gamer, the highest reward is to improve in the game and, unlike many others, enjoy being compared to their peers. By knowing the capabilities of themselves and others, gamers *understand the power of diversity* and typically have a stronger value of teamwork. In a constantly changing game world, a gamer not only *thrives on change*, but also looks forward to it. Gamers *see learning as fun* and will often seek alternatives to solve problem simply to find a unique response to the problem. Finally, in a constantly changing and complex gaming world, gamers tend to *marinate on the edge*. Brown & Thomas claim that these qualities give the players a strategic upper hand not only in games, but also in real world situations.

While some suggest that perceptual and visual-spatial abilities are innate and therefore cannot be modified through training, research has been directed at investigating the types of perceptual skills developed through video game play (Kennedy, Boyle, Traynor, Walsh, & Hill, 2011). Many studies have demonstrated beneficial effects of playing video games and recently certain genres of games have become associated with perceptual benefits. Specifically, action video games are identified as having the largest benefit to attentional and perceptual abilities. Action video games enhance top-down processing and encourage users to allocate their attentional resources more flexibly. This genre of games, distinguished by the speed of play,
requires the users to maintain high levels of perceptual and cognitive loads, peripheral visual fields, high levels of divided attention, and anticipation of the next move spatially (i.e. where the enemy may appear) and temporally (i.e. when the enemy will appear) (Green & Bavelier, 2012). The ability to ignore irrelevant or distracting stimuli and focus on a target is referred to as selective attention (Green & Bavelier, 2012). Many studies have demonstrated that action game play increases selective attention. Research has also shown that the minimum space between a target and distractors, wherein the target can still be identified, is also reduced by the use of action video games. This ability is thought to be indicative of spatial resolution of visual attention (Green & Bavelier, 2007).

Action video games have also proven to have effects on the time needed to recognize a specific target (Dye, Bavelier, 2010; Cohen, Green, Bavelier, 2007). Action video game players are more skillful to the attention to objects. In a multiple object-tracking task, video gamers can track more independent objects than non-gamers at a faster rate (Green & Bavelier, 2006; Trick, Jaspers-Fayerz, Sethi, 2005; Dye & Bavelier, 2010; Boot, Kramer, Simons, Fabiani, Gratton, 2008).

Green & Bavelier (2003) performed several tests on video gamers and non-video gamers to establish these differences in visual attention. The research demonstrated better performances in various visual attention tasks by gamers as well as video games’ abilities to improve skills in non-gamers. The first task used was a flanker compatibility task. The results of this task demonstrate that action game players have a larger attentional capacity and can ignore irrelevant stimuli in more difficult tasks than non-gamers. In an enumeration task, video gamers rapidly and accurately identified more items than non-gamers. This indicates that playing video games
may increase the number of stimuli that can be managed at one time. Together the results from the flanker and enumeration tasks indicate that video game playing enhances attentional capacity. Video game players in this study also performed a useful field of view task, which indicated that playing video games gave increased abilities for attentional resources and spatial distribution.

While action games have demonstrated the largest influence on skills, other genres of games have demonstrated different influences, including specific skills that are enhanced through regular practice. Slower paced strategy games, including adventure stories, real-time strategy, and role-playing games, increase executive control skills. Puzzle games increase problem solving and relational skills. Simulation games increase multi-variable optimization and long-term planning. Casual games, typically played using a phone, web browser or tablet, and generally played in small increments, improve hand-eye coordination and short-term strategy (Green & Bavalier, 2003; Apperlay, 2006; Griffith, Voloschin, Gibb, & Bailey, 1983; Dorval & Pepin, 1986; Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994).

**Perceptual abilities of surgeons.** A number of studies have examined visual-spatial perception (VSP) as a predictor of surgical performance. Many studies have reported significant correlations between these skills and time to complete surgical tasks. A study by Wanzel et al. (2003) found that Intermediate and high VSP scores predicted a reduction in time and demonstrated a significant correlation with improved efficiency. The authors could not verify a correlation between low VSP scores and improved surgical skills.

Stefanidis et al. (2006) found that intermediate VSP scores predicted a reduction in time. Van Herzeele et al. (2010) also found that intermediate VSP scores correlated with improved
efficiency. Risucci, Geiss, Gellman, Pinard, & Rosser (2001) found that low-level VSP scores correlated with time. The results also showed that intermediate and high-level VSP scores predicted a reduction in time.

Many of the identified skills seem to be valuable for a robotic surgeon’s performance. Visual attention is an important element of minimally invasive surgery because the attention is focused on the screen and almost always on the target zone of the surgery. However, visual stimuli around this target zone could be an attentional alert to a peripheral problem arising. If the surgeon enlarges his or her focus of visual attention, he or she can process peripheral information more quickly and efficiently. Hand-eye coordination is, compared to laparoscopy, a re-established axis of work in robotic surgery. While many have evaluated video games’ abilities to prepare both robotic and laparoscopic skills, none have evaluated a video gamer’s ability on a robotic simulator and the perceptual skills underlying those skills.
CHAPTER THREE: METHODOLOGY

Recruitment

Participants in this study included video gamers, expert robotic surgeons, medical students, and “laypeople.” The video gamers were recruited from a local university, which offers degrees specializing in game design and development (i.e. Florida Interactive and Entertainment Academy (FIEA)). To participate as a video gamer, participants were enrolled in a program at FIEA and self-reported daily video game play of at least two hours per day, five days per week. Expert robotic surgeons were recruited from within Florida Hospital, Florida Hospital Nicholson Center training courses, Columbia University Medical Center, and at relevant surgical conferences (e.g. Society of Laparoscopic Surgeons, World Robotics Gynecology Congress, and Society of Robotic Surgeons). To participate, these individuals were practicing physicians in the surgical field and had performed at least 100 robotic surgical procedures, of which each performed at least 50% or more of the procedure on the surgical console. The number of robotic cases performed was self-reported prior to consent and documented in the Pre-Questionnaire. Medical students of varying school years were recruited from a local university (i.e. the University of Central Florida’s College of Medicine) and from those affiliated with Florida Hospital Nicholson Center. The laypeople were recruited from within Florida Hospital and during the data collection at other sites. To participate, a layperson could not have had any formal medical training or exposure to the robotic simulator and could not play video games more than two hours per day, five days per week (greater than ten hours total).

Potential subjects were excluded from this study in the case of having experience in more than one participant category. For example, a medical student or expert robotic surgeon who
engaged in regular gameplay of more than two hours per day, five days per week would be excluded from participating in this study. Also, potential gamer participants were excluded if they were not currently enrolled at a university or had extensive medical experience (e.g. currently or previously work in the healthcare field).

Materials

For this study, several data components were gathered via subjective questionnaires and objective assessments of skills. There are four components of data that were gathered for each participant: a pre-questionnaire, computer-based perceptual tests, robotic surgical simulation exercise metrics, and a post-questionnaire.

Questionnaires. The pre-questionnaire (Appendix A) was administered after consent and was used to gather general demographic information from each participant (e.g. age, gender, handedness). This questionnaire was also used to collect information pertaining to the participant’s occupation. This included the number of hours of video game play the participant engages in, the participant’s year in medical school, or the number of robotic cases he or she has performed. Included in the pre-questionnaire were also questions aimed at determining other aspects of video game play and additional hobbies that may contribute to the subject’s performance on the surgical simulator.

The post-questionnaire (Appendix B) was used to collect information regarding each participant’s experiences on the simulator. More specifically, the questions aimed to examine if the participants developed a strategy for winning against the simulation, or if they felt the simulator mimicked a game that they play frequently.
**Computer-based perceptual tests.** Three perceptual tests were used to measure each participant’s perceptual skills: the Flanker compatibility test, a subsidizing task, and a multiple object-tracking task. The Flanker compatibility test requires the participant to indicate the orientation of a single arrow in the center of a group of several other arrows. This tests attentional capacity by requiring the subject to focus solely on the relevant arrow and ignore other stimuli. For this test, the participant performed two trials of twenty exercises. The data points collected for this were the percentage of correct answers and the time taken for each response.

The subsidizing task requires subjects to identify how many dots appear on the screen by pressing the correct number key. The number of dots can vary between four and seven and must be identified within two seconds of the dots appearing. This task tests each participant’s attentional capacity and was completed in two trials of 20 dot representations. The data points collected for this were the percentage of correct answers and the time taken for each response.

The Multiple Object Tracking (MOT) task assesses visual attention and requires users to track a specific object while it moves across the screen with other identical objects. For this test, subjects completed two “easy” trials, two “normal” trials, and two “difficult” trials. The easy trials require participants to track two shapes within eight total shapes, the normal require tracking three shapes within eight, and the difficult requires four of the eight dots to be tracked. The data collected for this test was the percentage correct for each trial.

**Simulation.** The dV-Trainer is one of the three commercially available robotic surgical simulators. This simulator was selected for use in this study from previously conducted research, which compared the validity and usability of three of the systems (the dVSS, the dV-Trainer, and
the RoSS). The results of the study found that most participants preferred the dVSS in terms of comfort and usability; however, most subjects chose the dV-Trainer in terms of cost-preference. Face, content, and construct validity were found for most components of the simulators in the dVSS and dV-Trainer, but not the RoSS (Tanaka et al., In Press). The dV-Trainer was also the most accessible and easily transportable robotic simulator at the Nicholson Center.

The exercises on the dV-Trainer train basic psychomotor skills and some basic surgical skills, such as knot tying and suturing. Participants performed four total exercises in the simulated environment. Pick & Place is a warm-up exercise, which requires users to use the virtual robotic instruments to pick up colored jacks and place them into corresponding colored bowls. This exercise trains the user to leverage the abilities of the wristed instruments to manipulate objects in the environment and specifically trains the skill of endowrist manipulation (Figure 7).
Basic Camera Targeting is a warm-up exercise, which requires users to utilize the camera control pedal to navigate the camera in a specific manner. To do so, the camera must be placed so that the camera’s crosshairs align perfectly with a target. This exercise trains users to move the camera effectively and specifically trains the skill of camera control (Figure 8).
Ring & Rail 1 requires the user to use the virtual instruments to manipulate a ring up a rail and to the corresponding platform. The user must perform this task efficiently while rotating the instrument to compensate for the many curves in the rail. The primary skill that this exercise trains is endowrist manipulation, while the secondary skill trained is camera control (Figure 9).

![Figure 9. The Ring & Rail 1 exercise in the dV-Trainer](image)

Basic Suture Sponge requires users to use the virtual instruments to drive a needle through the indicated points on a sponge. The exercise requires users to alternate between their right and left hands and between driving the needle from top and bottom. This exercise primarily trains basic needle driving skills and trains secondary skills of needle control and endowrist manipulation (Figure 10).
Each exercise trains a specific skill set as seen in Table 1. The user performed Pick & Place and Basic Camera Targeting as “warm up” exercises to become acclimated to using the controls of the system. Ring & Rail 1 and Basic Suture Sponge served as the primary exercises for data collection. When a user completes all of the exercises on the dV-Trainer, specific metrics are shown to them: Overall Score, Economy of Motion (cm), Time to Complete (sec), Excessive Instrument Force (sec), Instrument Collisions (count) Instruments Out of View (cm), and Master Workspace Range (cm).
<table>
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<th>Skills Trained</th>
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<td><strong>Warm-up Exercises</strong></td>
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<td><strong>Pick &amp; Place</strong></td>
<td>Introduction to using stereo vision and EndoWrist instruments for picking up and placing objects.</td>
<td>Place colored objects in matching colored containers.</td>
<td>Endowrist Manipulation</td>
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<tr>
<td><strong>Basic Camera Targeting</strong></td>
<td>Learn to accurately position the camera while working in a large workspace while practicing to keep the instruments in view and developing stereo depth acuity.</td>
<td>Manipulate the camera to position light blue sphere camera targets in the center of your screen’s dark blue crosshairs.</td>
<td>Camera Control</td>
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<td><strong>Core Exercises</strong></td>
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<tr>
<td><strong>Ring &amp; Rail 1</strong></td>
<td>Coordinate control of an object’s position and orientation along a trajectory using the EndoWrist instruments</td>
<td>Pick up a ring and guide the ring along a curved rail</td>
<td>Endowrist manipulation, Camera Control</td>
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<tr>
<td><strong>Basic Suture Sponge</strong></td>
<td>Improve dexterity and accuracy when driving a needle through a deformable object.</td>
<td>Insert and extract a needle through several targets on the edge of a sponge with random variations in their positions.</td>
<td>Endowrist manipulation, Camera Control, Needle Control, Needle Driving</td>
</tr>
</tbody>
</table>

Economy of motion measures the total distance that the instrument tips move. The time to complete is the total time the user spends performing the exercise. Excessive instrument force is the total time that the user places excessive force on the instruments above a prescribed threshold. The instrument collisions metric is the total number of instrument-on-instrument
collisions, which exceed a minimum force threshold. The instrument out of view metric is the total distance traveled by the instruments outside of the user’s field of view. Master workspace range is the larger of the two radii of motion of the user’s working volume on the master controllers.

The overall score is a composite score of all of the metrics. These primary metrics, as well as other exercise specific metrics (e.g., needle drops or missed targets), are exported from the simulator and used to form the scoring system.

Design

Prior to participating in this study, each participant was consented by either a research coordinator or study investigator. During the consent process, the coordinator or investigator ensured that the potential subject met the inclusion criteria. After consenting, the participants completed the pre-questionnaire described above. The participants then completed the three perceptual tasks. Prior to beginning each perceptual test, participants received standardized instructions on how to perform each task.

After completing the perceptual tests, all participants performed one Warm-up Trial of Pick & Place and Basic Camera Targeting on the dV-Trainer. During this trial, the participants received standardized instruction on how to use the simulator and perform the exercises. After the Pick & Place exercise, the research team explained to participants how they were assessed on the simulator and what each metric means in terms of their overall score (Figure 11). This ensured that all participants understood how they were assessed for the exercises and how they could improve their performance. The participants then performed the first trial of core exercises
(i.e. Ring & Rail 1 and Basic Suture Sponge). Each participant received standardized instruction for both exercises.

![Figure 11. An example of the evaluation screen in the dV-Trainer](image)

After completing this trial, the participants completed the remaining seven trials of each exercise, alternating between the two exercises (i.e. Ring & Rail 1, Basic Suture Sponge, Ring & Rail 1, Basic Suture Sponge, etc.). The subjects alternated between the two exercises in an effort to lessen the potential of one exercise influencing the learning of the other. The subjects performed these exercises a total of eight times, including the Initial Trial, based on a previous study investigating the number of trials required for a novice to reach the plateau of their learning curve (Perrenot et al., 2012). After performing eight total trials, all participants completed the post-questionnaire (Figure 12).
Figure 12. An outline of the study design
CHAPTER FOUR: RESULTS

The demographic information was analyzed and used to evaluate the types of participants recruited and other characteristics specific to the group, e.g., the age, gender, type of video games played, year in medical school, etc. Data analysis consisted of four main analyses (Figure 13). The first analysis was the comparison of the scores on each perceptual test between the three groups. This highlighted any differences in the perceptual abilities of the participant groups that may exist prior to the simulation use.

The second main analysis conducted was a comparison between groups of the performance using the dV-Trainer for the Initial Trial of VR exercises. Three metrics were analyzed: Time to complete (seconds), Economy of Motion (cm), and Overall Score (points). This was used to examine the skills that the groups begin the training with. The third main analysis conducted was a comparison of the last trial (Trial 8) of dV-Trainer exercises between the groups. For this analysis the same performance metrics were used. This was used to determine if there was a difference between the groups in terms of their final performance on the simulator.

The fourth main analysis consisted of a examining the groups’ ability to acquire skills across the eight trials, including evaluating the groups’ learning curve. The metrics of the first trial were compared to the eighth trial to determine if one group improved significantly more than another. To look at this, a variable of the amount of change was created and the values for each metric across the eight trials were plotted on a graph to evaluate the curve that exists. This was evaluated to see if any group reaches its plateau before others. Analyses were also
performed to examine the video gamers’ abilities specifically. The types of video games and types of consoles played were evaluated in terms of the subject’s performance on the simulator.

![Diagram](image)

**Figure 13. An outline of the study analysis**

**Demographics**

Video gamers (n=40), medical students (n=24), laypeople (n=42), and expert surgeons (n=16) were analyzed in terms of demographic characteristics (Table 2). The participants were primarily male (66%) and predominantly right-handed (88%). The average age of all subjects was 29 (SD=7.559). Fifty-five percent of all participants indicated that they currently play video games. The gamers reported having played video games for an average of eighteen years (SD=5.71) and playing an average of twelve hours per week (SD=6.74).
Table 2. Descriptive characteristics of the participants

<table>
<thead>
<tr>
<th></th>
<th>Gamers</th>
<th>Students</th>
<th>Laypeople</th>
<th>Experts</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>40</td>
<td>24</td>
<td>42</td>
<td>16</td>
</tr>
<tr>
<td>Average Age</td>
<td>25</td>
<td>26</td>
<td>29</td>
<td>42</td>
</tr>
<tr>
<td>(SD=5.14)</td>
<td>(SD=4.62)</td>
<td>(SD=5.26)</td>
<td>(SD=6.67)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>31</td>
<td>17</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>Female</td>
<td>9</td>
<td>7</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Right Handed</td>
<td>35</td>
<td>23</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td>Left Handed</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>

On average, expert surgeons performed 135 laparoscopic (SD=94.55) and 95 robotic cases (SD=71.79) annually. These experts also reported performing an average of 1111 total laparoscopic cases (SD=725.41) and 624 total robotic cases (SD=607.13). Of the expert surgeons, 13% indicated that they currently play video games. Eighty-eight percent of expert surgeons provided that they have previously received formal robotic surgery training, with 94% of all expert surgeons indicating that have used a laparoscopic or robotic surgical simulator in the past.
Cognitive Tests

An analysis of the cognitive test performance was conducted using the scores from the second trial of the tasks. The first trial was not used for the evaluation under the assumption that the subjects used this trial as a warm-up. The metrics used for analysis in the Flanker task were percent correct, the time taken to make a selection for congruently presented arrows, and the time taken to select incongruently presented arrows. The Subsidizing task was analyzed in terms of the percent correct and the time taken to make a selection. The Multiple Object Tracking task was analyzed using the number of correct objects selected for the easy, normal, and difficult tests.

An exploratory data analysis was conducted on the Flanker and subsidizing tasks, resulting in descriptive characteristics and an evaluation of the score distribution. A Shapiro-Wilk test of normality indicated that the distribution of scores in the Flanker task significantly deviated from a normal distribution for all groups in the percent correct, all groups except for medical students in the congruent time, and laypeople in the incongruent time. No other groups deviated from a normal distribution of scores (Table 3). Appendix E provides graphical depictions of the distribution.
Table 3. Normality test for the Flanker task

<table>
<thead>
<tr>
<th></th>
<th>Statistic</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percent Correct</strong></td>
<td>Gamer</td>
<td>0.700</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Medical Student</td>
<td>0.550</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Layperson</td>
<td>0.631</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Expert</td>
<td>0.695</td>
<td>16</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>Gamer</td>
<td>0.722</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Medical Student</td>
<td>0.950</td>
<td>21</td>
</tr>
<tr>
<td><strong>(Incong.)</strong></td>
<td>Layperson</td>
<td>0.870</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Expert</td>
<td>0.760</td>
<td>16</td>
</tr>
<tr>
<td><strong>(Cong.)</strong></td>
<td>Gamer</td>
<td>0.979</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Medical Student</td>
<td>0.969</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Layperson</td>
<td>0.832</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Expert</td>
<td>0.985</td>
<td>16</td>
</tr>
</tbody>
</table>

In the subsidizing task, the laypeople in the percent correct metric significantly deviated from a normal distribution. No other groups significantly deviated from a normal distribution for the scores (Table 4). Appendix F provides graphical depictions of the distribution.
Table 4. Normality tests for the subsidizing task

<table>
<thead>
<tr>
<th></th>
<th>Statistic</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamer</td>
<td>0.965</td>
<td>40</td>
<td>p=0.250</td>
</tr>
<tr>
<td>Percent</td>
<td>Medical Student</td>
<td>0.950</td>
<td>22</td>
</tr>
<tr>
<td>Correct</td>
<td>Layperson</td>
<td>0.920</td>
<td>41</td>
</tr>
<tr>
<td>Expert</td>
<td>0.943</td>
<td>16</td>
<td>p=0.392</td>
</tr>
<tr>
<td>Gamer</td>
<td>0.974</td>
<td>40</td>
<td>p=0.490</td>
</tr>
<tr>
<td>Time</td>
<td>Medical Student</td>
<td>0.961</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Layperson</td>
<td>0.985</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Expert</td>
<td>0.909</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 5 provides the descriptive characteristics of the scores for the Flanker and subsidizing tasks. The mean and standard deviations of scores are provided for groups with normal distributions, while the median and interquartile range of scores are given for groups with a non-normal distribution. To determine if differences existed between the groups, parametric testing was used for metrics with a normal distribution. For all metrics with non-normal distribution, non-parametric testing was used.
Table 5. Descriptive characteristics of Flanker and subsidizing scores

<table>
<thead>
<tr>
<th></th>
<th>Flanker</th>
<th>Subsidizing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent Correct</td>
<td>Congruent Time</td>
</tr>
<tr>
<td>Gamers</td>
<td>100.00</td>
<td>428.59</td>
</tr>
<tr>
<td></td>
<td>(IQR=5.00)</td>
<td>(IQR=72.66)</td>
</tr>
<tr>
<td>Medical</td>
<td>100.00</td>
<td>414.92</td>
</tr>
<tr>
<td>Students</td>
<td>(IQR=2.50)</td>
<td>(IQR=56.10)</td>
</tr>
<tr>
<td>Lay</td>
<td>100.00</td>
<td>439.91</td>
</tr>
<tr>
<td>people</td>
<td>(IQR=5.00)</td>
<td>(IQR=85.47)</td>
</tr>
<tr>
<td>Experts</td>
<td>100.00</td>
<td>476.40</td>
</tr>
<tr>
<td></td>
<td>(IQR=5.00)</td>
<td>(IQR=99.80)</td>
</tr>
</tbody>
</table>

Using a Kruskal-Wallis test, significant differences were found between the groups for the congruent time ($\chi^2(3)=18.297$, $p<0.001$) and incongruent time ($\chi^2(3)=14.865$, $p<0.005$) metrics. No differences were found between the groups for the percent correct ($\chi^2(3)=1.107$). When looking at pairwise comparisons for the congruent time metric, the medical students were significantly faster than the experts ($p<0.05$) and laypeople ($p<0.005$). The gamers were also
significantly faster than experts (p<0.05). Medical students (p<0.005) and gamers (p<0.05) were significantly faster than experts in the incongruent time metric.

Using a Kruskal-Wallis test, no significant differences were found between the groups for the percent correct metric in the subsidizing task ($\chi^2(3)=5.296$, p=0.151). Using ANOVA, significant differences were found between the groups for the time metric in the subsidizing task (F(3, 115)=4.711, p<0.005). A Tukey post-hoc test revealed that the lay people (991.94 ± 138.00 sec, p<0.05) and experts (1058.59 ± 120.87 sec, p<0.005) took significantly more time than the gamers (921.40 ±116.87 sec) to complete the task. The experts (1058.69 ± 120.87 sec, p<0.05) were also significantly slower than the medical students (957.99 ± 148.45 sec).

The scores for the MOT were also evaluated to determine if differences exist between the groups. A Kruskal-Wallis test was used to test the second trial of each level of the task (i.e. easy, normal, and difficult). Differences were found for the difficult level (p<0.05), but not for the easy and normal levels (p=0.656 and p=0.130 respectively). No significant pairwise differences were found for the groups.

A Pearson correlation was conducted to determine if age was associated with the scores of any metrics. A significant correlation was found between age and the time taken for congruent arrows (r=0.280, p<0.005) and incongruent arrows (r=0.339, p<0.005) on the Flanker task. Age significantly correlated with time in the subsidizing task (r=0.251, p<0.05), however the percent correct metric did not have a significant association. The percent correct in the normal trial of the MOT task had a significant association with age (r=-0.221, p<0.05).
Simulator Scores

An exploratory analysis was conducted to examine the average of the simulator metrics for trial 1 and trial 8 in the Ring & Rail 1 and Suture Sponge exercises. Trial 1 and trial 8 were the primary sources for analysis under the assumption that trial 1 was representative of baseline skills, while trial 8 was representative of acquired skills for those exercises. The Shapiro-Wilk test of normality was used to evaluate the distribution of the scores.

All groups for the Overall Score metric, the gamers in the Economy of Motion metric, and all groups except for the experts in the Time to Complete metric for trial 1 in the Ring & Rail 1 exercise deviated from a normal distribution. All other groups demonstrated a normal distribution (Table 6). Appendix G provides graphical depictions of the distribution. The medical students and experts in the Overall Score metric, the gamers and laypeople in the Economy of Motion and Time to Complete metrics deviated from a normal distribution for trial 1 of the Suture Sponge exercise. All other groups demonstrated a normal distribution in trial 1 (Table 6). Appendix H provides graphical depictions of the distribution.
Table 6. Normality testing for the simulator scores in Trial 1

<table>
<thead>
<tr>
<th></th>
<th>Statistic</th>
<th>df</th>
<th>Sig.</th>
<th>Statistic</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ring &amp; Rail 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamer</td>
<td>0.791</td>
<td>40</td>
<td>p&lt;0.001</td>
<td>0.954</td>
<td>40</td>
<td>p=0.106</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical Student</td>
<td>0.745</td>
<td>23</td>
<td>p&lt;0.001</td>
<td>0.868</td>
<td>24</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Layperson</td>
<td>0.778</td>
<td>42</td>
<td>p&lt;0.001</td>
<td>0.964</td>
<td>42</td>
<td>p=0.211</td>
</tr>
<tr>
<td>Expert</td>
<td>0.648</td>
<td>16</td>
<td>p&lt;0.001</td>
<td>0.762</td>
<td>16</td>
<td>p&lt;0.005</td>
</tr>
<tr>
<td><strong>Suture Sponge</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamer</td>
<td>0.887</td>
<td>40</td>
<td>p&lt;0.005</td>
<td>0.932</td>
<td>40</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td><strong>Economy of</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical Student</td>
<td>0.929</td>
<td>23</td>
<td>p=0.102</td>
<td>0.945</td>
<td>24</td>
<td>p=0.208</td>
</tr>
<tr>
<td>Layperson</td>
<td>0.973</td>
<td>42</td>
<td>p=0.419</td>
<td>0.886</td>
<td>42</td>
<td>p&lt;0.005</td>
</tr>
<tr>
<td>Expert</td>
<td>0.953</td>
<td>16</td>
<td>p=0.536</td>
<td>0.964</td>
<td>16</td>
<td>p=0.734</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamer</td>
<td>0.914</td>
<td>40</td>
<td>p&lt;0.01</td>
<td>0.934</td>
<td>40</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Medical Student</td>
<td>0.892</td>
<td>23</td>
<td>p&lt;0.05</td>
<td>0.962</td>
<td>24</td>
<td>p=0.474</td>
</tr>
<tr>
<td>Layperson</td>
<td>0.927</td>
<td>42</td>
<td>p&lt;0.05</td>
<td>0.946</td>
<td>42</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Expert</td>
<td>0.951</td>
<td>16</td>
<td>p=0.507</td>
<td>0.894</td>
<td>16</td>
<td>p=0.065</td>
</tr>
</tbody>
</table>

All groups in the Overall Score metric, the experts in the Economy of Motion metric, and the medical students and laypeople in the Time to Complete metric deviated from a normal
distribution in trial 8 of the Ring & Rail 1 exercise. All other groups demonstrated a normal distribution (Table 7). Appendix I provides graphical depictions of the distribution. All groups in the Overall Score metric, gamers and laypeople in the Economy of Motion metric, and laypeople in the Time to Complete metric deviated from a normal distribution for trial 8 of the Suture Sponge exercise (Table 7). Appendix J provides graphical depictions of the distribution.
Table 7. Normality testing for the simulator scores in Trial 8

<table>
<thead>
<tr>
<th></th>
<th>Statistic</th>
<th>df</th>
<th>Sig.</th>
<th>Statistic</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ring &amp; Rail 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamer</td>
<td>0.497</td>
<td>40</td>
<td>p&lt;0.001</td>
<td>0.823</td>
<td>40</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Overall</td>
<td>Medical Student</td>
<td>0.559</td>
<td>24</td>
<td>p&lt;0.001</td>
<td>0.759</td>
<td>24</td>
</tr>
<tr>
<td>Score</td>
<td>Layperson</td>
<td>0.620</td>
<td>42</td>
<td>p&lt;0.001</td>
<td>0.824</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Expert</td>
<td>0.860</td>
<td>16</td>
<td>p&lt;0.05</td>
<td>0.661</td>
<td>16</td>
</tr>
<tr>
<td>Economy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamer</td>
<td>0.948</td>
<td>40</td>
<td>p=0.066</td>
<td>0.918</td>
<td>40</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Of the Motion</td>
<td>Medical Student</td>
<td>0.930</td>
<td>24</td>
<td>p=0.097</td>
<td>0.918</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Layperson</td>
<td>0.953</td>
<td>42</td>
<td>p=0.084</td>
<td>0.791</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Expert</td>
<td>0.834</td>
<td>16</td>
<td>p&lt;0.01</td>
<td>0.905</td>
<td>16</td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamer</td>
<td>0.976</td>
<td>40</td>
<td>p=0.532</td>
<td>0.961</td>
<td>40</td>
<td>p=0.188</td>
</tr>
<tr>
<td>Medical Student</td>
<td>0.913</td>
<td>24</td>
<td>p&lt;0.05</td>
<td>0.983</td>
<td>24</td>
<td>p=0.946</td>
</tr>
<tr>
<td>Layperson</td>
<td>0.874</td>
<td>42</td>
<td>p&lt;0.001</td>
<td>0.866</td>
<td>42</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Expert</td>
<td>0.897</td>
<td>16</td>
<td>p=0.073</td>
<td>0.897</td>
<td>16</td>
<td>p=0.071</td>
</tr>
</tbody>
</table>

Tables 8-11 provide the descriptive characteristics of the scores for trial 1 and trial 8 of the simulator exercises. The mean and standard deviations of scores are provided for groups with
normal distributions, while the median and interquartile range of scores are given for groups with a non-normal distribution. To determine if differences existed between the groups, non-parametric testing was used for the groups due to the non-normal distribution of the scores.

Table 8. Descriptives of Trial 1 of Ring & Rail 1

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Overall Score</th>
<th>Economy of Motion</th>
<th>Time to Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamer</td>
<td>40</td>
<td>614.94</td>
<td>69.08</td>
<td>67.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=537.37)</td>
<td>(IQR=25.74)</td>
<td>(IQR=35.33)</td>
</tr>
<tr>
<td>Medical</td>
<td>24</td>
<td>589.55</td>
<td>72.18</td>
<td>59.41</td>
</tr>
<tr>
<td>Student</td>
<td></td>
<td>(IQR=473.67)</td>
<td>(SD=27.08)</td>
<td>(IQR=43.29)</td>
</tr>
<tr>
<td>Laypeople</td>
<td>42</td>
<td>594.27</td>
<td>75.03</td>
<td>62.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=517.19)</td>
<td>(SD=25.45)</td>
<td>(IQR=28.60)</td>
</tr>
<tr>
<td>Expert</td>
<td>16</td>
<td>1138.59</td>
<td>45.90</td>
<td>40.00</td>
</tr>
<tr>
<td>Surgeon</td>
<td></td>
<td>(IQR=436.36)</td>
<td>(SD=10.11)</td>
<td>(SD=10.54)</td>
</tr>
<tr>
<td>Category</td>
<td>n</td>
<td>Overall Score</td>
<td>Economy of Motion</td>
<td>Time to Complete</td>
</tr>
<tr>
<td>--------------</td>
<td>-----</td>
<td>---------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Gamer</td>
<td>40</td>
<td>439.26</td>
<td>566.58</td>
<td>517.88</td>
</tr>
<tr>
<td>Medical</td>
<td>24</td>
<td>502.20</td>
<td>535.86</td>
<td>446.18</td>
</tr>
<tr>
<td>Student</td>
<td></td>
<td>(IQR=236.09)</td>
<td>(SD=185.01)</td>
<td>(SD=155.02)</td>
</tr>
<tr>
<td>Laypeople</td>
<td>42</td>
<td>467.52</td>
<td>495.94</td>
<td>424.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(SD=136.33)</td>
<td>(IQR=229.81)</td>
<td>(IQR=232.25)</td>
</tr>
<tr>
<td>Expert</td>
<td>16</td>
<td>675.57</td>
<td>298.42</td>
<td>204.05</td>
</tr>
<tr>
<td>Surgeon</td>
<td></td>
<td>(IQR=345.51)</td>
<td>(SD=67.47)</td>
<td>(SD=62.76)</td>
</tr>
</tbody>
</table>
Table 10. Descriptives for Trial 8 of Ring & Rail 1

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Overall Score</th>
<th>Economy of Motion</th>
<th>Time to Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamer</td>
<td>40</td>
<td>1142.27</td>
<td>50.61 (SD=14.20)</td>
<td>29.24 (SD=10.12)</td>
</tr>
<tr>
<td>Medical Student</td>
<td>24</td>
<td>1143.75</td>
<td>52.04 (SD=16.71)</td>
<td>28.64 (IQR=10.99)</td>
</tr>
<tr>
<td>Laypeople</td>
<td>42</td>
<td>1108.06</td>
<td>62.25 (IQR=74.62)</td>
<td>33.37 (IQR=17.66)</td>
</tr>
<tr>
<td>Expert Surgeon</td>
<td>16</td>
<td>1161.96</td>
<td>36.38 (IQR=64.79)</td>
<td>21.83 (IQR=10.87)</td>
</tr>
</tbody>
</table>
Table 11. Descriptives for Trial 8 of Basic Suture Sponge

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Overall Score</th>
<th>Economy of Motion</th>
<th>Time to Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamer</td>
<td>40</td>
<td>716.30</td>
<td>296.57</td>
<td>250.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=537.76)</td>
<td>(IQR=102.45)</td>
<td>(SD=65.02)</td>
</tr>
<tr>
<td>Medical Student</td>
<td>24</td>
<td>939.84</td>
<td>306.42</td>
<td>225.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=580.61)</td>
<td>(SD=76.12)</td>
<td>(SD=48.17)</td>
</tr>
<tr>
<td>Laypeople</td>
<td>42</td>
<td>695.93</td>
<td>304.34</td>
<td>219.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=587.58)</td>
<td>(IQR=92.75)</td>
<td>(IQR=109.02)</td>
</tr>
<tr>
<td>Expert</td>
<td>16</td>
<td>1277.64</td>
<td>210.04</td>
<td>135.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=117.54)</td>
<td>(SD=54.72)</td>
<td>(SD=40.83)</td>
</tr>
</tbody>
</table>

Using a Kruskal-Wallis test, differences between the groups were found for the Overall Score ($\chi^2(3)=12.90$, $p<0.01$), Economy of Motion ($\chi^2(3)=20.28$, $p<0.001$), and Time to Complete ($\chi^2(3)=32.55$, $p<0.001$) metric of trial 1 of Ring & Rail 1. When looking at pairwise differences, experts scored significantly higher than laypeople ($p<0.005$), medical students ($p<0.05$), and gamers ($p<0.05$) in the Overall Score metric. Experts were significantly more efficient than
medical students (p<0.005), gamers (p<0.001), and laypeople (p<0.001) in the Economy of Motion metric. Experts were significantly faster than laypeople (p<0.001), medical students (p<0.001), and gamers (p<0.001) in the Time to Complete metric.

Significant differences were also found for the overall score ($\chi^2(3)=28.31$, p<0.001), economy of motion ($\chi^2(3)=31.15$, p<0.001), and time to complete ($\chi^2(3)=39.62$, p<0.001) metrics for trial 1 of the Suture Sponge exercise. When looking at pairwise differences, experts scored significantly higher than gamers (p<0.001), laypeople (p<0.001), and medical students (p<0.005) in the Overall Score metric. Experts were significantly more efficient than medical students (p<0.001), laypeople (p<0.001), and gamers (p<0.001) in the Economy of Motion metric. Experts were significantly faster than medical students (p<0.001), laypeople (p<0.001), and gamers (p<0.001) in the Time to Complete metric.

Significant differences were also found between the groups for the overall score ($\chi^2(3)=10.65$, p<0.05), economy of motion ($\chi^2(3)=20.99$, p<0.001), and time ($\chi^2(3)=21.85$, p<0.001) metrics for trial 8 of the Ring & Rail 1 exercise. When looking at pairwise differences, experts scored significantly higher than laypeople (p<0.05) in the Overall Score metric. Experts were significantly more efficient than laypeople (p<0.001) in the Economy of Motion metric. Experts were significantly faster than gamers (p<0.05), medical students (p<0.05) and laypeople (p<0.001) in the Time to Complete metric.

The groups also demonstrated significant differences for the overall score ($\chi^2(3)=22.79$, p<0.001), economy of motion ($\chi^2(3)=23.62$, p<0.001), and time ($\chi^2(3)=32.48$, p<0.001) metrics for trial 8 of the Suture Sponge exercise. When looking at pairwise differences, experts scored significantly higher than laypeople (p<0.001) and gamers (p<0.005) in the Overall Score metric.
Experts were significantly more efficient than medical students (p<0.005), gamers (p<0.001), and laypeople (p<0.001) in the Economy of Motion metric. Experts were significantly faster than medical students (p<0.001), laypeople (p<0.001), and gamers (p<0.001) in the Time to Complete metric.

The average scores for each group across the eight trials were also depicted graphically (Figures 14-19). This allowed for a visual analysis of the learning curve of the groups. A closer evaluation of the groups’ ability to acquire basic robotic skills over the eight trials was conducted to evaluate if any one group improved significantly more than other groups. The difference between trial 1 and trial 8 was calculated for each participant and determined as the amount of change.
Figure 14. Ring & Rail 1 Overall Score for groups across eight trials
Figure 15. Ring & Rail 1 Economy of Motion for groups across eight trials
Figure 16. Ring & Rail 1 Time to Complete for groups across eight trials
Figure 17. Suture Sponge Overall Score for groups across eight trials
Figure 18. Suture Sponge Economy of Motion for groups across eight trials
Figure 19. Suture Sponge Time to Complete for groups across eight trials

An exploratory analysis was conducted on the data. Appendices K and L provide graphical depictions of the distribution of the scores. A Shapiro-Wilk test of normality was also performed (Table 12). Tables 13-14 provide the descriptive characteristics of the amount of change for the metrics in the simulator exercises. The mean and standard deviations of scores are provided for groups with normal distributions, while the median and interquartile range of scores are given for groups with a non-normal distribution.
Table 12. Normality test for the amount of change between Trial 1 and Trial 8

<table>
<thead>
<tr>
<th></th>
<th>Ring &amp; Rail 1</th>
<th></th>
<th></th>
<th>Suture Sponge</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>df</td>
<td>Sig.</td>
<td>Statistic</td>
<td>df</td>
<td>Sig.</td>
</tr>
<tr>
<td>Gamer</td>
<td>0.845</td>
<td>40</td>
<td>p&lt;.001</td>
<td>0.973</td>
<td>40</td>
<td>p=.432</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>0.793</td>
<td>23</td>
<td>p&lt;.001</td>
<td>0.960</td>
<td>23</td>
<td>p=.439</td>
</tr>
<tr>
<td><strong>Score</strong></td>
<td>0.862</td>
<td>42</td>
<td>p&lt;.001</td>
<td>0.903</td>
<td>42</td>
<td>p&lt;.005</td>
</tr>
<tr>
<td>Layperson</td>
<td>0.679</td>
<td>16</td>
<td>p&lt;.001</td>
<td>0.835</td>
<td>16</td>
<td>p&lt;.01</td>
</tr>
<tr>
<td>Expert</td>
<td>0.918</td>
<td>40</td>
<td>p&lt;.01</td>
<td>0.924</td>
<td>40</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td><strong>Economy</strong></td>
<td>0.951</td>
<td>23</td>
<td>p=.314</td>
<td>0.971</td>
<td>23</td>
<td>p=.697</td>
</tr>
<tr>
<td><strong>of</strong></td>
<td>0.971</td>
<td>42</td>
<td>p=.362</td>
<td>0.923</td>
<td>42</td>
<td>p&lt;.01</td>
</tr>
<tr>
<td><strong>Motion</strong></td>
<td>0.887</td>
<td>16</td>
<td>p=.05</td>
<td>0.958</td>
<td>16</td>
<td>p=.624</td>
</tr>
<tr>
<td>Gamer</td>
<td>0.910</td>
<td>40</td>
<td>p&lt;.005</td>
<td>0.941</td>
<td>40</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>0.904</td>
<td>23</td>
<td>p&lt;.05</td>
<td>0.930</td>
<td>23</td>
<td>p=.096</td>
</tr>
<tr>
<td>Layperson</td>
<td>0.938</td>
<td>42</td>
<td>p&lt;.05</td>
<td>0.946</td>
<td>42</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Expert</td>
<td>0.858</td>
<td>16</td>
<td>p&lt;.05</td>
<td>0.961</td>
<td>16</td>
<td>p=.674</td>
</tr>
</tbody>
</table>
Table 13. Descriptives for the amount of change in the Ring & Rail 1 exercise

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Overall Score</th>
<th>Economy of Motion</th>
<th>Time to Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamer</td>
<td>40</td>
<td>332.26</td>
<td>-17.43</td>
<td>-36.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=508.98)</td>
<td>(IQR=31.09)</td>
<td>(IQR=31.52)</td>
</tr>
<tr>
<td>Medical</td>
<td>23</td>
<td>521.29</td>
<td>-21.35</td>
<td>-31.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=487.21)</td>
<td>(SD=26.12)</td>
<td>(IQR=39.87)</td>
</tr>
<tr>
<td>Laypeople</td>
<td>42</td>
<td>460.14</td>
<td>-12.77</td>
<td>-31.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=520.18)</td>
<td>(SD=28.47)</td>
<td>(IQR=22.52)</td>
</tr>
<tr>
<td>Expert</td>
<td>16</td>
<td>21.18</td>
<td>-5.16</td>
<td>-10.81</td>
</tr>
<tr>
<td>Surgeon</td>
<td></td>
<td>(IQR=407.89)</td>
<td>(SD=11.74)</td>
<td>(IQR=6.61)</td>
</tr>
</tbody>
</table>
Table 14. Descriptives for the amount of change in the Suture Sponge exercise

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Overall Score</th>
<th>Economy of Motion</th>
<th>Time to Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamer</td>
<td>40</td>
<td>466.83</td>
<td>-219.26</td>
<td>-256.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(SD=288.61)</td>
<td>(IQR=267.31)</td>
<td>(IQR=303.21)</td>
</tr>
<tr>
<td>Medical</td>
<td>23</td>
<td>442.22</td>
<td>-229.34</td>
<td>-220.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(SD=380.32)</td>
<td>(SD=173.36)</td>
<td>(SD=134.64)</td>
</tr>
<tr>
<td>Laypeople</td>
<td>42</td>
<td>246.89</td>
<td>-192.23</td>
<td>-202.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IQR=454.84)</td>
<td>(IQR=176.81)</td>
<td>(IQR=169.92)</td>
</tr>
<tr>
<td>Expert</td>
<td>16</td>
<td>568.25</td>
<td>-88.38</td>
<td>-68.38</td>
</tr>
<tr>
<td>Surgeon</td>
<td></td>
<td>(IQR=608.39)</td>
<td>(SD=64.30)</td>
<td>(SD=46.19)</td>
</tr>
</tbody>
</table>

A Kruskal-Wallis test was then used to determine if the amount of change was different between each of the groups. The groups demonstrated significantly different amounts of change for the Overall Score ($\chi^2(3)=8.30$, $p<0.05$) and Time ($\chi^2(3)=25.84$, $p<0.001$) metrics in the Ring & Rail 1 exercise. No differences were found between the groups for the Economy of Motion metric in Ring & Rail 1 ($p=0.062$). When looking at pairwise comparisons, no differences were
found for the Overall Score metric. Experts decreased their time significantly less than gamers (p<0.001), medical students (p<0.001), and laypeople (p<0.005) in the Time to Complete metric.

Significant differences were also found between the groups for the Economy of Motion ($\chi^2(3)=15.35, p<0.005$) and Time ($\chi^2(3)=24.78, p<0.001$) metrics of Suture Sponge. No differences were found for the Overall Score metric. When looking at pairwise differences, experts improved their efficiency significantly less than gamers (p<0.005), medical students (p<0.05), and laypeople (p<0.05) for the Economy of Motion metric. Experts reduced their time significantly less than gamers (p<0.001), laypeople (p<0.001), and medical students (p<0.005) for the Time to Complete metric.

A Pearson correlation was also used to determine if an association existed between the metrics in the first trial of simulator usage and age, the hours of reported gameplay, and the type of game reported. Age demonstrated a significant correlation with the economy of motion (r=-.340, p<0.005) and time (r=-.423, p<0.005) in Ring & Rail 1. Age was not associated with the overall score metric for this exercise. However, for the Suture Sponge exercise, age was associated with the overall score (r=.378, p<0.005), as well as the economy of motion (r=-0.296, p<0.005), and time (r=-0.385, p<0.005).

A Pearson correlation was performed to evaluate if an association existed between the metrics for the first of the simulator trials and the cognitive scores. The first trial was used for this evaluation with the supposition that it was representative of the baseline skills of the participants, as the cognitive scores were representative of the baseline perceptual skills of the participants. The time to complete metric in the Ring & Rail 1 exercise significantly correlated with the percent correct metric in the Flanker task (r=-0.240, p<0.05). No other simulation
metrics correlated with the Flanker scores. No significant correlations were found between the metrics of the subsidizing task and any of the simulation metrics. No correlation was found between the metrics of and the scores for any of the trials of the MOT task.

**Video Games**

The role of video games on the cognitive and simulator scores was examined further using the hours of reported gameplay and the type of game reported. The game type played was characterized as none, slow-paced, fast-paced, and both. This variable was developed using participant responses to the types of games that they play regularly. For example, first person shooters were considered a fast-paced game, while a puzzle game was considered slow-paced.

Using a Pearson correlation, the hours of gameplay were significantly correlated with age (r=-0.293, p<0.005). The hours of gameplay were significantly correlated with the time metric for the congruent (r=-0.250, p<0.05) and the incongruent (r=-0.240, p<0.005) arrows in the Flanker task. The percent correct did not have a significant correlation. The hours of gameplay were significantly correlated with the time in the subsidizing task (r=0.251, p<0.05), however this was not associated with the percent correct metric. Hours of gameplay did not correlate with any MOT trials.

The game type significantly correlated with age (r=-0.341, p<0.005). The game type significantly correlated with the time for congruent (r=-0.306, p<0.005) and incongruent (r=-0.240, p<0.005) in the Flanker task. The percent correct in the Flanker task did not demonstrate a significant correlation with game type. The game type significantly correlated with the percent correct (r=0.199, p<0.05) and the time (r=1.288, p<0.005) in the subsidizing task. The game type
significantly correlated with the difficult trial of the MOT task (r=0.184, p<0.05). No other correlations with the MOT task were found.

The hours of reported gameplay did not correlate with any metrics from either simulated exercise in trial 1. The type of game played correlated to the time metric in the Suture Sponge exercise (r=0.213, p<0.05) and the Ring & Rail 1 exercise (r=0.195, p<0.05). No other metrics had significant correlation to game type for either exercise. Appendix M provides graphical depictions of the correlation between hours of gameplay and simulation metrics from trial 1 and trial 8.
CHAPTER FIVE: CONCLUSIONS

The assumption that video gamers will outperform others using a virtual reality simulator is common. The manipulation of the hand controls and the user’s interaction with the synthetic environment seem comparable to that of a video game. These similarities gave rise to several studies in laparoscopic surgery, many of which concluded that prior video game experience may be an indicator of increased laparoscopic abilities and that video games are valuable training tools for basic laparoscopic skills. Contrary to these findings, the results of the current study were unable to confirm a relationship between playing video games and increased abilities in a robotic surgery simulator. Expert video gamers demonstrated scores about equivalent to medical students and laypeople, where all individuals in these groups had no prior experience with robotic surgery or associated simulators. The expert surgeons scored significantly higher than all of the non-expert groups, with the video gamers showing no advances even close to the performance of the surgeons.

The video gamers in this study did not perform better than laypeople or medical students in the perceptual tests. The medical students were typically faster than all other groups, with the gamers being faster only in the subsidizing task. Increasing age was found to have a relationship with several aspects of the perceptual tasks, including a slower reaction time in the Flanker and subsidizing tasks. Also, the number of correct selections in the MOT normal trial decreased as age increased. Age may not have demonstrated a relationship with the other levels of the MOT because the easy trial was manageable for most participants and the difficult trial was too challenging. Thus, the effect of age was more prominent in the normal trial.
Specific aspects of gameplay demonstrated associations with performance in the perceptual tasks. As the number of hours of gameplay per week increased, time taken to make a selection decreased in the Flanker task and increased in the subsidizing task. As the type of video game moved towards a mix of fast-paced and slow-paced games, time in the Flanker task decreased and subjects answered more questions correctly in subsidizing and the difficult trial of the MOT. However, with this trend, the subjects also took longer in the subsidizing task. Generally, the type of game played a more influential role on the performance in these perceptual tasks than the amount of game play.

The expert surgeons outperformed all other groups in the first trial of the simulation exercises. They scored significantly higher, were significantly more efficient, and significantly faster than all other groups in the Ring & Rail 1 and Suture Sponge exercises. This is expected due to the high level of expertise in the expert group. The gamers scored higher and were more efficient than medical students and lay people in Ring & Rail 1, but the differences were not significant. The gamers scored a lower score, were less efficient, and were slower than the medical students and laypeople in the Suture Sponge exercise. These differences were also not significant.

The differences between the groups were less distinct in the eighth trial of the exercises. Experts scored significantly higher and were significantly more efficient than laypeople for the Ring & Rail 1 exercise. The experts were also significantly faster than all other non-surgical groups. Gamers and medical students surpassed laypeople in the Overall Score, Economy of Motion, and Time to Complete metrics, although the differences were not significant. In the Suture Sponge exercise, experts scored significantly higher than gamers and laypeople. The
experts were also significantly more efficient and faster than all groups in this exercise. When comparing the non-expert groups, the medical students scored highest, the gamers were most efficient, and laypeople were fastest in this exercise. These differences were non-significant.

The gamers’ learning curve followed a similar pattern to the other non-expert groups; however, none of these groups improved significantly more than any other. Gamers improved steadily across the eight trials, but were unable to achieve scores close to those of expert robotic surgeons. Gamers, similarly to laypeople, lack a medical “culture.” This includes having sense of clinical relevance and context behind the simulator metrics (e.g. why it is important to perform a surgery fast and efficiently). It is possible that the non-expert groups in this study gained important psychomotor skills, but were unable to increase their performance more without the cognitive (i.e. clinical) foundation. The majority of the expert surgeons in this study did not play video games, and it is not clear if an expert with video game experience would surpass those without. Also, experts have developed a proprioceptive and kinesthetic awareness in regards to the robotic system. By performing hundreds of cases, they have the advantage over other groups of knowing how certain motions should feel. It is possible that the gamers would have benefitted from playing games with controls similar to that of the master controllers. Medical students are often used in research studies as novice subjects, however the results of this study do not show these individuals performing better than gamers or the average person. From this, one may assume that medical students do not actually qualify as surgical novices and should not be included in research studies as such.

The expert surgeons demonstrated steady performance across the eight trials and improved significantly less than the other groups for the Time metric of Ring & Rail 1 and the
Time and Economy of Motion metrics in the Suture Sponge exercise. It is likely that the experts have less room for improvement because they are already proficient in the tasks. It is also possible that the experts were unable to improve their performance more due to limitations imposed on them by the simulator. For example, the workspace in the dV-Trainer is smaller than in the actual da Vinci system. Also, certain tissue properties in a simulated environment are not the same as in real life. The experts are accustomed to a certain experience when performing tasks in the robotic systems and the constraints of the simulator may have limited them from achieving superior performance.

While these results are conflicting with laparoscopic research, they align with the few studies that have examined the impact of video game play on robotic surgical skills. So why does prior video game experience impact basic laparoscopic skills, but not robotic? Differences may be contributed to the distinctness of the systems with which the users are interacting. The skills developed in two-dimension video games may transfer more appropriately to laparoscopic surgery, which uses a two-dimensional screen, as opposed to the three-dimensional view in robotics. Laparoscopy also involves contrasting movements to the primarily fine motor movements of robotic surgery and it is possible that gamers are more inclined to exhibit the manual dexterity associated with laparoscopy. The movements associated with robotic surgery are also more intuitive than the proprioceptive challenge that laparoscopy presents. It is possible that gaming skills give users an advantage in overcoming the psychomotor difficulties, while the robot’s intuitive nature renders the advantage extraneous.
**Research Relevance**

In a technologically dependent society where video games have become an integral past time, it is important to determine the role that video games play in the perceptual and psychomotor development of video game users entering specific fields. This study has further emphasized that the effect of video game play on surgical skills is nuanced by the surgical technique. This reinforces the importance of critically evaluating the impact of technologies and training methods before implementing them into curricula. The findings can be generalized to domains outside of medicine utilizing robotic and computer-controlled systems, speaking to the scope of the gamers’ abilities and pointing to the capacity within these systems (e.g. Unmanned vehicle operation).

This study is unique in its relation to previous research in part due to the populations included in the research. No other video game study compared experienced gamers without medical experience to expert robotic surgeons. The results of this study are limited by the effect of age on various aspects of performance. Multiple associations with age were found including that as age increased, the number of hours of gameplay per week decreased. Also, as age increased, participants were more inclined to play slower paced video games. There was a large difference in age between the gamers and the experts; however, this is normal due to the nature of the groups.

**Promising Future Directions**

The research regarding the use of video games for training in robotic surgery is nascent. Future research should further delve into the differences of the performance of gamers in laparoscopic and robotic tasks. Comparing gamers in both modalities would highlight the
differences in performance. Research should also investigate if video game experience allows for better retention of skills, particularly leading to less or slower skill degradation during periods of inactivity. Are gamers more inclined to perform better if they have a contextual understanding of the procedures and ramifications of not succeeding? Future research should also examine the impact alternative skillsets may have on a user’s abilities in a robotic surgery system (e.g. sports, musical instruments, knitting, martial arts). The intuitive nature of the robot may be more inclined to more natural psychomotor skills.

Although gamers do not demonstrate increased performance in a 3D robotic surgery simulator, their abilities are beneficial to other modalities. As video games become more accessible and more frequent, it is important to continue to evaluate how these skills affect skill performance. The culmination of the research for video game use in surgery has provided a preliminary view of the skills future generations of medical students will possess and insight on how we can leverage videogame play to better prepare medical students to be better residents and in turn better surgeons.
APPENDIX A: FLORIDA HOSPITAL IRB APPROVAL LETTER
DATE:       June 8, 2015
TO:         Roger Smith, PhD
FROM:       Florida Hospital Institutional Review Board (IRB)

PROJECT TITLE:  [568233-11] Video Game Proficiency & Surgical Robotic Skills
SPONSOR:     FH
REFERENCE #: Continuing Review/Progress Report

SUBMISSION TYPE:  Continuing Review/Progress Report
ACTION:       APPROVED
APPROVAL DATE:  June 8, 2015
EXPIRATION DATE:  June 7, 2016
REVIEW TYPE:   Expedited Review

Note: If this is an expedited or exempt action, the IRB members will be made aware via published
meeting minutes.

Thank you for your submission of Continuing Review/Progress Report materials for this project. The
Florida Hospital IRB has APPROVED your submission. This approval is based on an appropriate risk/
benefit ratio and a study design wherein the risks have been minimized. All research must be conducted
in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulations. Material
reviewed for this submission includes:

- Consent Form - 568233_Informed_Consent_06_06_16___for_IRB_Approval.docx (UPDATED:
  06/9/2015)
- Continuing Review/Progress Report - 568233 Continuing Review Progress.pdf (UPDATED:
  06/9/2015)
- Other - Change_Request_Form_00.05.2015[1].docx (UPDATED: 06/9/2015)

Please remember that informed consent is a process beginning with a description of the study and
assurance of participant understanding followed by a FHIRB approved signed consent form. Informed
consent must continue throughout the study via a dialogue between the researcher and research
participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by the FHIRB prior to
initiation. Please use the appropriate revision forms for this procedure.
APPENDIX B: UCF IRB OUTCOME LETTER
Notice that UCF will Rely Upon Other IRB for Review and Approval

From: UCF Institutional Review Board  
FWA0000351, IRB0001138

To: Alyssa D.S. Tanaka

Date: October 07, 2015

IRB Number: SBE-15-11660

Study Title: Video Game Experience and Basic Robotic Skills

Dear Researcher:

The research protocol noted above was reviewed by the University of Central Florida IRB Designated Reviewer on October 07, 2016. The UCF IRB accepts the Florida Hospital’s Institutional Review Board review and approval of this study for the protection of human subjects in research. The expiration date will be the date assigned by the Florida Hospital’s Institutional Review Board and the consent process will be the process approved by that IRB.

This project may move forward as described in the protocol. It is understood that the Florida Hospital’s IRB is the IEB of Record for this study, but local issues involving the UCF population should be brought to the attention of the UCF IRB as well for local oversight, if needed.

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

Failure to provide a continuing review report for renewal of the study to the Florida Hospital’s IRB could lead to study suspension, a loss of funding and/or publication possibilities, or a report of noncompliance to sponsors or funding agencies. If this study is funded by any branch of the Department of Health and Human Services (DHHS), an Office for Human Research Protections (OHRP) IRB Authorization form must be signed by the signatory officials of both institutions and a copy of the form must be kept on file at the IRB office of both institutions.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

_SIGNATURE_

Signature applied by Patricia Davis on 10/07/2015 12:06:05 PM EDT

IRB Coordinator
APPENDIX C: PRE-QUESTIONNAIRE
PRE-TEST

GENERAL

DEMOGRAPHICS:

1. What is your age? ____________________________ Years

2. What is your gender? □ Male □ Female

3. What is your dominant hand? □ Right □ Left

CURRENT OCCUPATION

4. Which best describes your current occupation? Select one
□ Medical Student (if yes, specify year)
   Your Year: □ First □ Second □ Third □ Forth □ Other: _____________

□ OTHER Student Specify MAJOR: ___________________________ (if Other Student, specify year)
   Your Year: □ First □ Second □ Third □ Forth □ Other: _____________

□ Robotic Surgeon Your clinical specialty: ___________________________

   Years of Experience as a Robotic Surgeon _______________________

   Number of Robotic cases per year _______________________

   Total Number of Robotic Cases (entire career) _______________________

   Years of Experience in Laparoscopic Surgery _______________________

   Number of Laparoscopic cases per year _______________________
Total Number of Laparoscopic Cases (entire career) ____________

☐ Clinical Medical Staff. Your clinical specialty: ________________________________
   Number of years in clinical practice ________________

☐ OTHER. Specify OTHER: ________________________________
   Number of years in practice ________________

PRIOR ROBOTIC TRAINING
5. Have you received or are receiving training in robotic surgery? ☐ Yes ☐ No

6. Have you used any robotic or laparoscopic simulator? ☐ Yes ☐ No
   6a. If yes, how many hours? __________

HOBBIES AND VIDEO GAME EXPERIENCE
7. Do you have any particular hobbies or sports (except video games) that you engage in frequently? ☐ Yes ☐ No
   7a. If yes, please list:
       ____________________________ ________________
       ____________________________ ________________
       ____________________________ ________________
   7b. How many hours per week do you spend TOTAL on these other (non-video game) hobbies or sports? __________

8. Are you currently a Video Game user? ☐ Yes ☐ No
8a. If a video game user in the past, at what age did you stop playing?  

Complete following questions **ONLY** if you answered **YES** to question 8.

9. Do you consider yourself a Video Game expert?  
   ☐ Yes  ☐ No

10. What is your experience in video game play?  
    10a. Number of years of experience playing video games  
         ________  years
    10b. Number of hours of video game play per week  
         ________  hours/week

11. What kind of video game do you play? How many hours per week you play each type of game?

   - ☐ Fast-paced action video game  
     ________  hours/week
   - ☐ Slower-paced strategy game  
     ________  hours/week
   - ☐ Puzzle game  
     ________  hours/week
   - ☐ Sport game  
     ________  hours/week
   - ☐ Racing game  
     ________  hours/week
   - ☐ First Person Shooter game  
     ________  hours/week
   - ☐ Adventure game  
     ________  hours/week
   - ☐ Rhythm game  
     ________  hours/week
   - ☐ Role playing game  
     ________  hours/week
   - ☐ Massive multiplayer online game  
     ________  hours/week
   - ☐ Simulation  
     ________  hours/week
12. Please give the names of the video games you play most frequently

________________________________________________________________________

________________________________________________________________________

13. What attracts you to these games

________________________________________________________________________

________________________________________________________________________

14. Which gaming platform do you most frequently use? (Select one)

☐ Console

☐ PC/Mac

☐ Tablet

☐ Cellphone

☐ Other (specify):

________________________________________________________________________

15. Which console(s) you most frequently use?? (Select all that apply)

☐ X-box 360

☐ X-box One

☐ Play Station 3

☐ Play Station 4

☐ Wii

☐ Wii U

☐ Other (specify):

________________________________________________________________________

16. What would you like to see in a video game made just for YOU?
APPENDIX D: POST-QUESTIONNIARE
POST TEST

According to your experience with the dV-Trainer, please check the value that you agree most strongly with below. Please check only one per question.

1. I was able to identify strategies or “tricks” that helped me improve my score (Select ONE)

☐ Strongly Disagree  ☐ Disagree  ☐ Neutral  ☐ Agree  ☐ Strongly Agree

1a. If any, please specify:

____________________________________________________________________

2. I had specific expectations of what the simulator would be like prior to using it. (Select ONE)

☐ Strongly Disagree  ☐ Disagree  ☐ Neutral  ☐ Agree  ☐ Strongly Agree

2a. If any, please specify:

____________________________________________________________________

3. The simulator mimicked a video game that I play regularly (Select ONE)

☐ Strongly Disagree  ☐ Disagree  ☐ Neutral  ☐ Agree  ☐ Strongly Agree

3a. If so, what game or type:

____________________________________________________________________

4. I feel that my performance on the simulator aligned closely with my real-world surgical, clinical, or gaming performance (Select ONE)

☐ Strongly Disagree  ☐ Disagree  ☐ Neutral  ☐ Agree  ☐ Strongly Agree

5. I feel simulator scores adequately rewarded my efforts (Select ONE)

☐ Strongly Disagree  ☐ Disagree  ☐ Neutral  ☐ Agree  ☐ Strongly Agree
6. I became bored with continuous simulator practice. *(Select ONE)*

☐ Strongly Disagree  ☐ Disagree  ☐ Neutral  ☐ Agree  ☐ Strongly Agree

7. Please indicate which learning style most accurately describes you:

☐ Spatial (Visual) - I prefer using pictures, images, and spatial understanding

☐ Auditory (Aural) - I prefer using sound and music

☐ Linguistic (Verbal) - I prefer using words, both in speech and writing

☐ Kinesthetic (Physical) - I prefer using my body, hand, and sense of touch

☐ Mathematical (Logical) - I prefer using logic, reasoning and systems

8. Please indicate which learning style you believe simulator practice is most suitable for:

☐ Spatial (Visual) - using pictures, images, and spatial understanding

☐ Auditory (Aural) - using sound and music

☐ Linguistic (Verbal) - using words, both in speech and writing

☐ Kinesthetic (Physical) - using my body, hand, and sense of touch

☐ Mathematical (Logical) - using logic, reasoning and systems

9. Which exercise did you find to be particularly difficult? The most demanding? *(Select ONE)*

☐ Ring and Rail  ☐ Suture Sponge  ☐ None

9a. Please explain:

__________________________________________________________

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10. Which exercise did you find to be particularly easy? The least demanding? (Select ONE)

☐ Ring and Rail  ☐ Suture Sponge  ☐ None

10a. Please explain:

________________________________________________________________________

11. What was your goal when performing exercises? (Select ONE or explain Other)

☐ Achieve high score  ☐ Improve accuracy  ☐ The fastest time  ☐ Just finish

11a. Other (specify)

________________________________________________________________________

12. I feel there is a connection between the skills developed on the simulator and those tested in the cognitive exercises. (Select ONE)

☐ Strongly Disagree  ☐ Disagree  ☐ Neutral  ☐ Agree  ☐ Strongly Agree

THANK YOU FOR YOUR PARTICIPATION AT THIS STUDY.
APPENDIX F: SUBSIDIZING METRICS DISTRIBUTION
APPENDIX G: SCORE DISTRIBUTION FOR TRIAL 1 OF RING & RAIL 1
APPENDIX H: SCORE DISTRIBUTION FOR TRIAL 1 OF SUTURE SPONGE
APPENDIX I: SCORE DISTRIBUTION FOR TRIAL 8 OF RING & RAIL 1
APPENDIX J: SCORE DISTRIBUTION FOR TRIAL 8 OF SUTURE SPONGE
Suture Sponge Trial 8

Overall Score

Category

Gamer  med student  layperson  expert

116*  79*  115
APPENDIX K: SCORE DISTRIBUTION FOR THE AMOUNT OF CHANGE IN RING & RAIL 1
APPENDIX L: SCORE DISTRIBUTION FOR THE AMOUNT OF CHANGE IN SUTURE SPONGE
Suture Sponge Amount of Change

Time to Complete (sec)

Category

Gamer
med student
layperson
expert

101
68
APPENDIX M: CORRELATION OF HOURS OF GAMEPLAY AND SIMULATOR PERFORMANCE
REFERENCES


