Virtual Reality Simulators: Valuable Surgical Skills Trainers or Video Games?

Ross E. Willis, PhD,* Pedro Pablo Gomez, MD,* Srinivas J. Ivatury, MD,* Hari S. Mitra, BS,† and Kent R. Van Sickle, MD*

*Department of Surgery, University of Texas Health Science Center, San Antonio, Texas; and †School of Medicine, University of Texas Health Science Center, San Antonio, Texas

BACKGROUND: Virtual reality (VR) and physical model (PM) simulators differ in terms of whether the trainee is manipulating actual 3-dimensional objects (PM) or computer-generated 3-dimensional objects (VR). Much like video games (VG), VR simulators utilize computer-generated graphics. These differences may have profound effects on the utility of VR and PM training platforms. In this study, we aimed to determine whether a relationship exists between VR, PM, and VG platforms.

METHODS: VR and PM simulators for laparoscopic camera navigation ([LCN], experiment 1) and flexible endoscopy ([FE] experiment 2) were used in this study. In experiment 1, 20 laparoscopic novices played VG and performed 0° and 30° LCN exercises on VR and PM simulators. In experiment 2, 20 FE novices played VG and performed colonoscopy exercises on VR and PM simulators.

RESULTS: In both experiments, VG performance was correlated with VR performance but not with PM performance. Performance on VR simulators did not correlate with performance on respective PM models.

CONCLUSIONS: VR environments may be more like VG than previously thought. (J Surg 71:426-433. © 2014 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: surgical education, simulation, virtual reality, physical model

COMPETENCY: Patient Care

INTRODUCTION

Surgical simulators can be classified into 2 distinct categories: physical model (PM) and virtual reality (VR).[1] VR and PM simulators differ in terms of whether the trainee is manipulating actual 3-dimensional (3D) objects (PM) or computer-generated 3D objects (VR). PM simulators such as suturing models, laparoscopic box trainers, and procedure manikins have been in existence longer than VR simulators, such as the Simbionix Lap Mentor. VR-based trainers have advanced to the point where they are able to mimic physical characteristics of instrumentation and provide haptic feedback. Additionally, VR-based simulators have the ability to record basic measurements such as time to complete a given exercise and complex metrics such as instrument tip trajectory (i.e., path of an instrument tip in 3D space). Given the absence of computer mechanisms on PM simulators such as laparoscopic box trainers, these models rely solely on observer-based scoring and assessment to record even the most basic measurements. VR and PM simulators vary greatly in terms of cost. For example, PM box trainers range in price from $1500 to $10,000, whereas VR laparoscopic simulators can range from $40,000 to $150,000.[2]

One of the most remarkable differences between PM and VR simulators is regarding graphical representation of the surgical field. In PM simulators, the trainee manipulates actual 3D objects that are projected on a 2-dimensional (2D) monitor via a camera, whereas in VR simulators, the trainee manipulates computer-generated 3D objects that are displayed on a 2D monitor via computer-generated mathematical models of graphical rendering. Thus, VR simulators are similar to video games (VG) in that both use computer-generated graphics.

Previous research has reported conflicting results between VG performance and different models of surgical simulation. Relatively few studies have observed a significant correlation between actual VG performance and self-reported VG experience with performance on PM simulators.[3-5] However, other studies have not found significant relationships among these variables,[6-10] Interestingly, the relationship between self-reported and actual VG performance on VR simulators has been studied by several authors, with many of them finding significant correlations.[11-15]

Correspondence: Inquiries to Ross E. Willis, Department of Surgery, University of Texas Health Science Center, 7703 Floyd Curl, Mail Code 7737, San Antonio, TX 78229; fax: +(210) 567-2347; e-mail: willisr@uthscsa.edu

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The lack of cohesion among findings could be owing to the nature of the simulators employed in the studies. It is possible that the human visual perception system processes computer-generated images quite differently compared with camera-projected images of actual objects. Kober et al.[16] conducted a study examining electroencephalogram (EEG) patterns of study participants performing a spatial navigation task in 2D and 3D VR environments. They found that EEG patterns differed significantly between these 2 VR environments, thus indicating that different neurological processes are employed when interpreting visual cues within the 2 VR environments. As evidenced by this study, it is conceivable that there are even greater differences in the neurological processes that might be employed when interpreting PM environments.

We conducted 2 experiments aimed at determining whether relationships exist between VR, PM, and VG performance. Experiment 1 focused on the relationship between VG and VR and PM laparoscopic camera navigation (LCN) performance. Experiment 2 examined the relationship between VG and VR and PM flexible endoscopy (FE) (colonoscopy) performance. We hypothesized that VG performance would correlate with VR performance but not with PM performance, thus providing support for the theory that differences in graphical representation between the 2 types of simulators is at least partially responsible for discrepancies in the reported benefits of VR and PM training.

METHODS

Experiment 1

Overall, 20 laparoscopic novices (first- and second-year medical students) were recruited for this experiment. All participants completed a questionnaire that gathered basic demographic information including time spent playing VG between the ages of 5 and 12 years, 13 and 18 years, and 19 and 22 years. Participants rated current time playing VG using 4-option forced-choice response categories of 0 to 2 hours per week, 3 to 4 hours per week, 5 to 6 hours per week, and 7+ hours per week. Additionally, we collected self-reported VG skills level using a 5-point Likert scale ranging from complete novice to expert (1 = novice and 5 = expert). On completion of the questionnaire, participants played a VG (Marble Mania by Hudson Soft Company, Tokyo, Japan) that assessed fine motor skills on the Nintendo Wii (Nintendo Co, Kyoto, Japan) system. This VG platform was selected because it uses single handheld controller that is 5.83 in (148 mm) in length by 1.43 in (36.2 mm) in width and 1.21 in (30.8 mm) thick. This is approximately the size of a standard laparoscopic camera handle and only slightly smaller than a standard FE control head (but does not include the control knobs of the FE control head). The Wii controller makes use of motion-sensing technology via an accelerometer and optical sensor. A player's actions are transmitted to the video display and are based on the angle at which the controller is held and the speed at which the controller changes direction. In this sense, the Wii controller is different from other standard VG platform controllers that make exclusive use of pressing buttons and controlling knobs with the player's fingers and thumbs. The Marble Mania VG was selected because it requires precise, fine motor control and was previously used in a study by Kahol and Smith (as reported by Reilly[17]) at Banner Good Samaritan Medical Center in Phoenix, AZ, and had shown to improve performance on a VR laparoscopic simulator.

The objective of Marble Mania is to hold the Wii controller parallel to the ground and finely rotate the controller in all directions to change the axis of the virtual world, allowing a marble to roll to collect crystals and arrive at a goal in various mazes. The player receives a time for completion of the maze. If the marble falls from the maze, the participant is required to restart from the beginning of the maze with the timer continuing. Participants played 3 levels of the game. Level 2 ([Fig. 1] with the Wii controller super-imposed for illustration purposes) is a simple, continuous course shaped like an upside-down U with small areas without walls. Level 11 is a complex, discontinuous maze requiring participants to navigate through moving elevators, steps, and falls. Level 12 is a complex, continuous course requiring participants to navigate on a continuous course with large areas without walls with very little margin for error.

Following completion of the VG portion of the study, participants proceeded to the LCN exercises. PM and VR models were used in this experiment. To control for "warm-up" and learning effects, half of the participants were randomly selected to perform the PM followed by the VR model or vice versa.

The PM LCN exercise was the validated Tulane Trainer[18] (Fig. 2). Specifically, the participant used a standard laparoscope to locate and align a series of red targets adhered to white foam-core board and placed in a Plexiglas laparoscopic box trainer. Each target was comprised of a red circle with a solid black outline, with a horizontal black line extending the

FIGURE 1. Marble Mania level 2.