PROGRAM EXECUTIVE OFFICE FOR SIMULATION, TRAINING & INSTRUMENTATION

INVESTIGATING THE DISRUPTIVE EFFECT OF COMPUTER GAME TECHNOLOGIES ON MEDICAL EDUCATION AND TRAINING

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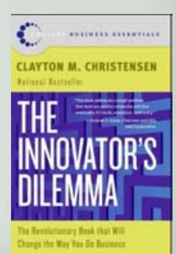
Topic Background

- The computer gaming industry is exporting powerful products and technologies to “serious” industries.
    - E.g. Defense, Medicine, Architecture, Education, City Planning, and Government
- Each industry is already served by established companies that typically do not use computer games to serve their customers.
- The rapid growth in the computational power and the social acceptance of these technologies has created an environment in which these are displacing established industry-specific computer hardware and software tools.

- **What does this mean to the medical education industry and profession?**



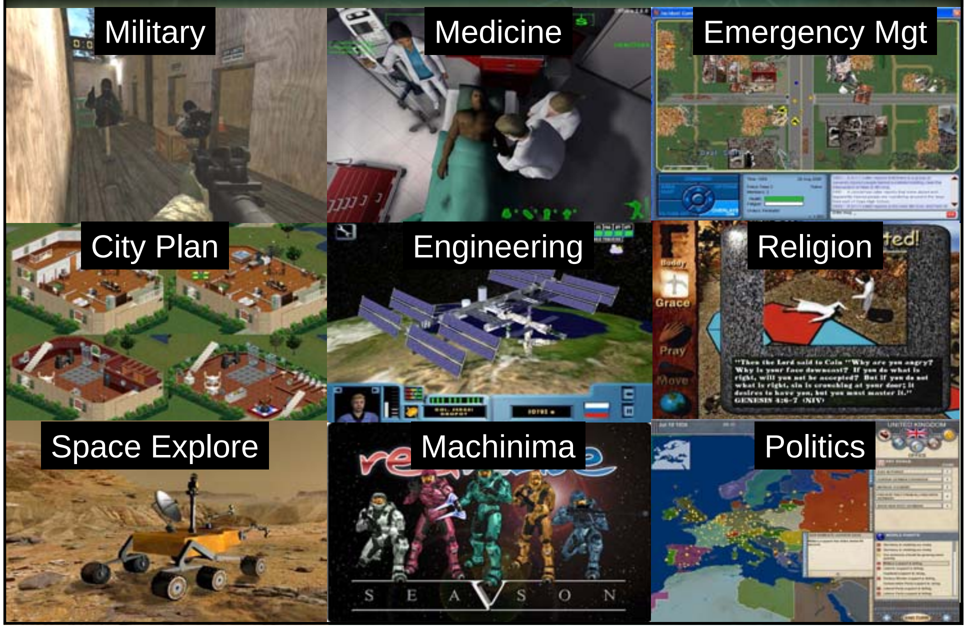
Proposition

- If Virtual Reality and systems using Game Technology are going to become an important next step in medical education and training,
- Then they must provide an advantage in at least one of the following areas:
  - Lower Cost
  - Better Access allowing Repetitive Practice
  - Reduced Training Time
  - Reduced Medical Errors

Hypotheses

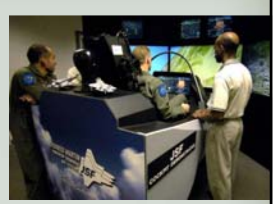
- **Hypothesis 1:** Training in laparoscopic surgery can be accomplished at a lower cost using virtual reality and game technology-based tools than through existing methods of training.
- **Hypothesis 2:** Virtual reality and game technology-based training environments provide better access to representative patient symptoms and allow more repetitive practice than existing forms of training.
- **Hypothesis 3:** Virtual reality and game technology-based training environments can reduce the training time required to achieve proficiency in laparoscopic procedures.
- **Hypothesis 4:** Virtual reality and game technology-based training can reduce the number of medical errors caused by residents and surgeons learning to perform laparoscopic procedures.

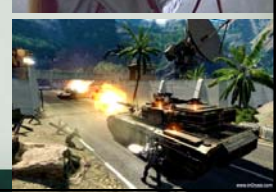
Industries Adopting Game Tech



Terminology (1)

- **Simulation:** the imitative representation of the functioning of one system or process by means of the functioning of another (Webster)
- **Virtual Reality:** an artificial environment which is experienced through sensory stimuli (as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment (Webster)
- **Video Game:** a mental contest, played with a computer according to certain rules for amusement, recreation, or winning a stake (Zyda 2005)

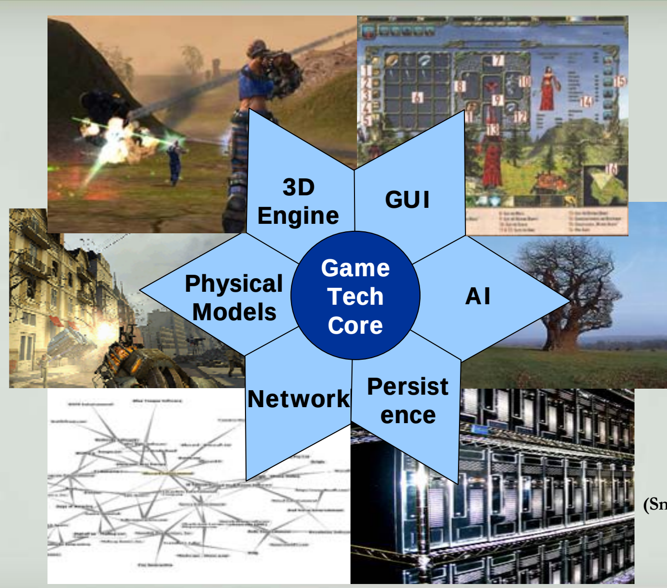




Terminology (2)

- **Serious Game:** a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives (Zyda 2005)
- **Game Technologies:** the software and hardware components that are developed specifically to enable a working computer game (Smith, 2008)

Computer Game Technologies



(Smith 2008)

Medical Training Problem

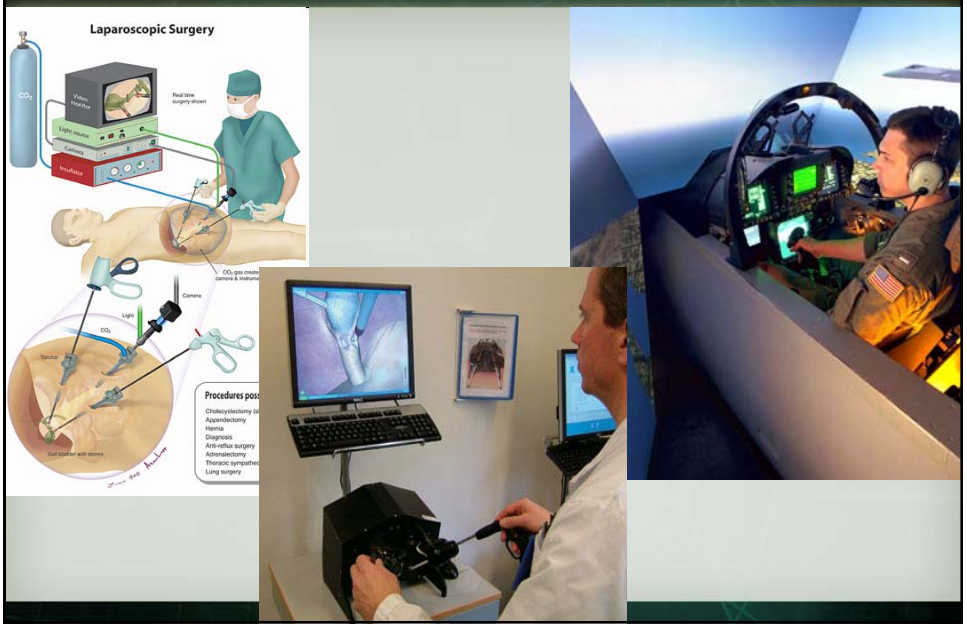
- Medical procedures are becoming more numerous and more complex – medical knowledge has "hypertrophied" (Cooke, 2006)
- Training residents to a common level of knowledge and competence is already impossible (Satava, 2008)
- Some procedures lend themselves well to computer-based training tools
- Laparoscopic surgery is especially amenable because of the intermediation of the camera, computer monitor, and long-rod effectors in real surgery

"The Perfect Storm"

(Murphy, 2007)

- Risk to patient health. (McDougall, 2007)
- Cost is a barrier to training. (Bridges, 1999)
- Availability of training opportunities. (Birden, 2007; Davis, 1999)
- Access to training. (Dunkin, 2007; Spitzer, 1997)
- Limited working hours. (Satava, 2004)
- Ethics of practicing on patients. (Satava, 2004; Murphy, 2007)
- Expectations around computer technologies. (Murphy, 2007)
- Insurance coverage of educational actions. (Satava, 2004)
- Volume of unique procedures. (Reznick & MacRae, 2006)
- Complexity of modern surgery. (McDougall, 2007)
- Quality of VR technology. (Murphy, 2007)
- Professional Acceptance. (Ziv, 2003)
- Learning from Mistakes. (Ziv, 2005)
- Proficiency-based Medicine. (Murray, 2005)

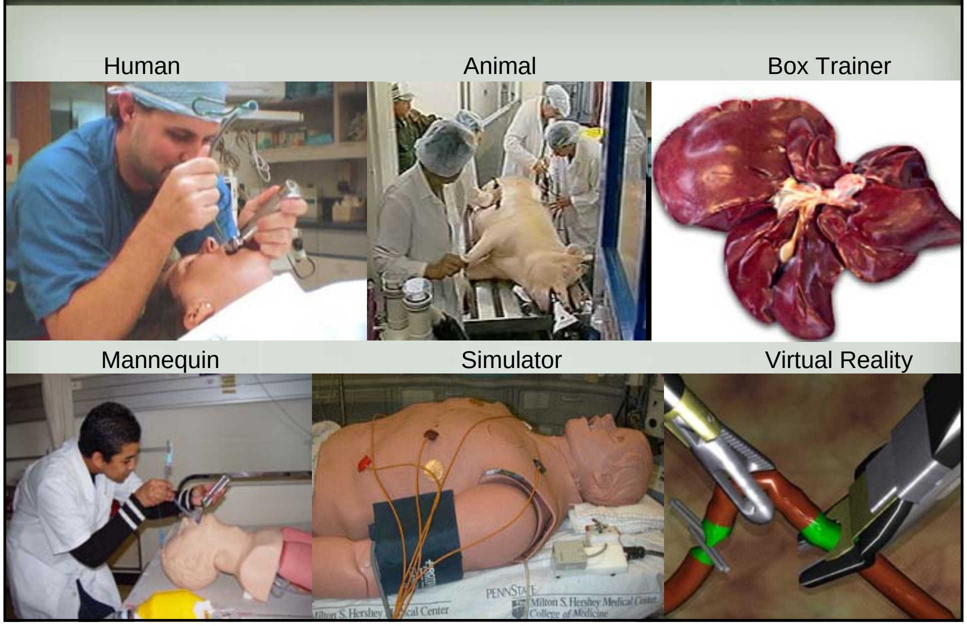
The Laparoscopic Pilot



Literature Review Areas

- Laparoscopic Surgical Education
- VR in Medical Training
- Medical Education System
- Simulation
- Computer Games
- Management of Innovation

Conceptual Framework



Human	Animal	Box Trainer	Mannequin	Simulation	VR/Game
Learn on humans: Living patients, the newly dead, and cadavers	Learn on animals: Living and newly dead pigs, cats, and others	Learn on organs in a box: Human-shaped box contains organs, tissue, or test devices	Learn on a physical replica: A full-body device with synthetic skin, organs, and fluids	Learn on an animated machine: Includes computer, hydraulics, pneumatics, and electrical responses	Learn on computer images: Mathematical models, visual images, sounds, and some tactile feedback
<u>Advantage</u> Exact Replica, Existing OR	<u>Advantage</u> Similarities, Availability	<u>Advantage</u> Availability, Convenience, Human Shape	<u>Advantage</u> Human Shape, Logistics	<u>Advantage</u> Rich Experience, Multi-Function, Programmable	<u>Advantage</u> Rich Experience, Flexibility, Low Cost
<u>Disadvantage</u> Scarcity, Single Use, Ethical Issues	<u>Disadvantage</u> Anatomy, Single Use, Social Mores	<u>Disadvantage</u> Not Alive, Single Use, Animal Organs	<u>Disadvantage</u> Static, Lacks Realism	<u>Disadvantage</u> High Cost, Complexity	<u>Disadvantage</u> Screen-barrier, Non-tactile
<u>Examples</u> Cadavers Live Patients	<u>Examples</u> Porcine Labs	<u>Examples</u> MIC-Trainer	<u>Examples</u> CPR Annie	<u>Examples</u> Sim One HPS	<u>Examples</u> MIST-VR LapSim

Research Method

- Analysis of the published research on the effects of simulation, game technology, and virtual reality in medical training.
- Over 200 papers on VR and simulation in medical training.
- Over 50 papers on the MIST-VR system

- Focus on Laparoscopic Surgery
  - Considered the most amenable specialty for VR
- Minimally Invasive Surgical Trainer – Virtual Reality (MIST-VR)
  - Most widely studied VR device

Reference Support to Hypotheses

Source		Hypothesis				Specialty				Nature and Content							
Author	Year	H1	H2	H3	H4	L	M	A	C	S	D	G	F	Ed	B	Eth	Comment
Hypothesis 1: Training in laparoscopic surgery can be accomplished for significantly lower costs																	
AHRQ	2000	X								X				X			Estimated cost associated with deaths from medical error is $37.6 billion
Bridges	1999	X								X							Learning in the OR is much more expensive than learning in VR
Brunner	2005	X	X	X	X	X	X			X	X						Students need new forms of trainining to achieve proficiency under current regulations on work hours.
Cohen	1999	X								X				X			between 44,000 and 98,000 people dying as a result each year
Derossis	1998	X				X				X							Collecting metrics in live surgery is difficult, using VR sims is less expensive
Eastridge	2003	X				X	X				X						Regulations limiting resident work hours leads to a need for a simulator to hone skills.
Frost	2004	X		X	X					X	X						Research study creates and applies model of cost/benefits of Immersion Medical's AccuTouch laparoscopic simulator.
Grantcharov	2003	X	X	X	X	X	X			X	X						It takes 10-30 operations for a laparoscopic surgeon to master skills.
Hamilton	2001	X								X	X						Wet tissues and sutures are an avoided cost when training with VR rather than humans or animals.

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Coded Items

Group 1: Hypothesis Addressed
H1 = Cost of Training
H2 = Access to Symptoms
H3 = Time to Proficiency
H4 = Error Reduction

Group 2: Medical Specialty
L = Laparoscopic Surgery (including arthroscopic, endoscopic, and minimally invasive)
M = MIST-VR (specific mention of this laparoscopic VR training device)
A = Anesthesiology (including airway management)
C = Cardiac Care

Group 3: Nature and Content of Reference
S = Scientific study was conducted
D = Specific device is used or referenced
G = Game technology is specifically referenced
F = Futuristic, Visionary, or Speculative discussion of medical education
Ed = Educational methods are described
B = Background information that will be useful
Eth = Ethics

Hypothesis 1: Lower Cost

- Surgery as a teaching event takes considerably longer.
- Ties up resources that could generate additional revenue. (Bridges & Diamond 1999)
  - Accumulates to 186 hours over a 4 year residency
  - Estimate operating room costs at $257.40 per hour.
- **Adds $47,970 to the cost of a medical education.**

- Other Cost Estimates
  - Frost & Sullivan (2004) estimate operating room cost at $1,500 per hour
  - Hyltander (2003) estimates Swedish operating room costs $1,000 per hour.
  - Richard Satava cites the cost as "$250 per 15 minutes" (May 20, 2008).
- **Using these ratios: $186,363 to $279,545 across a four year residency.**

H1: Return on Investment

Category	Description	Fixed Cost	Recurring Over Residency (4 Years)	After Residency (5th Year)	Total over 5 Years
Investment	AccuTouch Simulator	(72,000)	(18,664)	0	(90,664)
Time Savings	Instructor time		23,040	0	23,040
	Additional Procedures		0	114,400	114,400
Reduction in Errors	Complications		0	0	0
	Cancellations		13,600	0	13,600
Faster Time to Competence	Residents generating revenue		78,000	0	78,000
Equipment Breakage	Reduction due to better training		5,428	5,428	10,856
Other Financial Benefits	Reduction in alternative training		4,400	0	4,400
	Revenue from selling time on simulator		93,000	0	93,000
	Total Cost/Benefit	**(72,000)**	**198,804**	**119,828**	**246,632**

Derived from Frost & Sullivan 2004

Hypothesis 2: Better Access

- "The traditional Halstedian apprenticeship model of 'see one, do one, teach one' is no longer adequate to train surgeons, since good laparoscopic skills cannot be developed by merely watching an expert.
- Laparoscopic proficiency is only realized after sufficient practice in the minimally invasive environment. To this end, a variety of approaches have been developed to teach laparoscopic skills outside of the operating room; these methods include practicing on animal models or artificial tissues, training boxes, and virtual reality simulators." (Pearson et al, 2002)
- In laparoscopy, "see one" does not contribute to the learning process. Learning begins with "do one" (Jordan et al, 2001; Gallagher et al, 2001b; Madan & Frantzides, 2007).

H2: Better Access, Better Training

- Modern methods for delivering medical care are much more complicated (Cooke et al, 2006).
- Proficiency is reached after 10 to 30 surgeries. VR systems allow these to be moved off of patients (Grantcharov et al, 2003b and 2004; MacFadyen et al, 1998).
- Expectations of the public are higher now than when the current apprenticeship model was created (Cooke et al, 2006).
- Resident restriction of 80 hours per week is limiting training opportunities (McClusky et al, 2005; Brunner et al, 2005; Eastridge et al, 2003).
- Repeated practice of procedures, standardized tasks, and objective measurements are important factors in mastering laparoscopic skills and these are all lacking or limited in traditional OR-based training (Grantcharov et al, 2003b and 2004).
- Experiments allowing high school students to use MIST-VR (Ali et al, 2002).
- Experiments on resident performance with little sleep (DeMaria et al, 2005).

Hypothesis 3: Reduced Time

- Both MIST-VR and GI-Mentor differentiate experienced from inexperienced subjects based on their performance scores with the simulator (Adamsen et al, 2005).
- MIST-VR simulator could determine which students would never achieve proficiency in laparoscopy and should be dropped from a training program (Gallagher et al, 2004).
- Non-VR trained students are nine times more likely to fail to make progress in their performance than those who use VR in their training (Seymour, 2002).
- Students trained in VR are 29% faster at performing laparoscopic surgeries and make up to five times fewer mistakes (Enochsson et al, 2004; and Seymour, 2002).

Hypothesis 4: Reduced Errors

"There is no excuse for the surgeon to learn on the patient." (William J. Mayo, 1927).

- Medical error is responsible for between 44,000 and 98,000 deaths per year (IOM, 1999).
- Laparoscopic surgery has an error rate that is three times higher than that of open surgery. Error rate has not been decreasing over an eight year period as surgeons become more experienced at the procedures (Huang et al, 2005).
- VR systems are one tool that can improve the performance of surgeons because they become familiar with the appearance of organs and tissue on a two dimensional computer monitor (Huang et al, 2005).
- In laparoscopy, observation does little to convey the skills that must be mastered. Only actual practice has been effective at this (Jordan et al, 2001; Gallagher et al, 2001b; Madan & Frantzides, 2007).

Results

- H1 Lower Cost: **Supported**
  - Concrete measures of ROI and reduced costs.
- H2 Better Access: **Supported**
  - Much greater access to symptoms with simulation devices.
  - Reduces dependency on faculty members.
- H3 Reduced Training Time: **Supported**
  - Residents become proficient faster.
  - Graduates perform procedures faster.
- H4 Reduced Errors: **Supported**
  - Errors significantly reduced both early in training and throughout career.
- Model of Medical Education: **Supported**
  - Model of progressions in training methods support the adoption of VR as the next major means of training.

Recommended Future Work

- Cost advantages of simulation/VR versus other forms of training
  - Combine medical researchers with hospital/medical school comptrollers
- Compare level of access to patients and faculty in education
  - Limitations due to costs, insurance, social expectations, ethics

Misleading Assumptions

- Assumption 1: Didactic Education is Effective
  - Though surgeons or residents may learn new information during educational lectures, they do not incorporate it into their practice. It has no impact on their actions in delivering medicine. (Davis et al 1995 & 1999; Weller et al 2005)
- Assumption 2: Cost of Systems is Not an Issue
  - Scientific vs. Financial view of health care
- Assumption 3: Sufficient Access to Faculty and Patients is Possible
  - Availability of faculty is a major limitation in medical education (Dunkin et al, 2007; Satava, 2008)
  - Many studies assume adequate access a priori (Gerson & Van Dam, 2003)
- Assumption 4: Practicing on Live Patients is Acceptable
  - Medical schools, faculty, and residents are finding new restrictions on the type and amount of training that can be conducted with a live patient (Murphy et al, 2007; Murray et al, 2005; Satava, 2004a; Ziv et al, 2005).