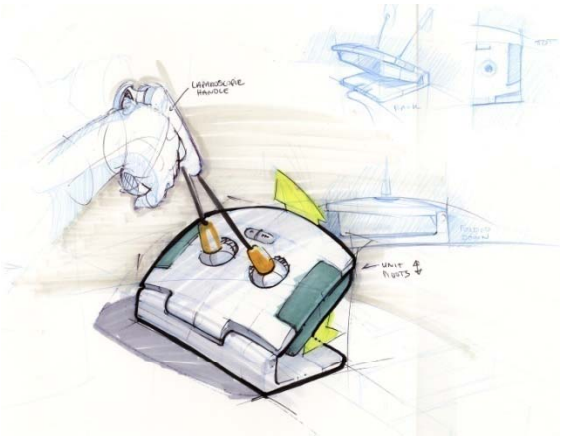
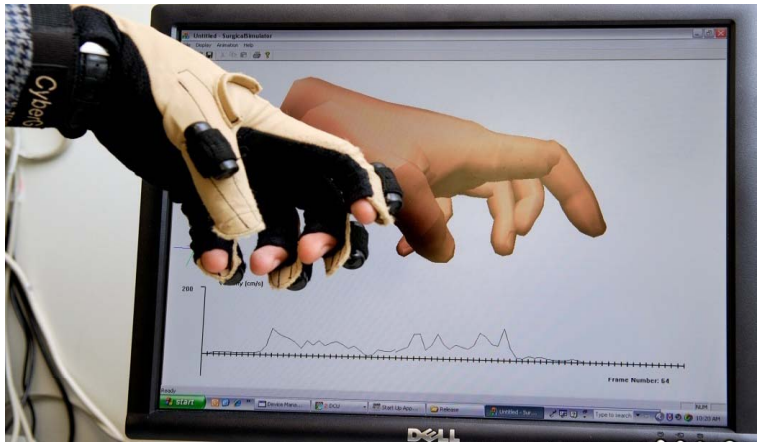
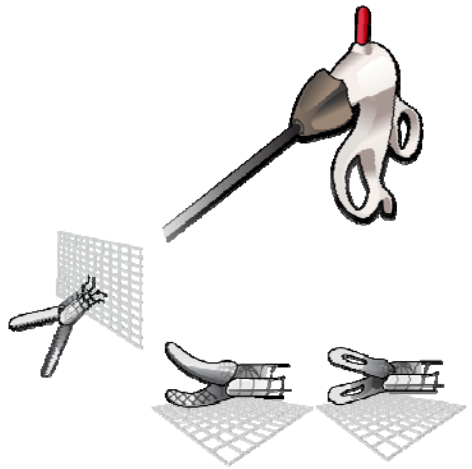
Teaching clinical skills and decision making in the digital age:

Development of closed loop simulators for training and evaluation of clinical professionals.







Kanav Kahol PhD,

Asst Professor, Dept of Biomedical Informatics, Arizona State University

Research Faculty, Simulation Education and Training Center, Banner Good Samaritan Medical Center

kanav@asu.edu

6028272546

Objectives

- To show how to measure and train both psychomotor and cognitive skills of surgeons.
- To enable understanding of solutions for feedback while maintaining the current levels of faculty involvement.
- To acquire an awareness of the potential for the use of simulation gaming platforms in training.
- To develop strategies for effective remediation.

Surgical Simulation Training

"Virtual reality–trained residents :

performed the procedure 30% faster, and

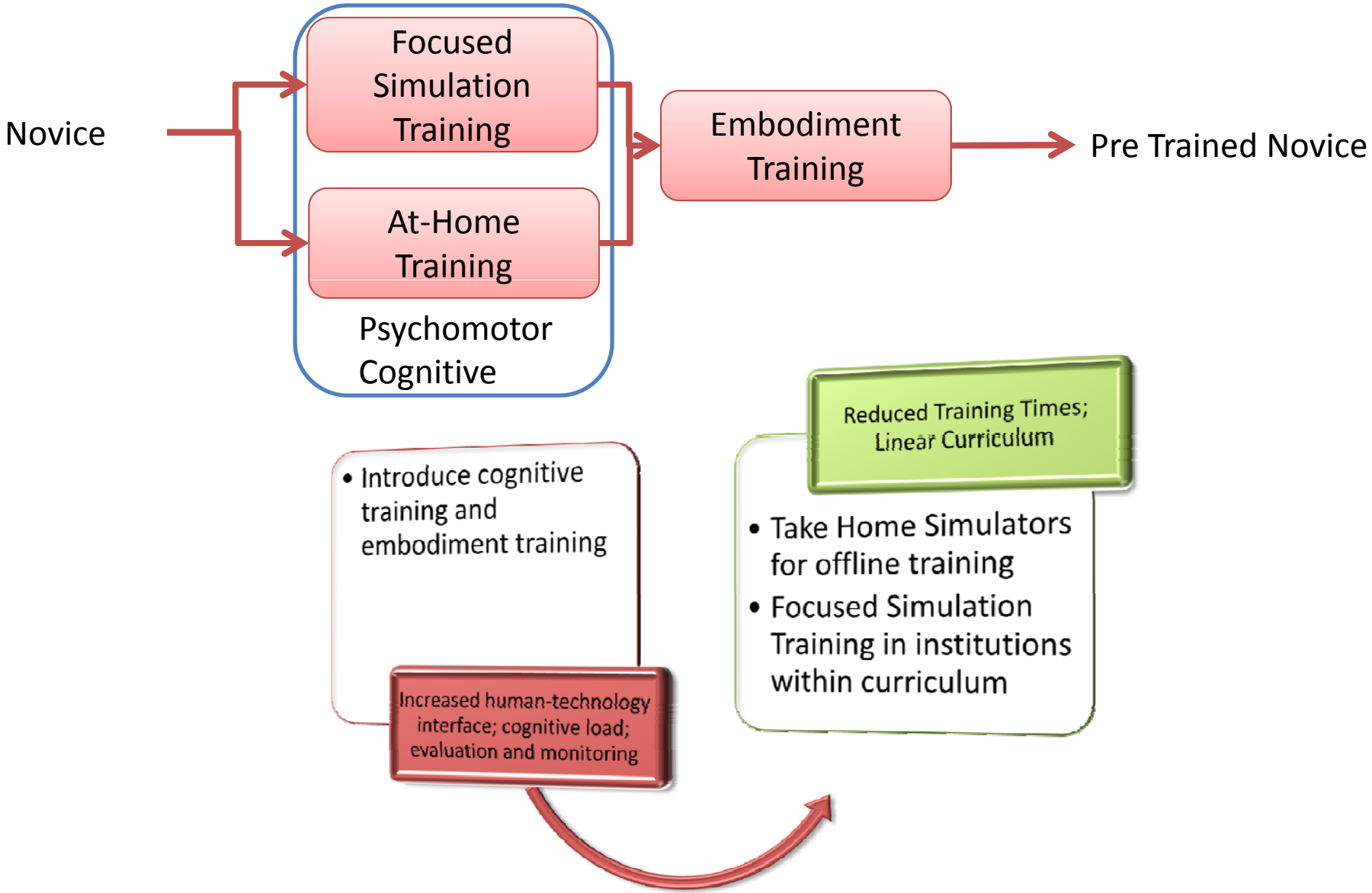
made six times fewer intraoperative errors

when dissecting the gallbladder from the liver

bed."

Virtual Reality training improves operating room performance; Results of a randomized, double blinded study. Seymour et al; *Ann Surg.,* 2002

New Directions

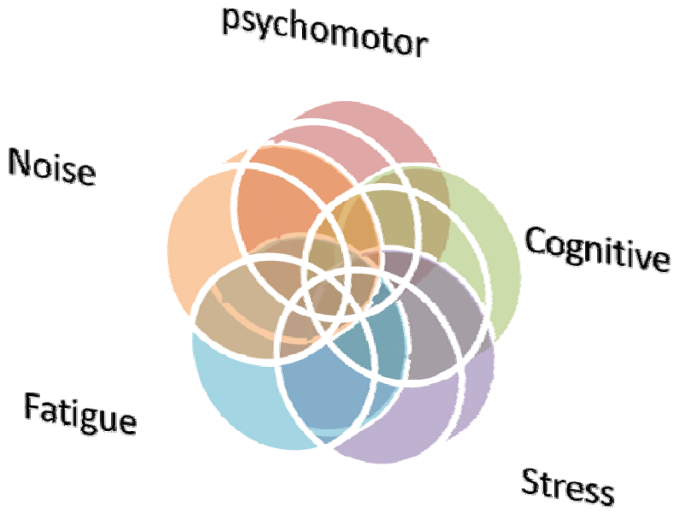


Initiatives

- Cognitive Simulators: Simulators that enhance critical thinking and hone cognitive skills.
- At-Home Simulator Systems: Simulator systems and monitoring architecture to support offline learning.
- Embodiment Simulators: Enabling clinical professionals to practice learnt skills in actual environments.
- Intelligent Tutoring Systems: Programs that adapt and offer real time feedback
- Use of Simulators Beyond Education: Measuring the effect of Fatigue
- Simulators Driven by real world: Simulators to measure and train team behaviors

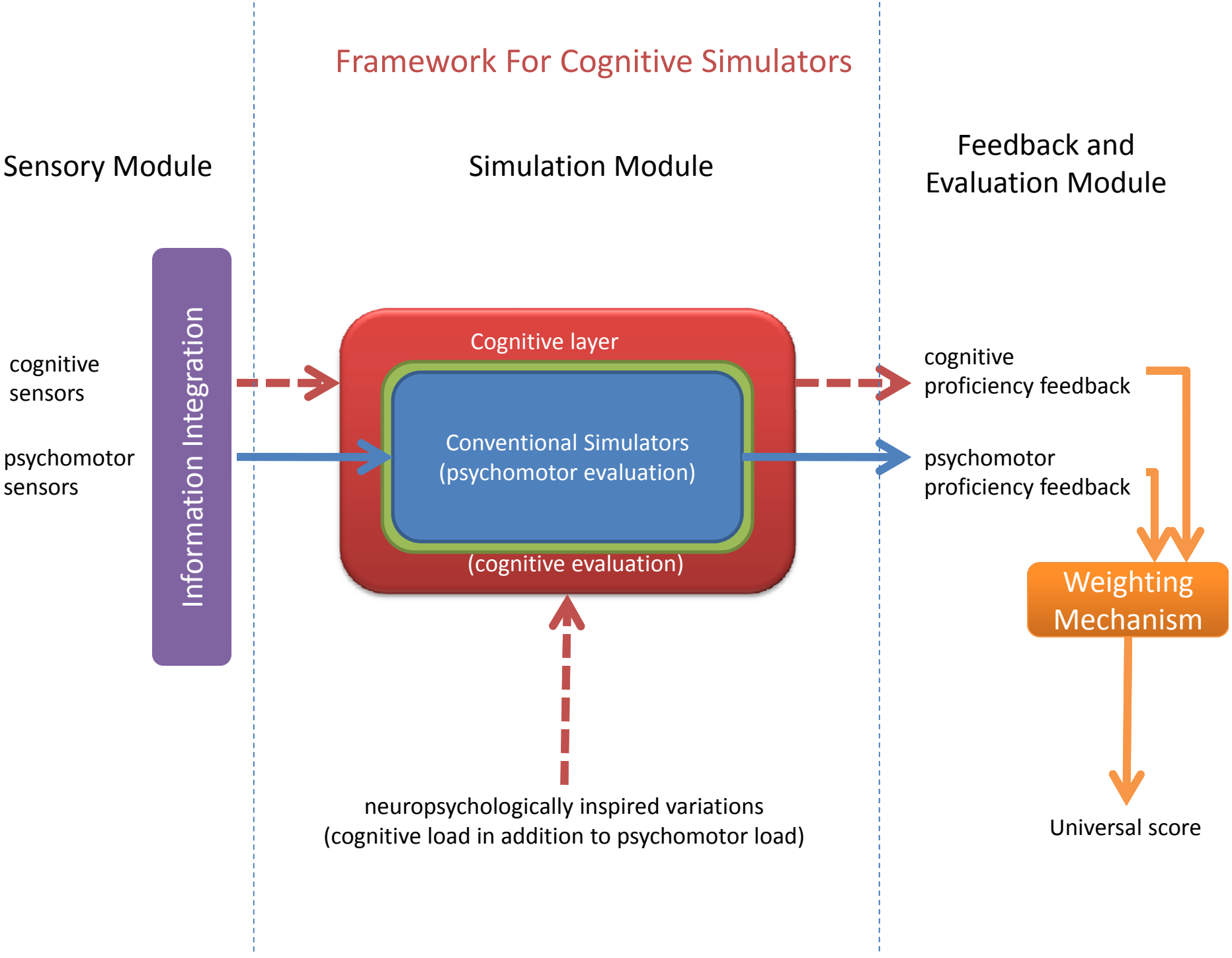
Cognitive Simulators

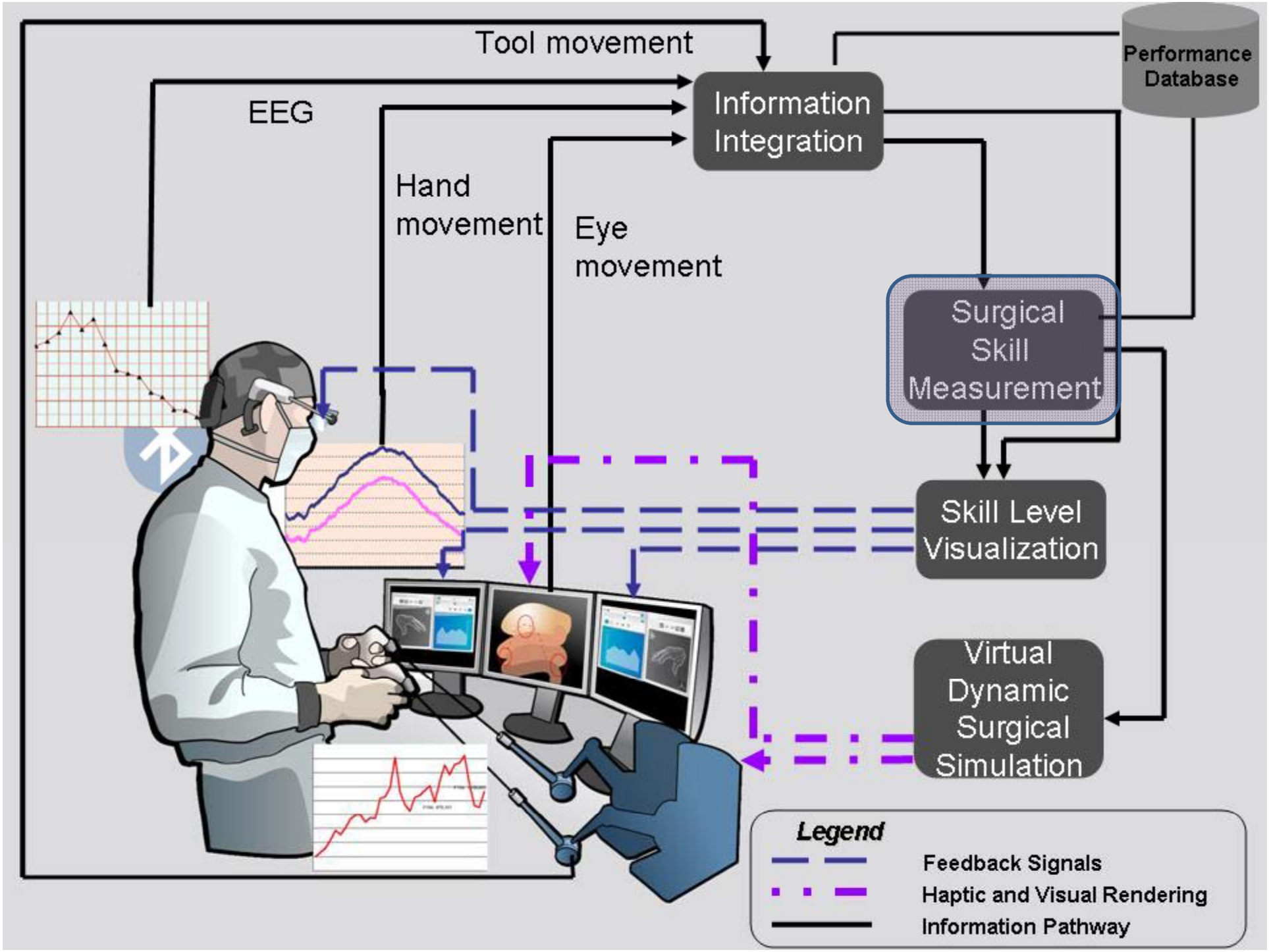
- A key aspect of surgery and for other skill based procedures lies in applying decision making skills while accomplishing psychomotor skills.
- When people perform two or more tasks simultaneously, the tasks are often executed slower and with more errors than when they are carried out as single tasks.



Multitasking Environments

- Significant research has been conducted to understand the relation between task interference, learning and experience. In general, task interference is severe during learning periods but reduces dramatically with practice. (Ruthruff 2006)
- Hence if simulators present multitasking environments with cognitive tasks as well as psychomotor tasks they will provide an adequate basis for training.

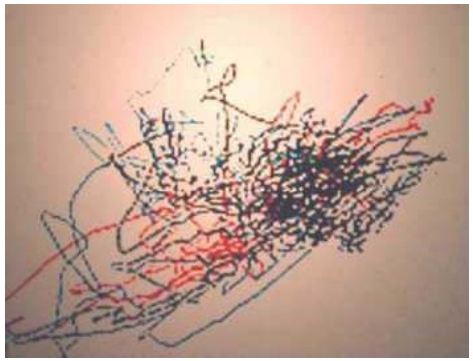

Framework For Cognitive Simulators
Sensory Module
Simulation Module
Feedback and Evaluation Module
cognitive sensors
psychomotor sensors
Information Integration
Cognitive layer
Conventional Simulators (psychomotor evaluation)
(cognitive evaluation)
cognitive proficiency feedback
psychomotor proficiency feedback
Weighting Mechanism
Universal score
neuropsychologically inspired variations
(cognitive load in addition to psychomotor load)


Tool movement
EEG
Hand movement
Eye movement
Information Integration
Performance Database
Surgical Skill Measurement
Skill Level Visualization
Virtual Dynamic Surgical Simulation
Legend
Feedback Signals
Haptic and Visual Rendering
Information Pathway

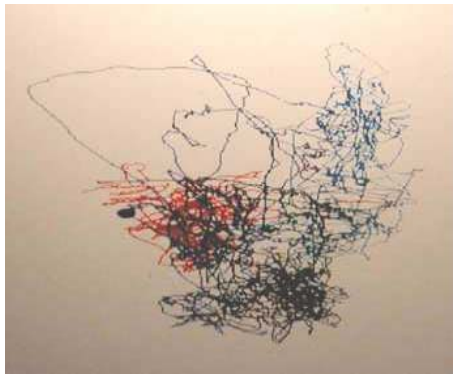
Objective Proficiency Measures

- Employ neurological and kinesiological features to analyze surgical proficiency
- Constructive task de-composition based feedback
  - Breaks a complex motion into simpler units that are easy to analyze and more importantly easy to comprehend and change by the user.

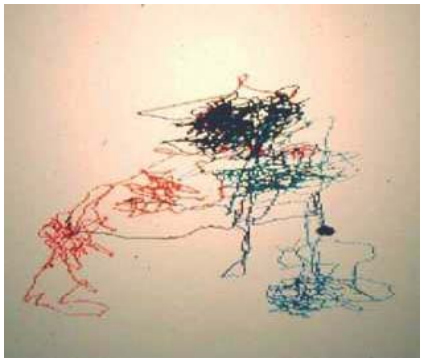
Tool movements



Novice



Intermediate

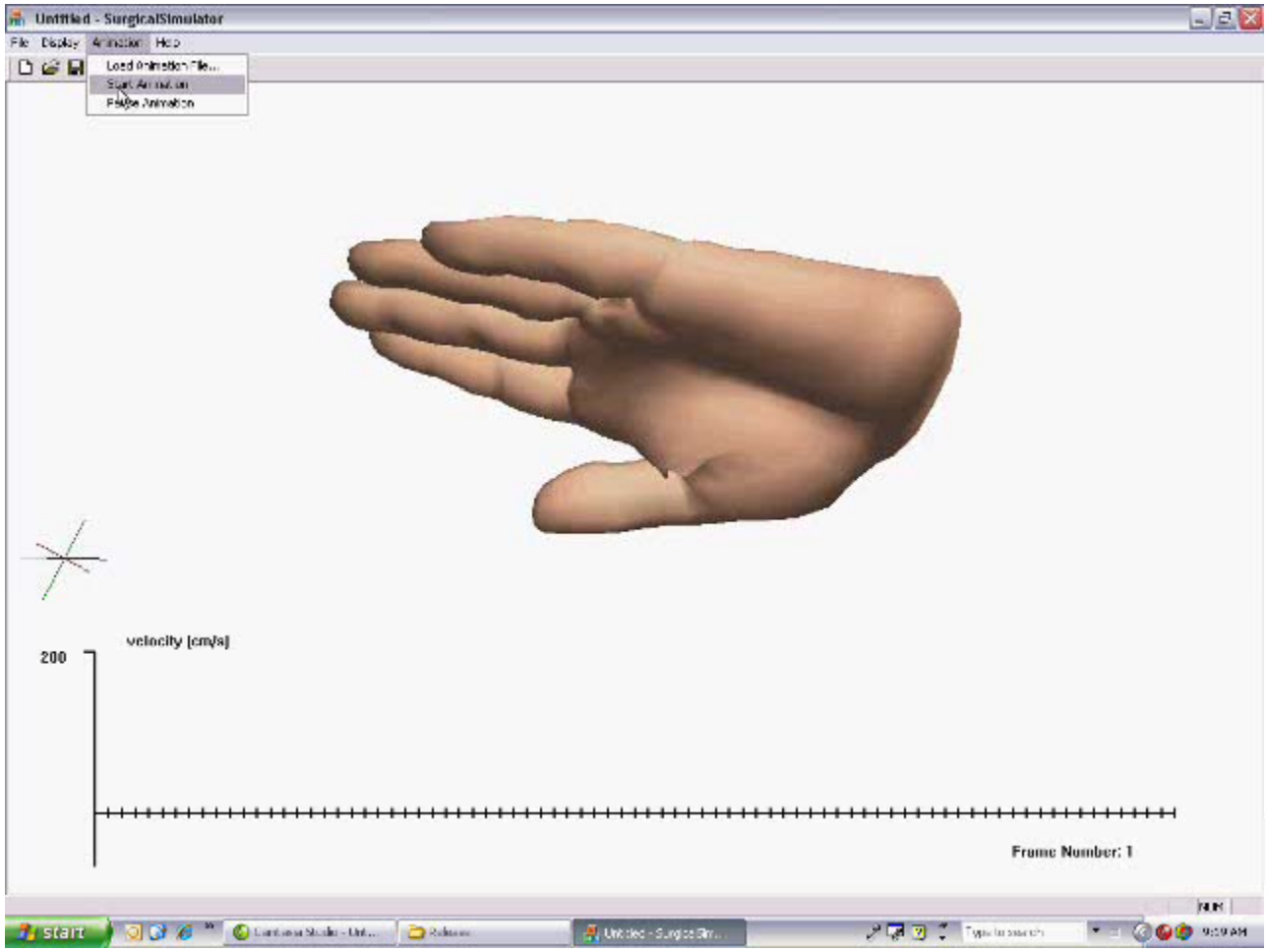


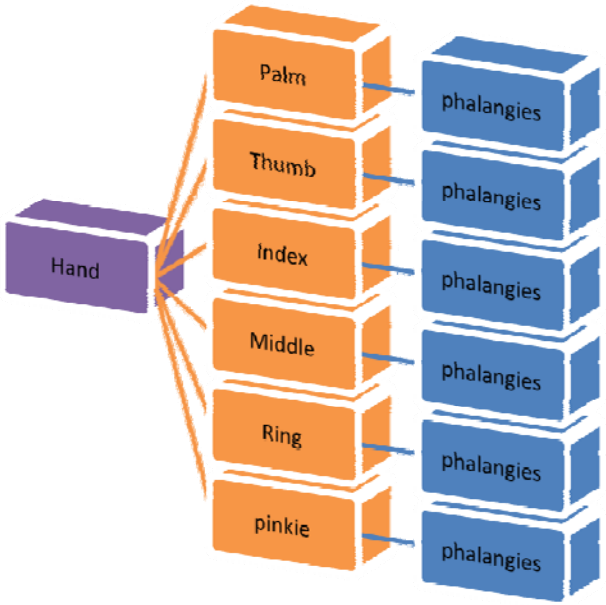
Expert

Rosen 2002

0.0042 moved 0.023 1.00 0.34
0.0043 moved 0.0023 1.04 0.37

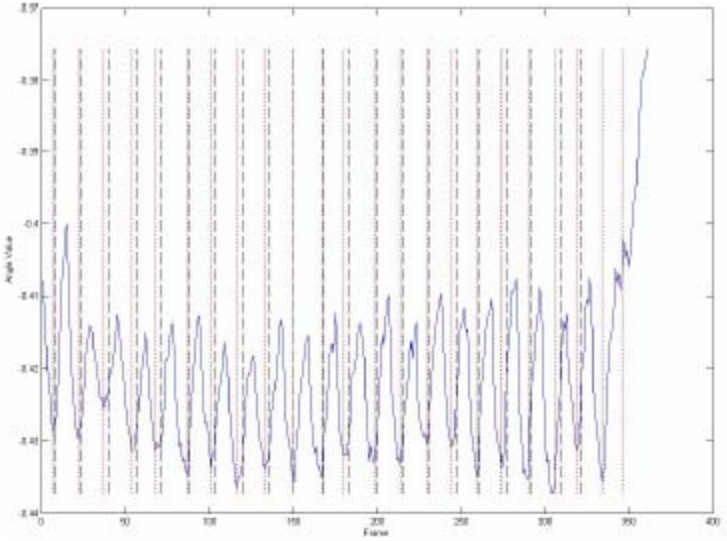
Hand Motion





Skill Analysis Systems

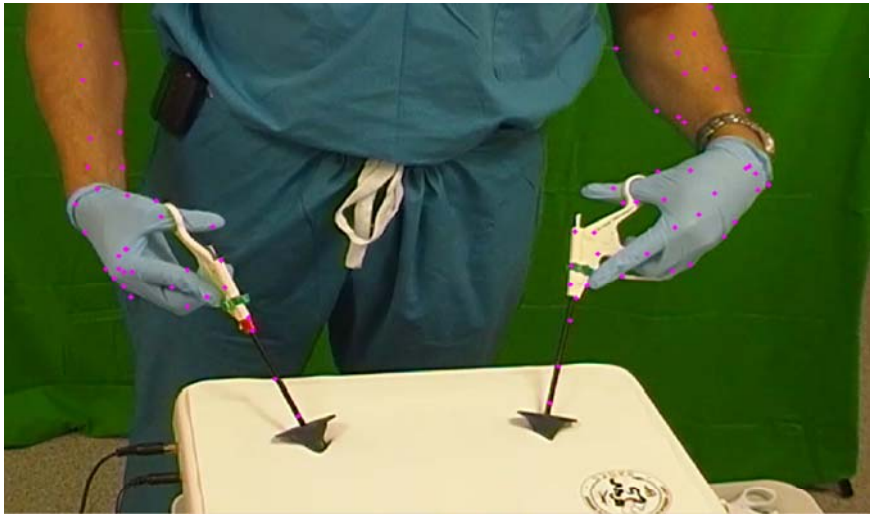
- Gesture Segmentation (Naïve Bayesian Classifiers)
- Coupled Hidden Markov Models with hierarchical hand representations
- Validated across
  - Level of experience in surgical activities.
  - Level of Fatigue.



Gesture	Expertise Recognition
In Movement	95%
Out Movement	95%
Left Movement	92%
Right Movement	95%
Up Movement	95%
Down Movement	95%
Rotation Clockwise	95%
Rotation Anticlockwise	95%
Grasp	95%

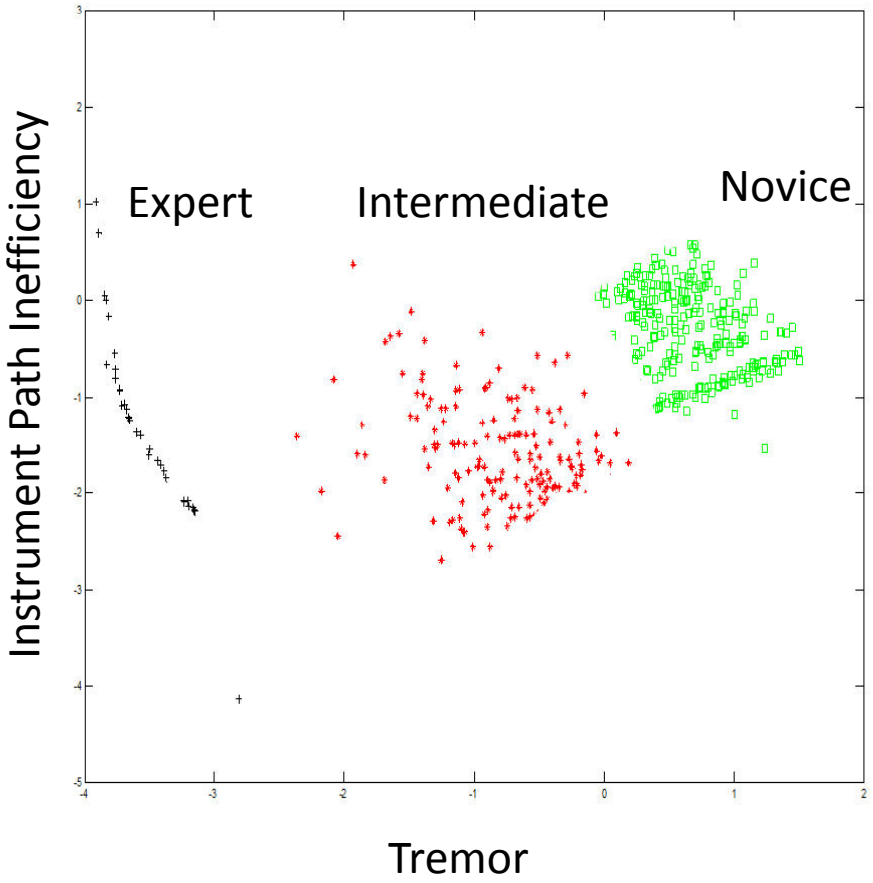
Computer Vision for Surgical Movement Analysis

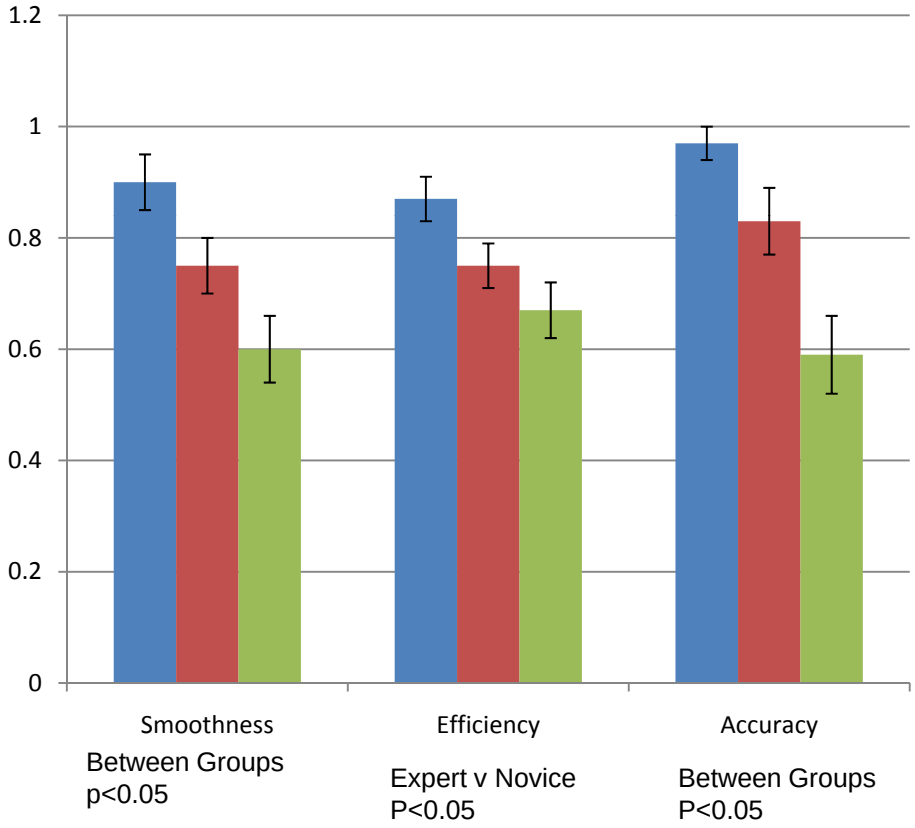
- NSF Sponsored grant to enable webcam based analysis of surgical movements.
- American Board of Surgery.

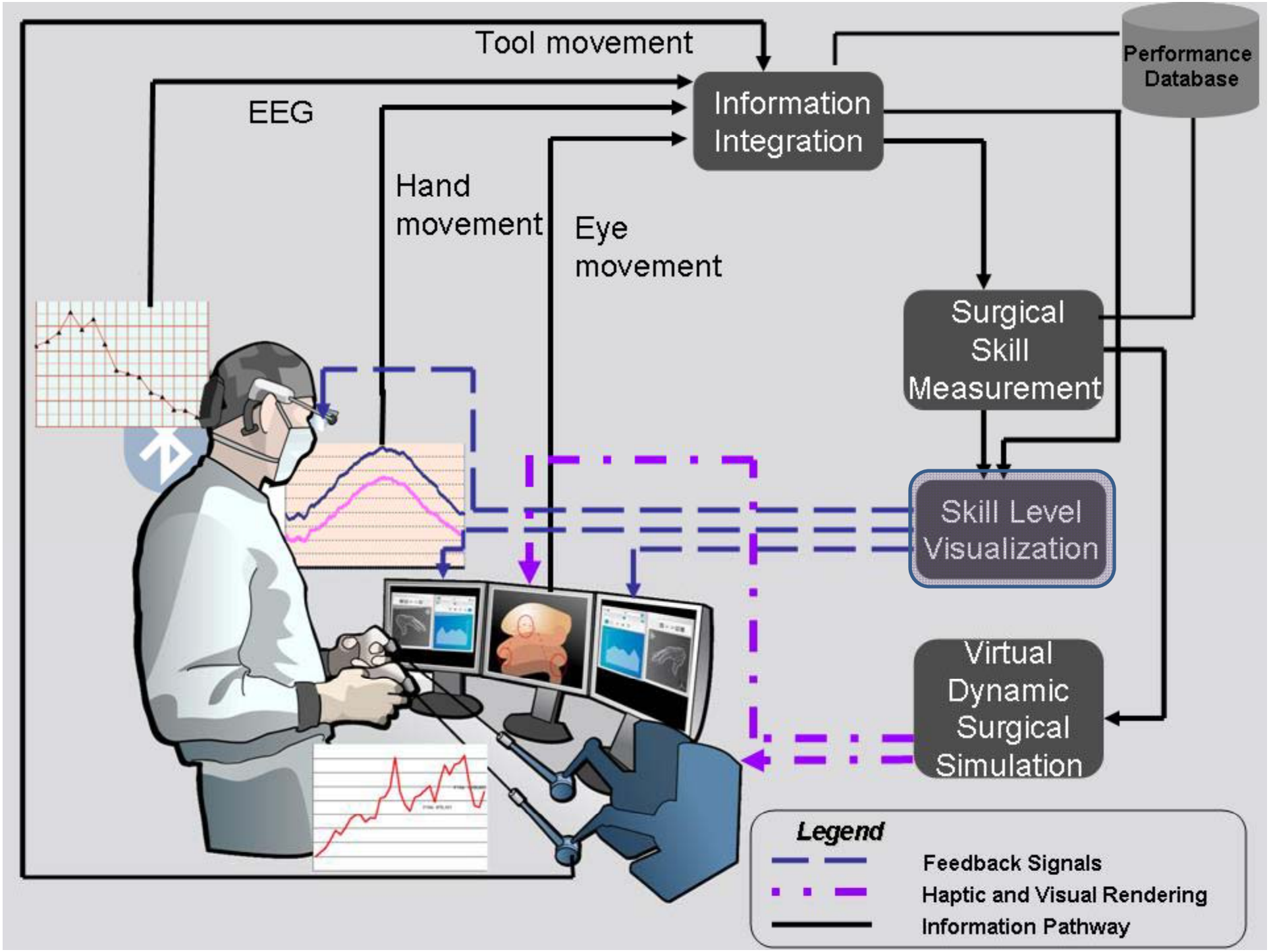


National Science Foundation
WHERE DISCOVERIES BEGIN

Initial Results



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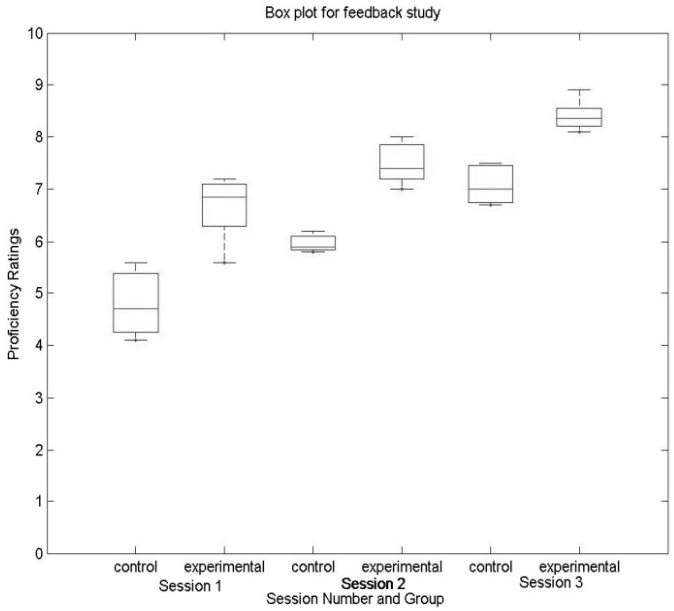
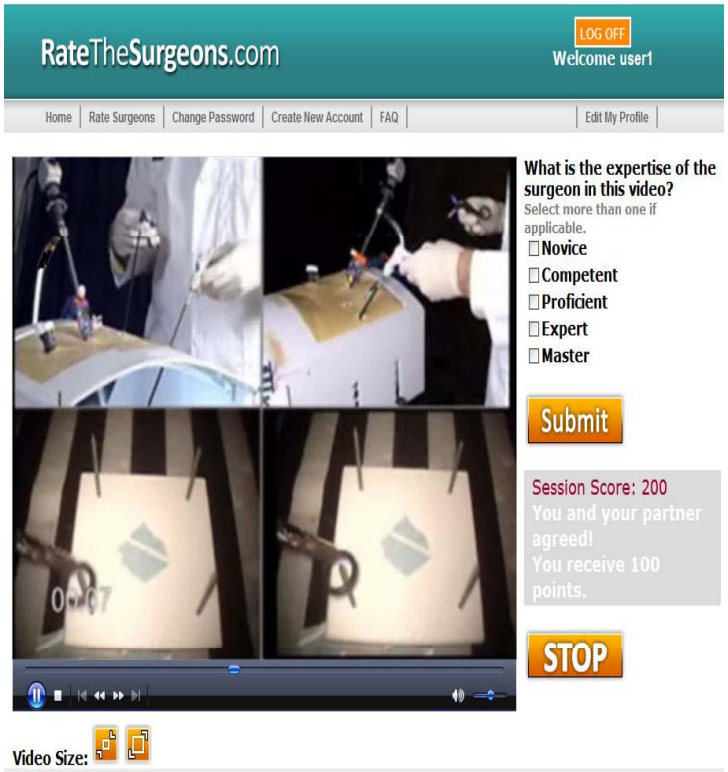
Feedback systems



Hand Movement Feedback System consistently improves performance

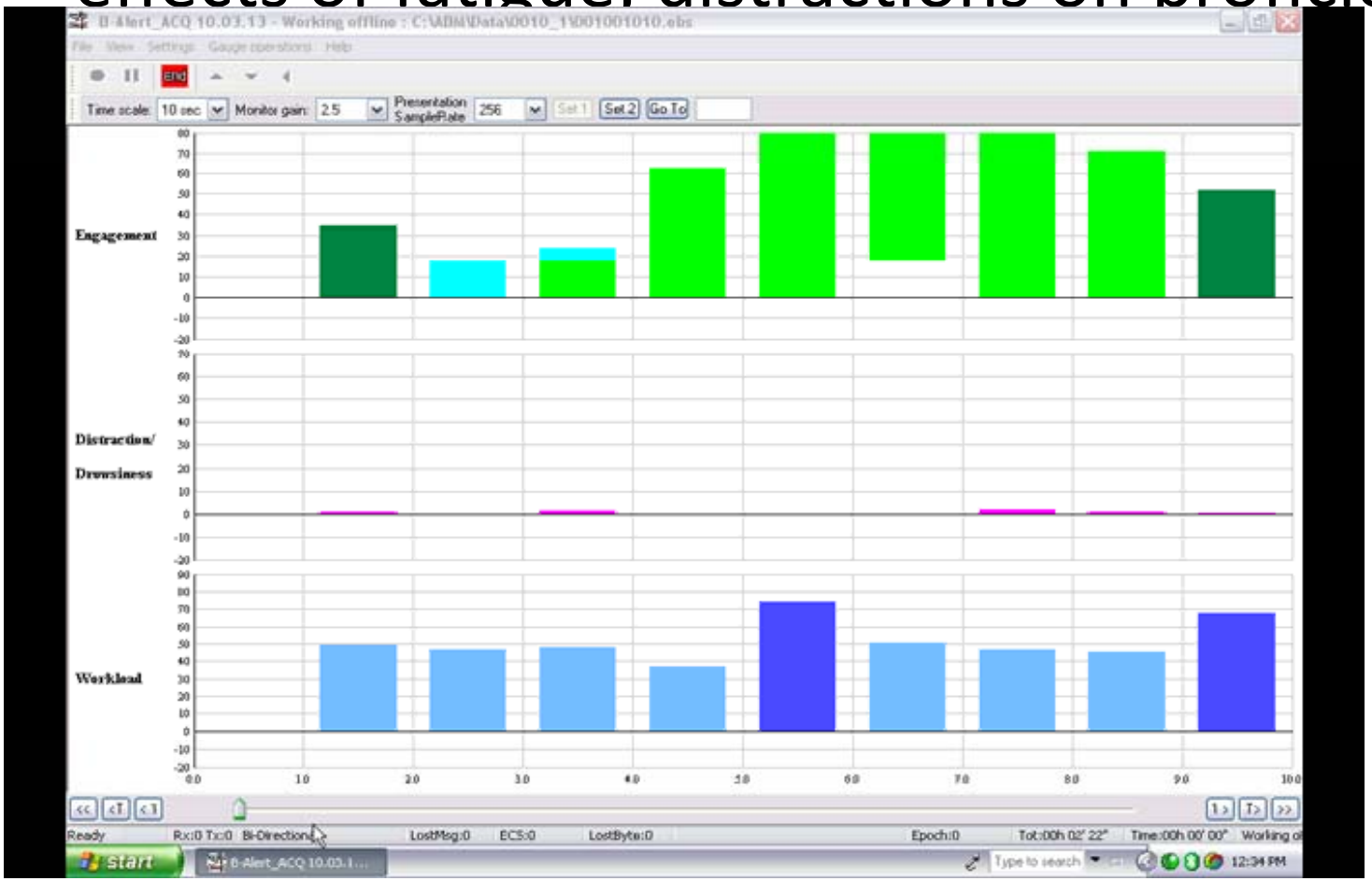
Website

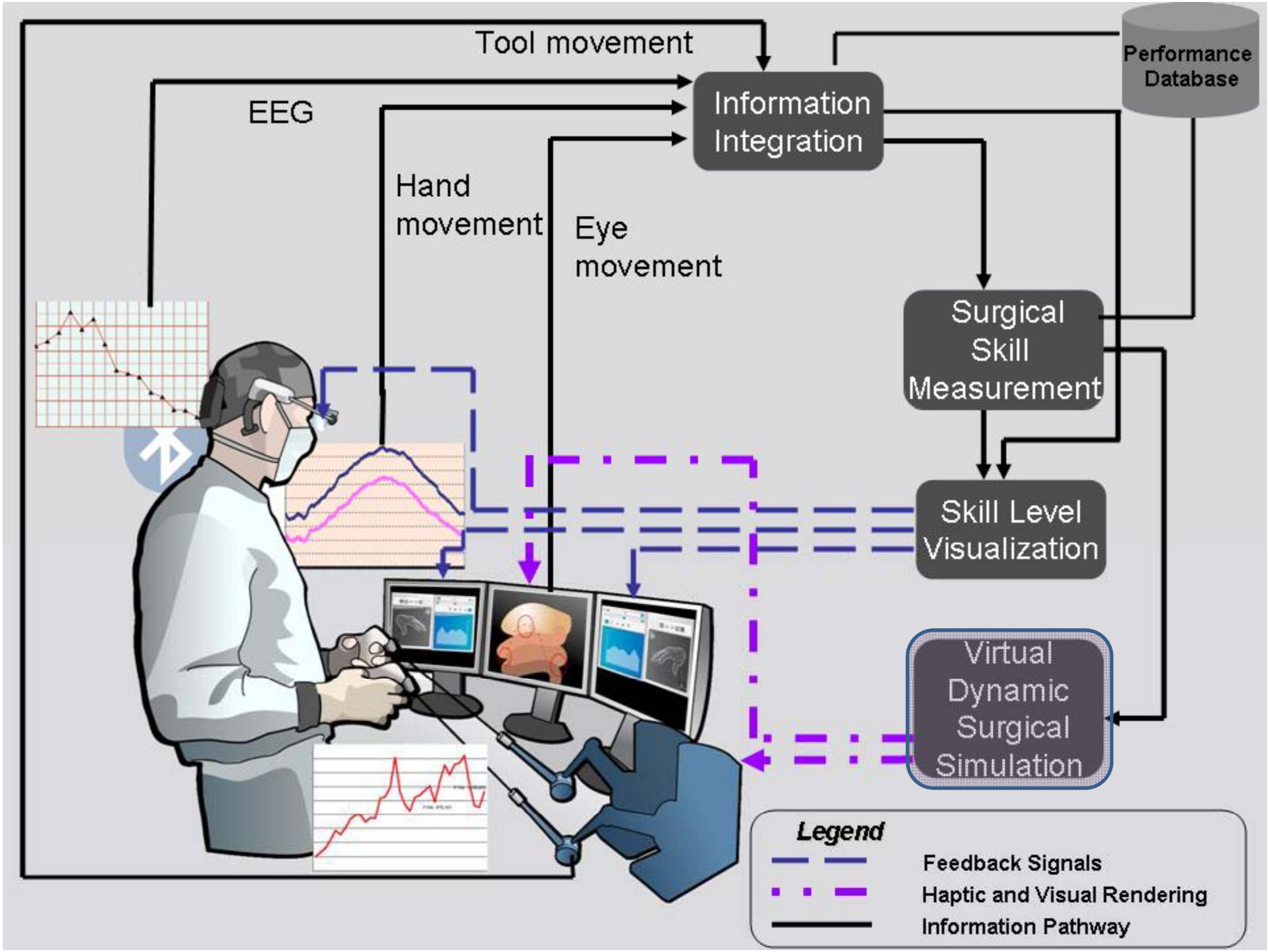
- We developed www.ratethesurgeons.com to upload videos and analysis automatically
- This enables experts to view the videos from their office and provide input.
- Novice raters can learn by viewing experts ratings on some videos along with detailed instructions to help them become proficient raters.



EEG Based Proficiency Measures

- EEG technology helps measure transient effects of fatigue, distractions on proficiency.

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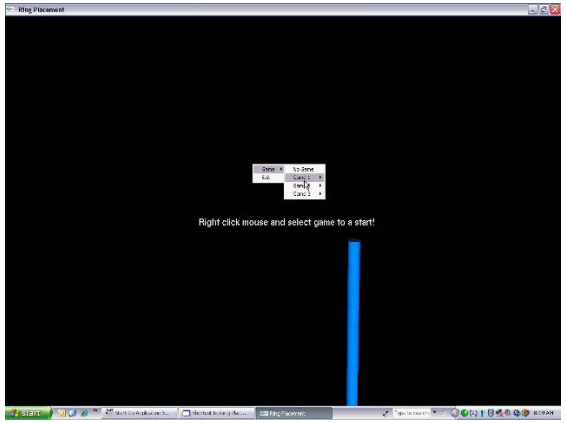
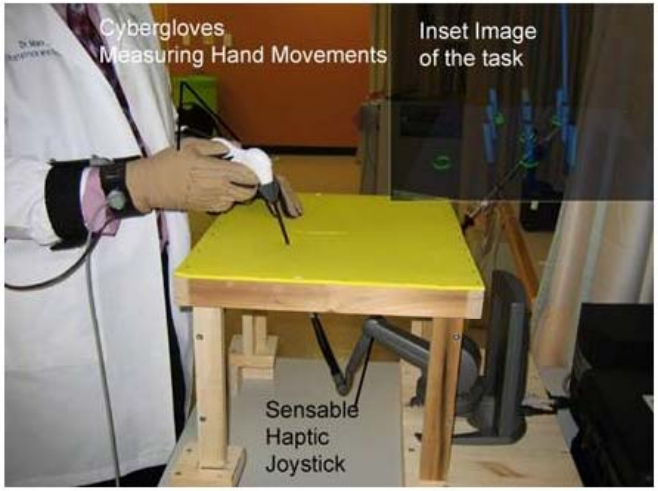
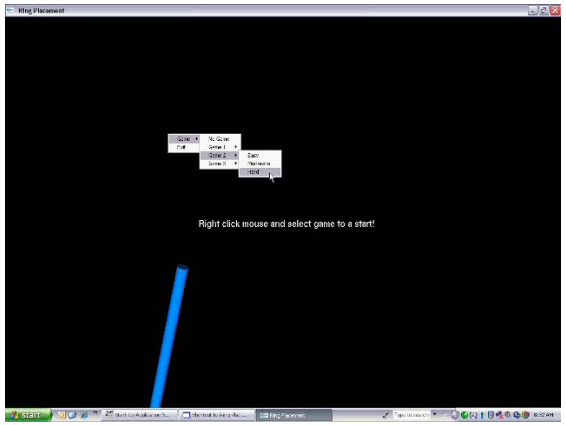
Dynamic Virtual Reality Systems for Cognitive Training

- Train the residents for attention, working memory, memory, intermodal transfer
- Modify existing simulations to include a cognitive layer.
- Treatment of surgery as a combination of psychomotor and cognitive skill.



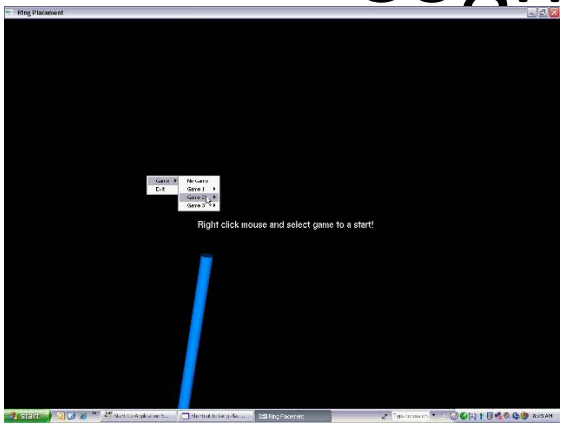
Original Task (Laparoscopic Training)



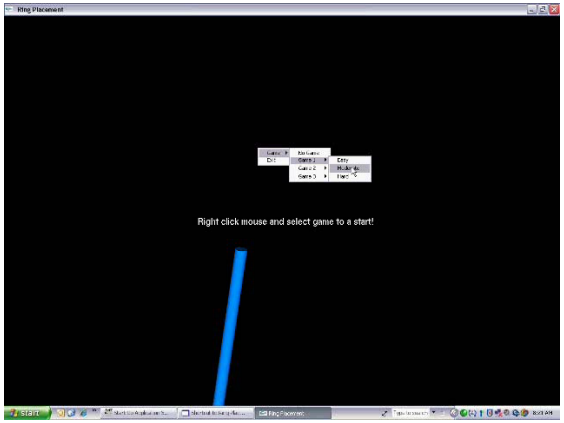


Modified to target working memory

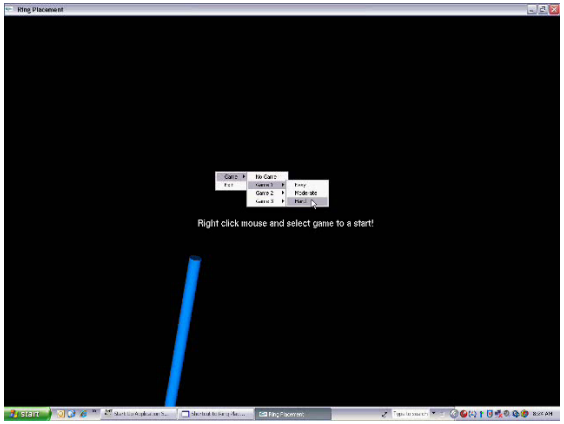
Example: Effect of Fatigue on Cognitive Skills



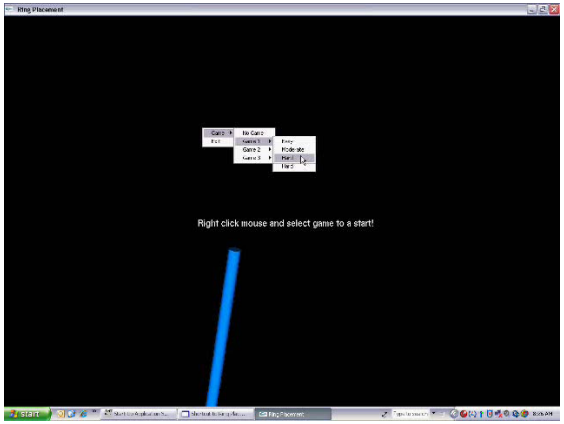
Attentional Task
Pre-Call Second Year



Attentional Task
Post-Call Second Year

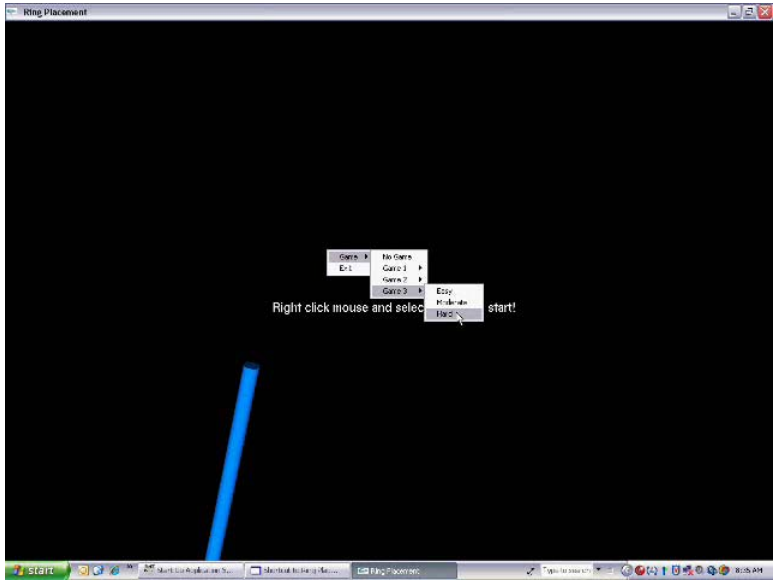


Visio-Haptic Transfer Task
Pre-Call Second Year

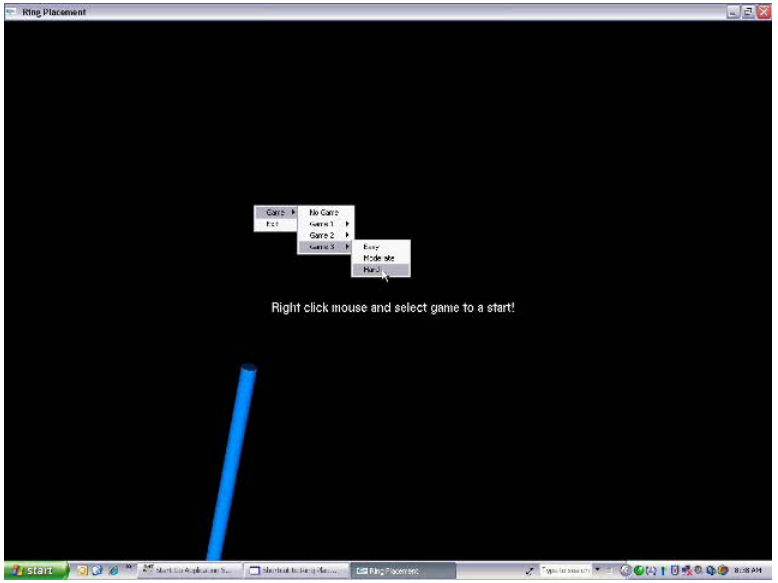


Visio-Haptic Transfer Task
Post-Call Second Year

Example: Effect of Fatigue on Cognitive Skills



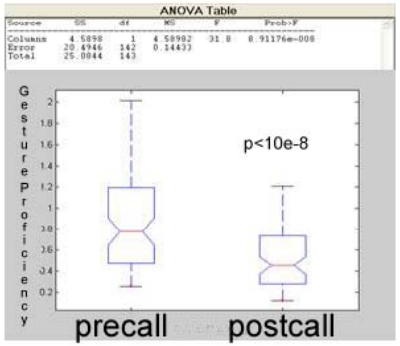
Orientation Task
Pre-Call First Year



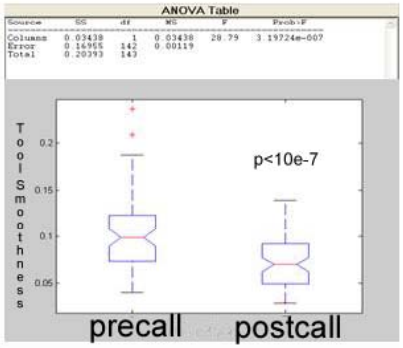
Orientation Task
Post-Call First Year

The programs adapts to a user's difficult spots.

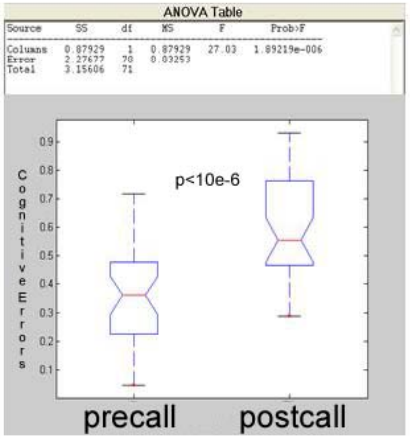
Overall Effect of Fatigue



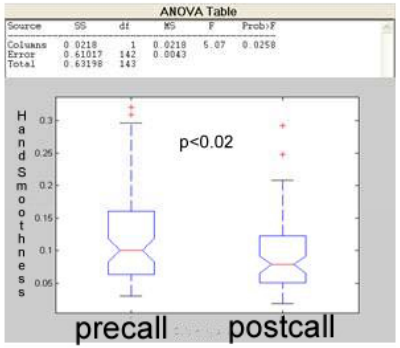
(a) Gesture Proficiency



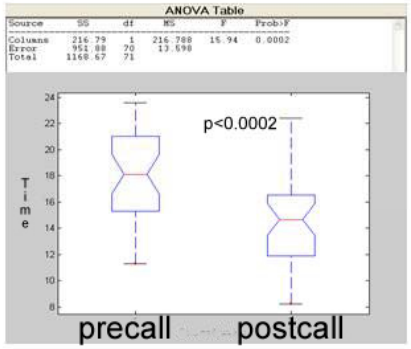
(b) Tool Movement Smoothness



(e) Cognitive Errors

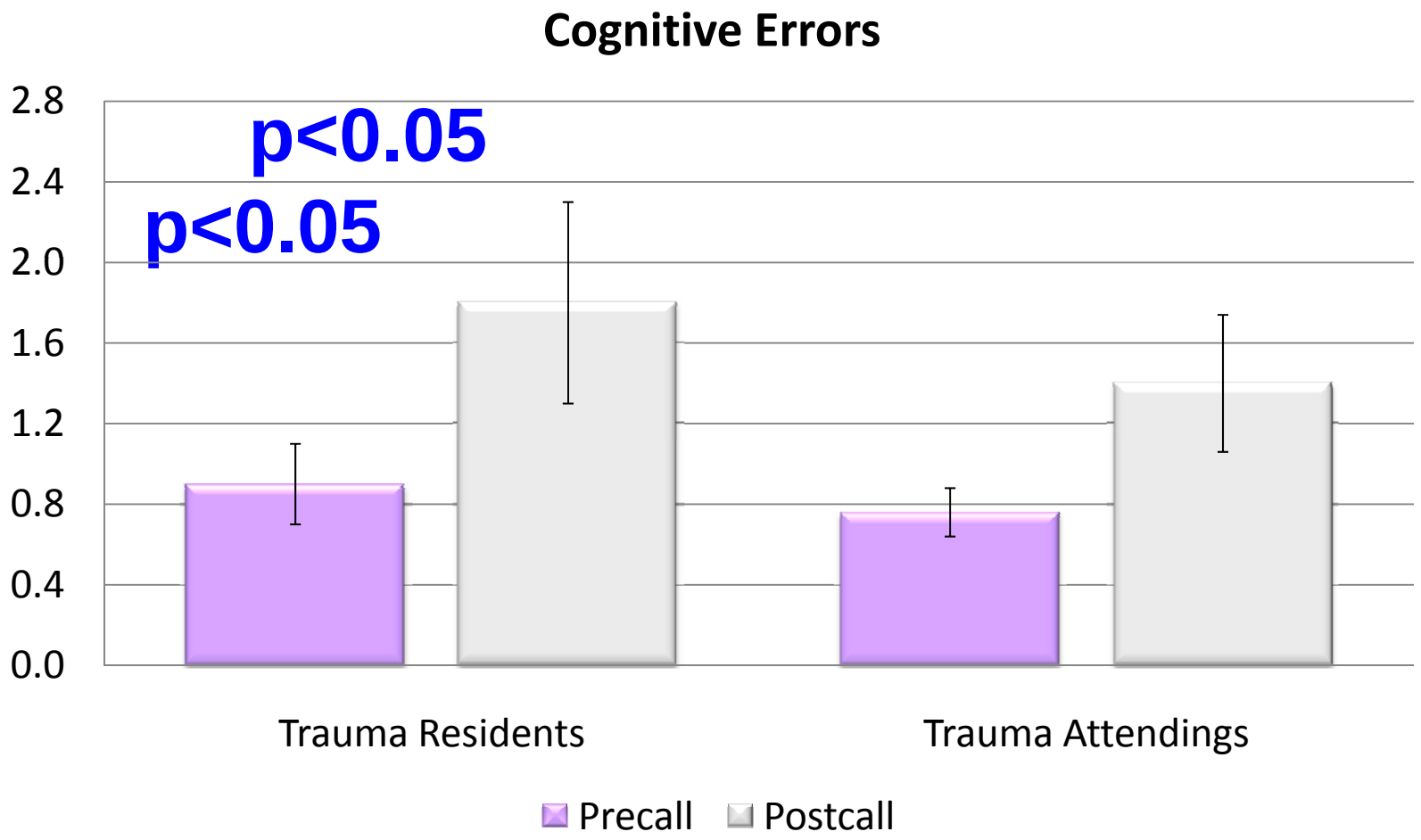


(c) Hand Movement Smoothness

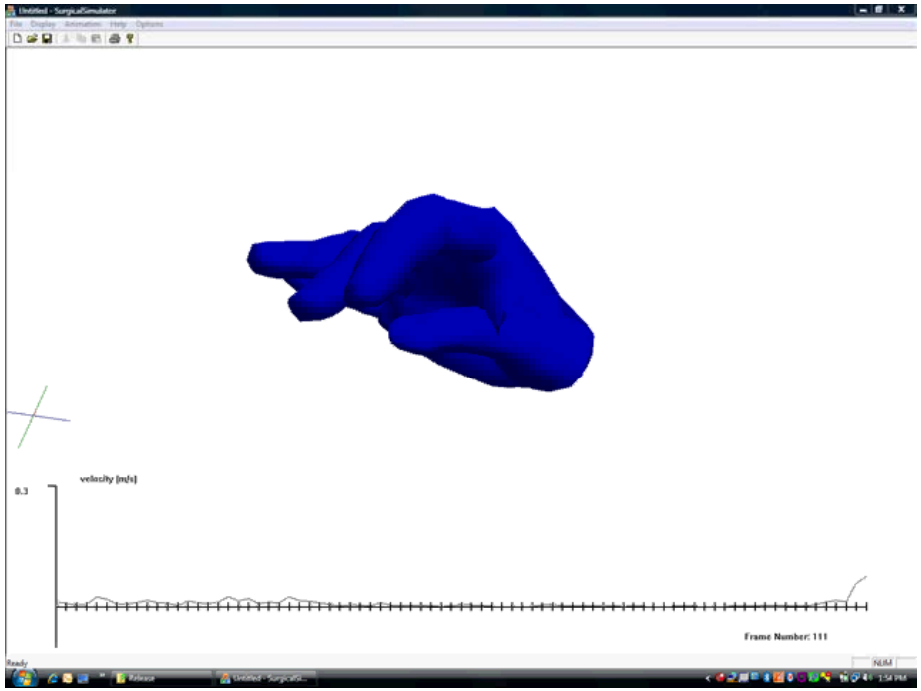


(d) Time Elapsed

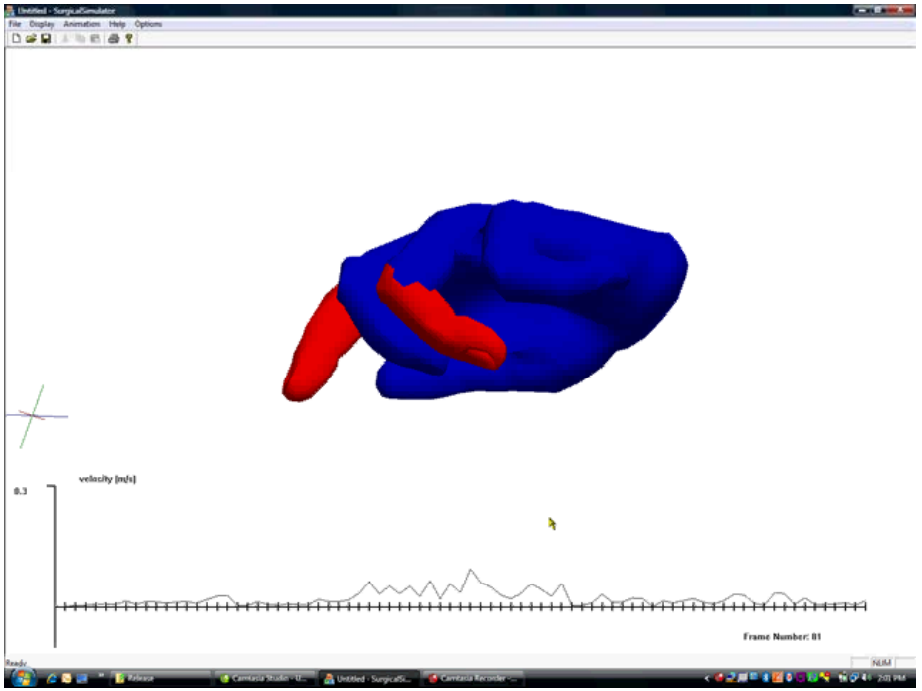
Attendings Versus Residents



Motorical Chunking: A measure of fatigue and expertise

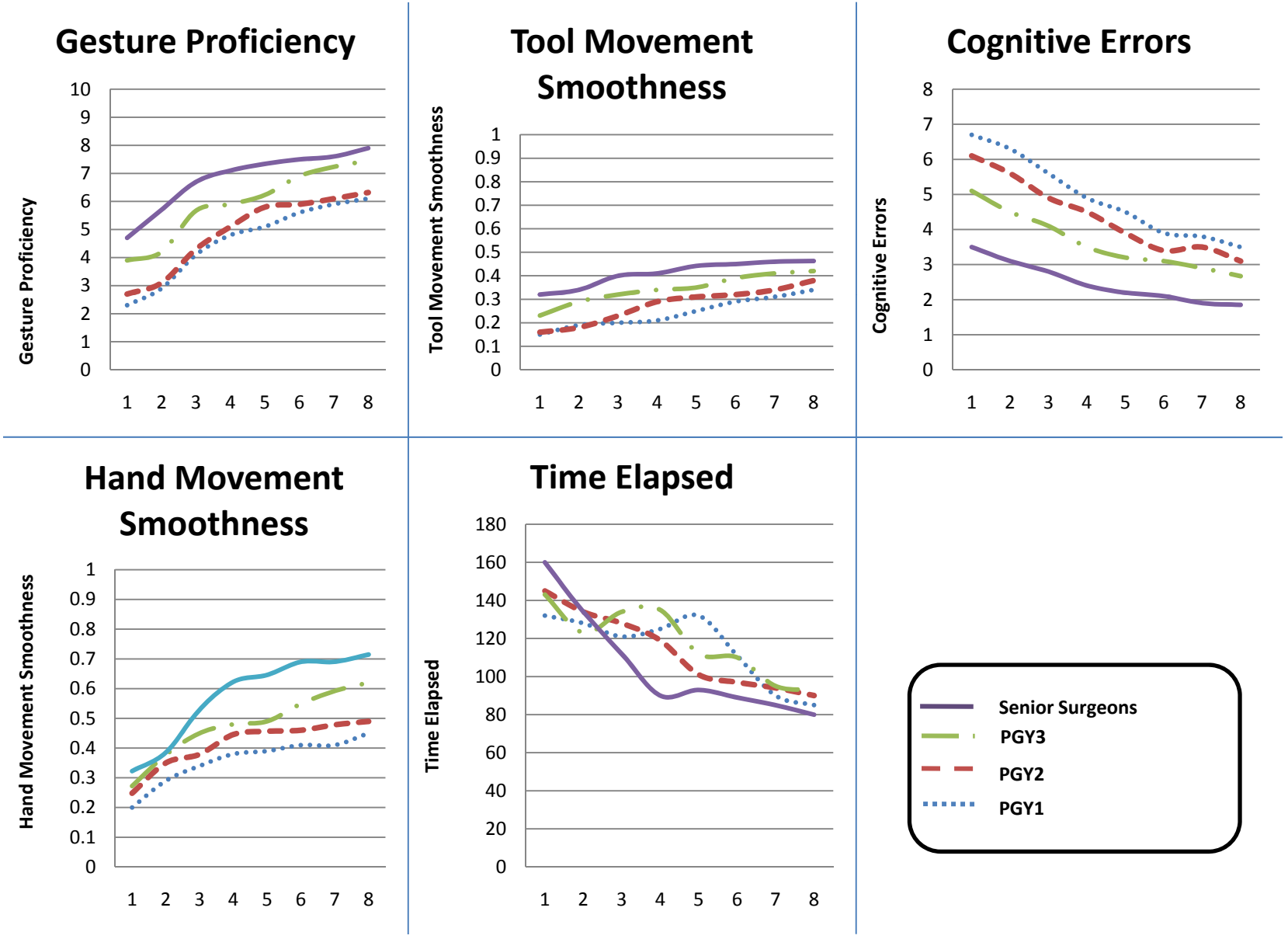


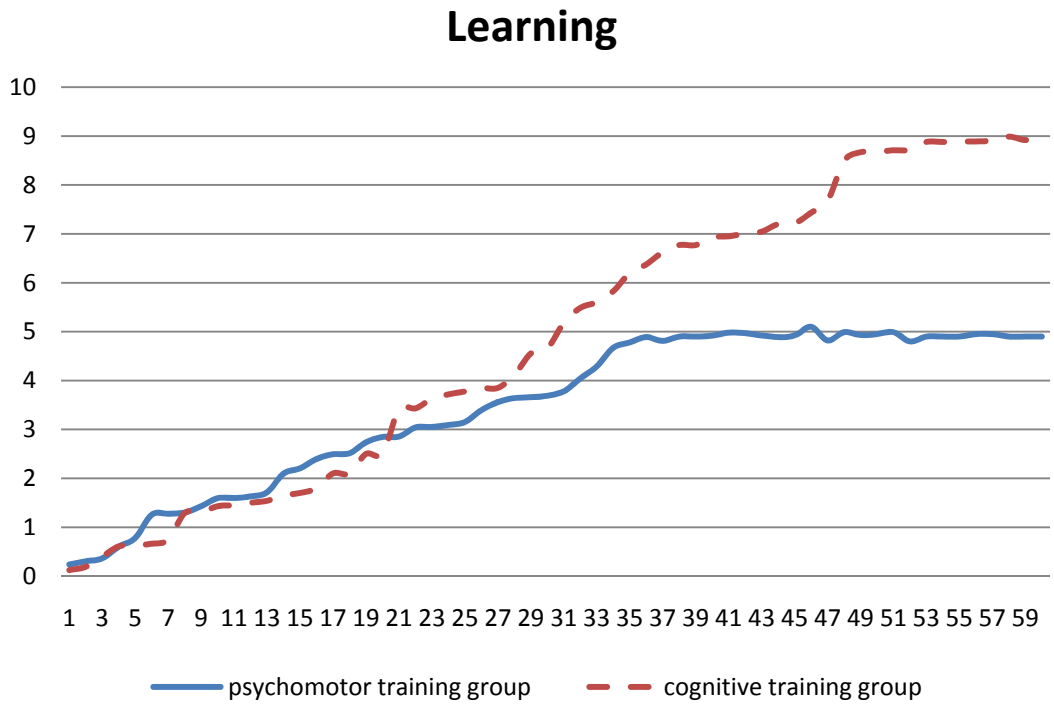
Before call Trauma Attending

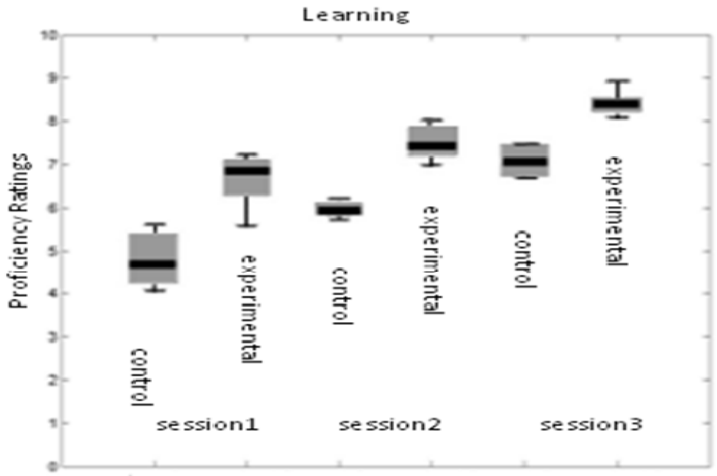


After call Trauma Attending

Learning


Gesture Proficiency
Gesture Proficiency
10
9
8
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8
Tool Movement Smoothness
Tool Movement Smoothness
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8
Cognitive Errors
Cognitive Errors
8
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8
Hand Movement Smoothness
Hand Movement Smoothness
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8
Time Elapsed
Time Elapsed
180
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8
Senior Surgeons
PGY3
PGY2
PGY1

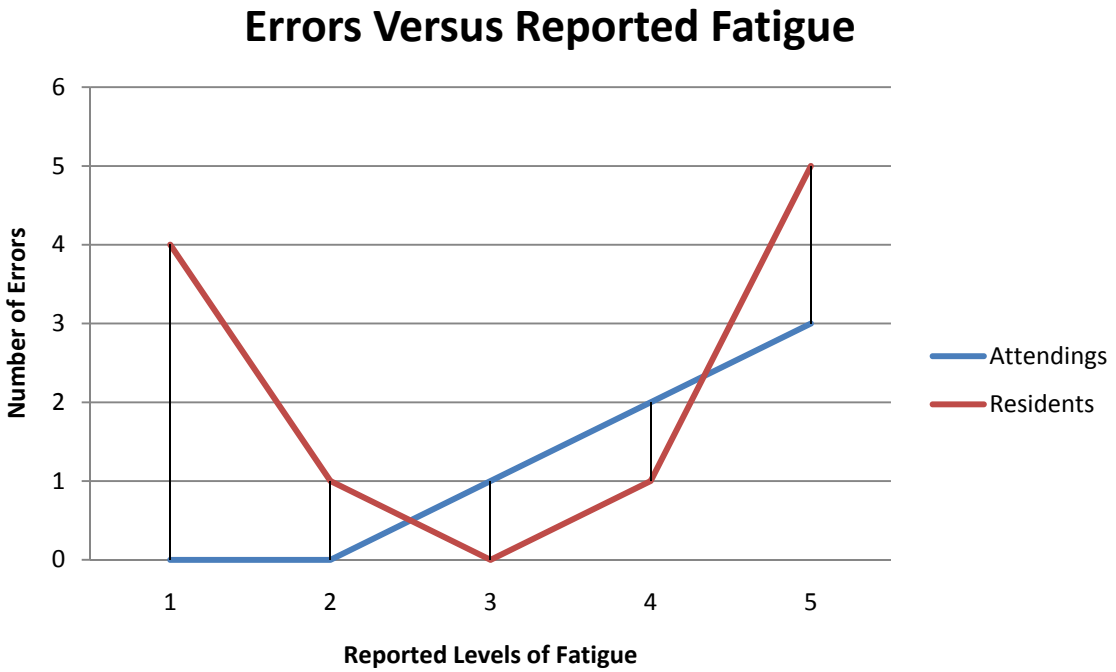




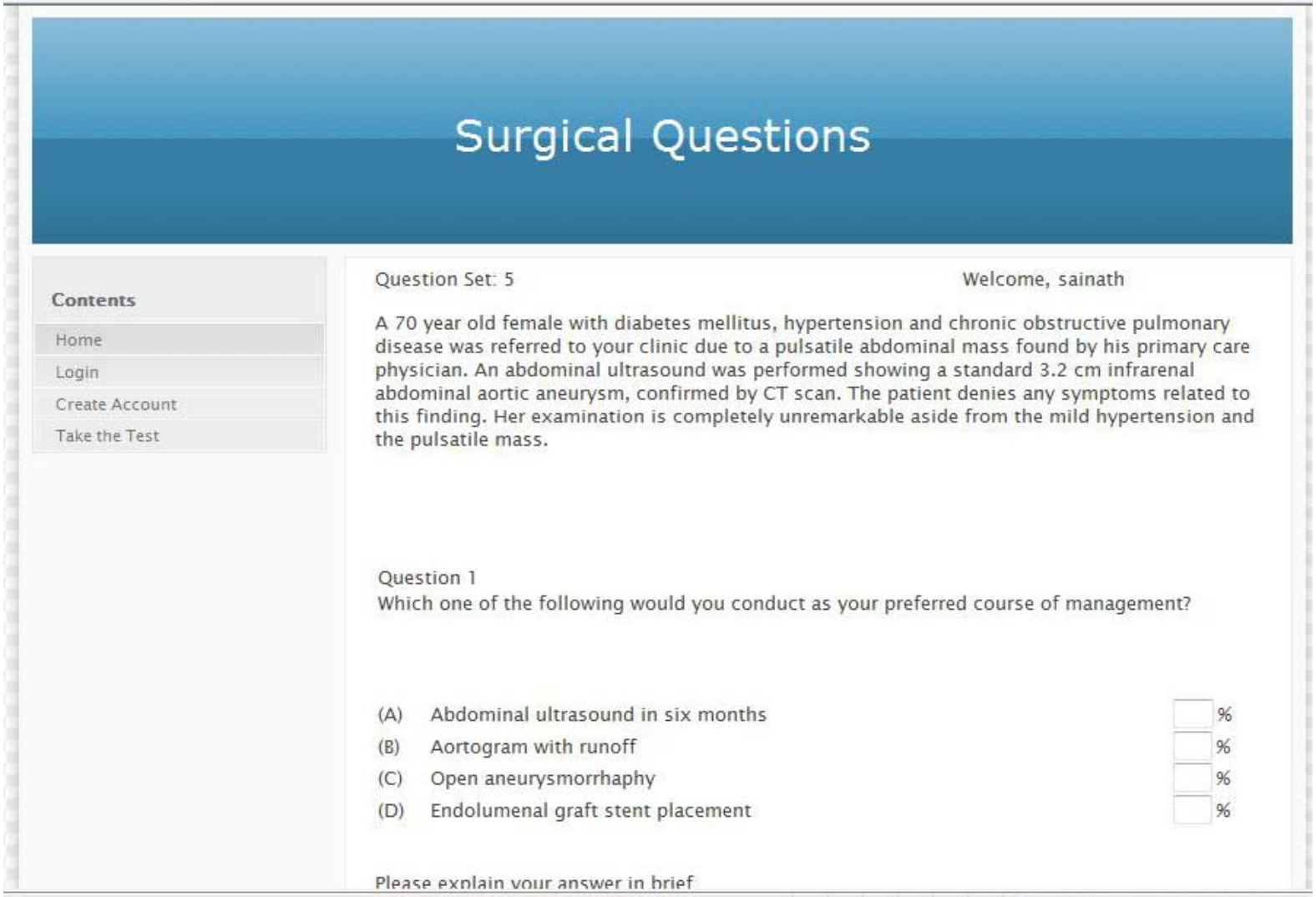
Transfer of skills to a simulated Electrodiathermy task

New work in Fatigue

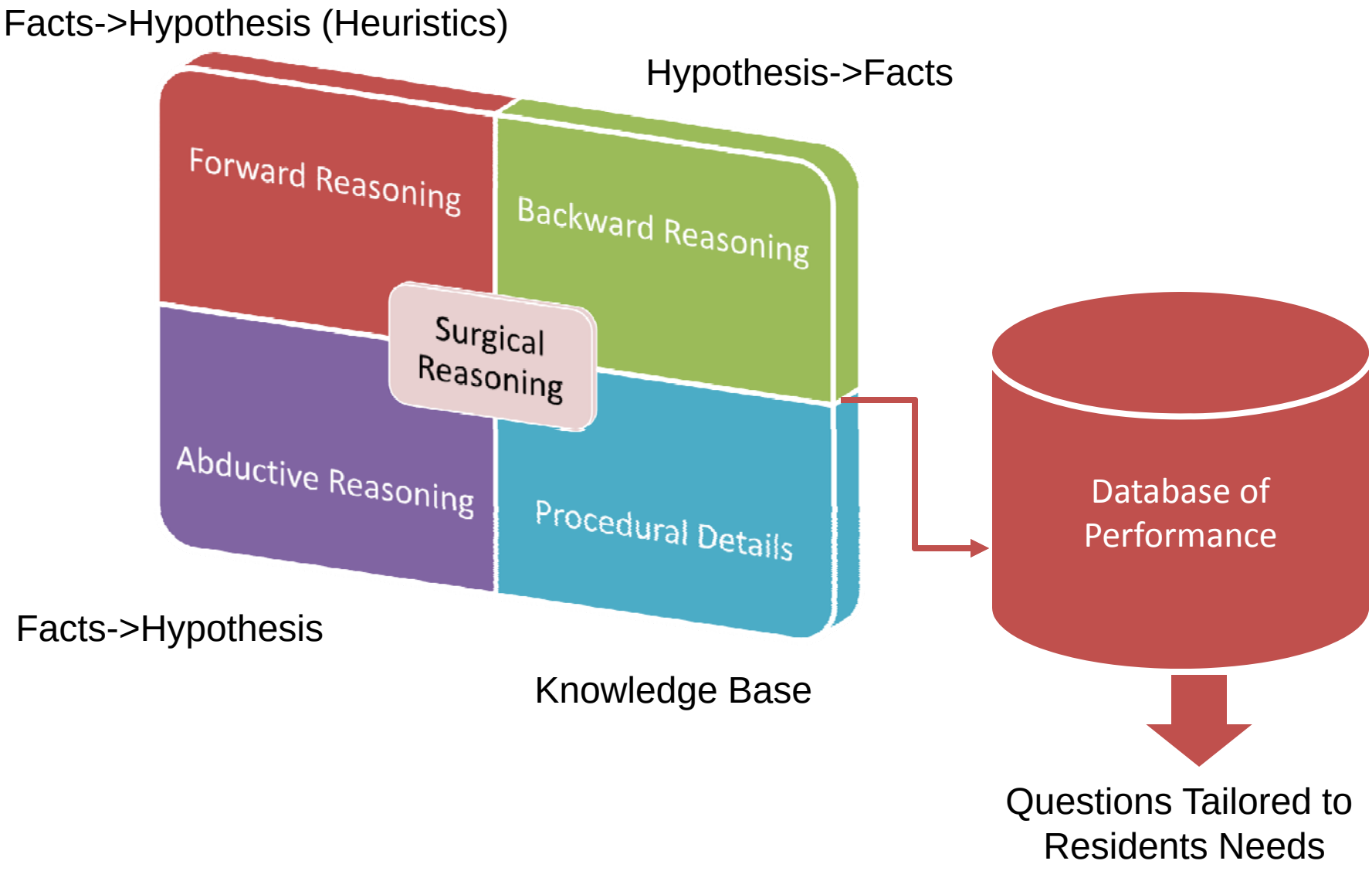
- Analysis of type of reasoning and fatigue
- Analysis of workload and fatigue relation
- Difference in specializations.



Example: Joint Project with American College of Surgeons Adverse Management Course

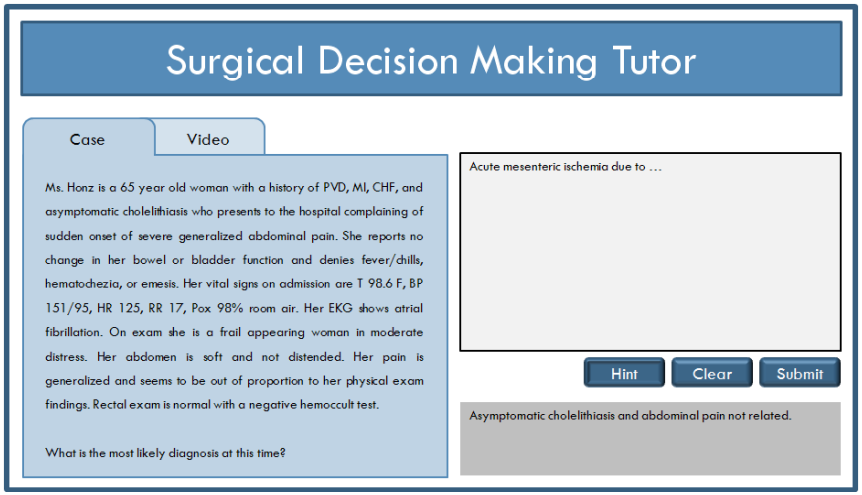


Intelligent Tutoring Systems

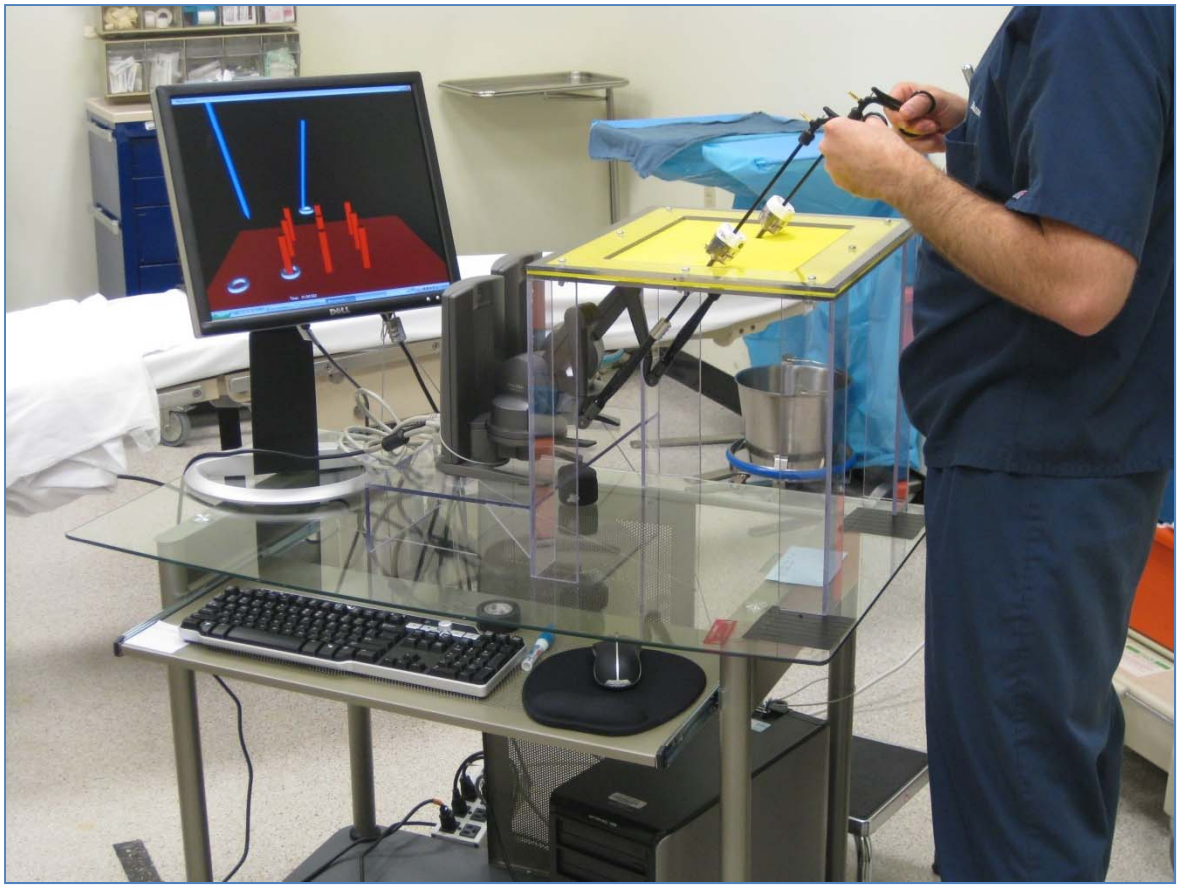


Novel Twist: Learning by Teaching

- The Best way to learn is to teach
- In collaboration with national Board of medical Examiners we are developing a not-so-intelligent virtual resident.
- Your intelligent residents teach this virtual resident on how to grasp surgical information and pass NBME exams.



Warm Up



Portable Simulator rolled into the OR.

Warmup Results

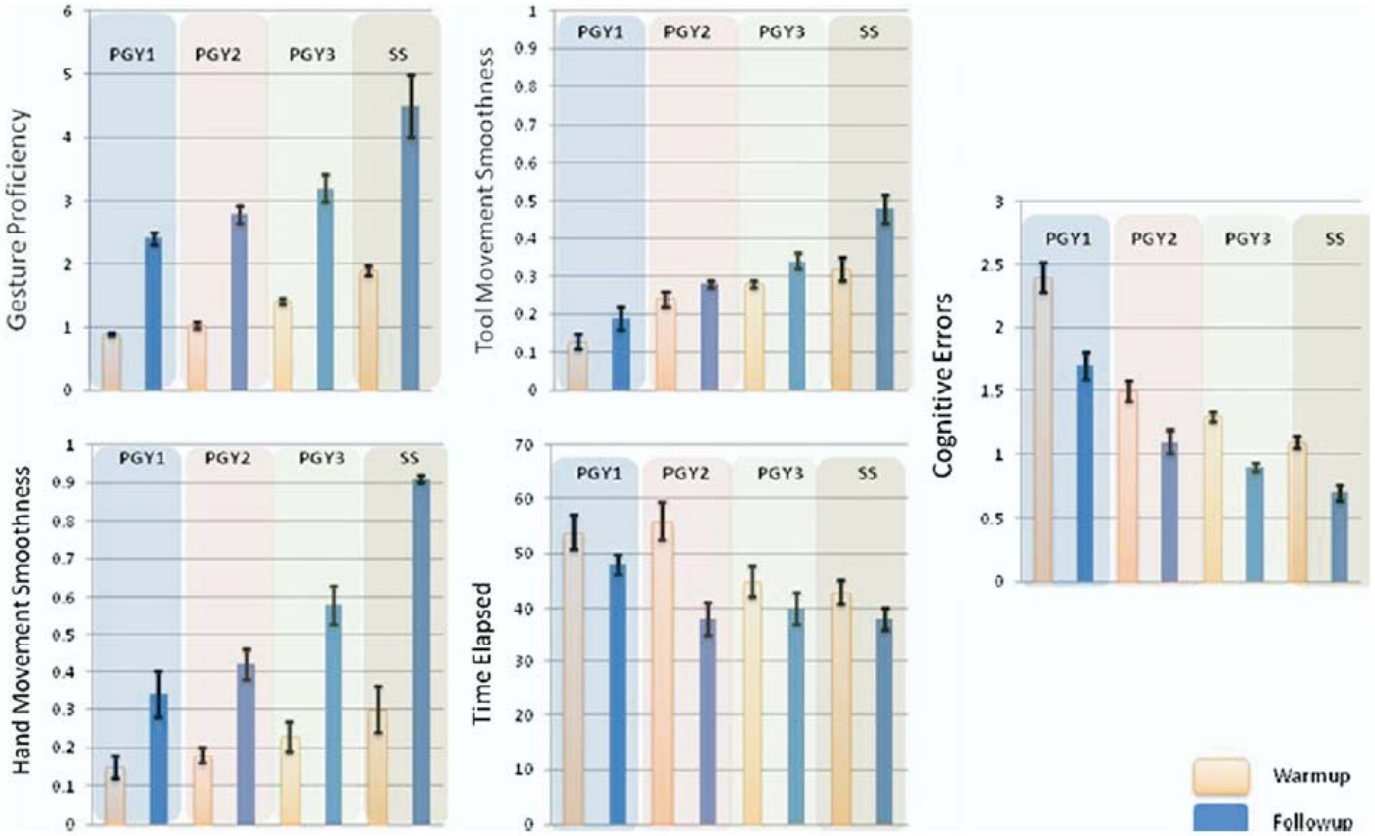


Figure 4. ANOVA plots comparing proficiency in warm-up condition and followup condition data grouped according to experience level. SS, senior surgeon.

Results from actual surgery

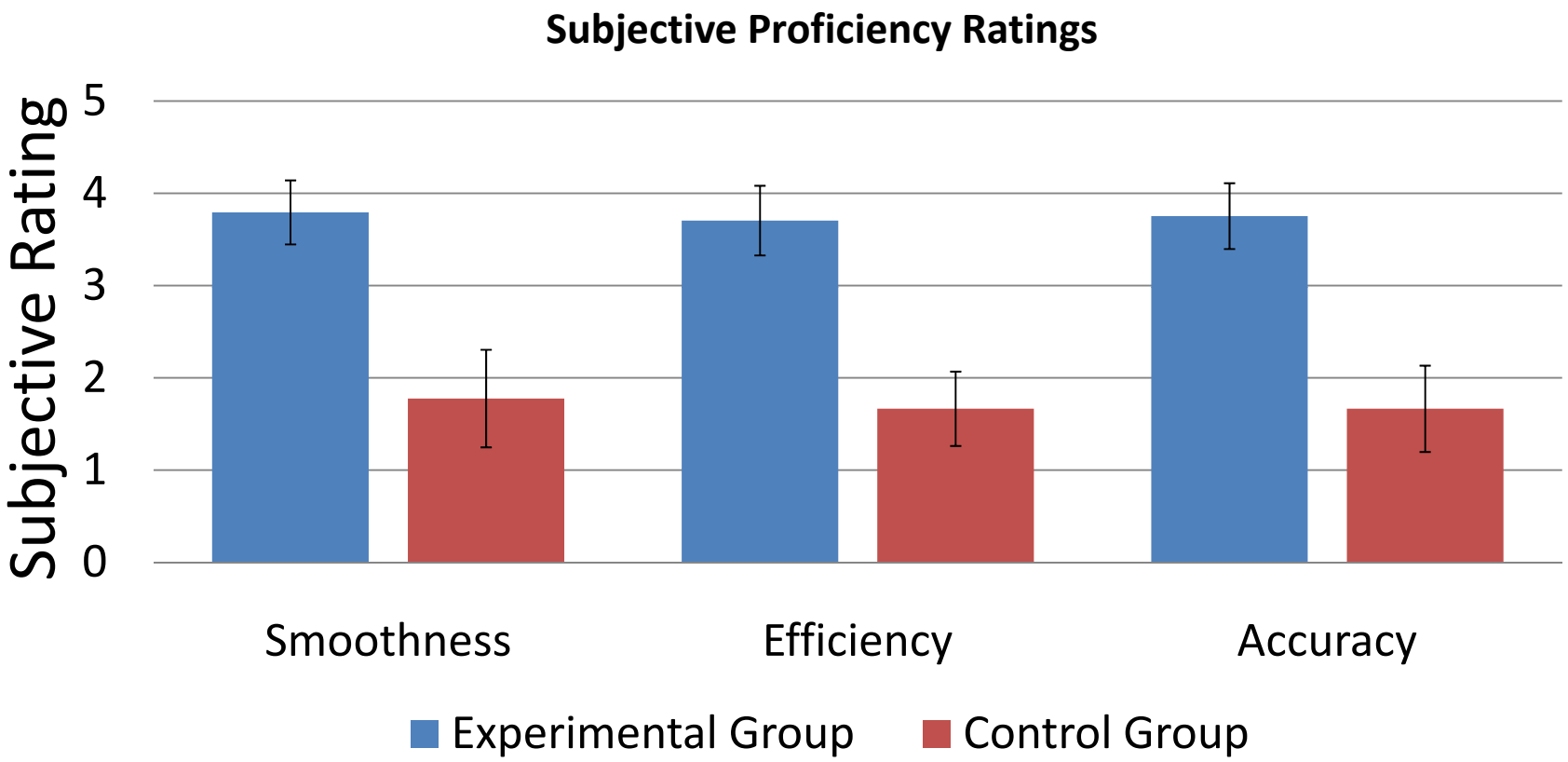
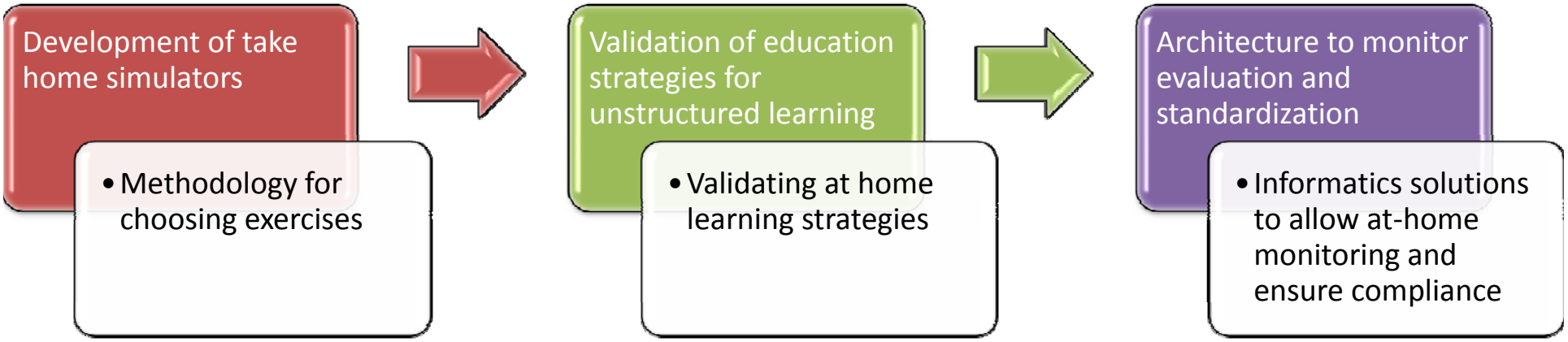


Figure average ratings for each proficiency metric on a scale of 1 to 5. All three were significant with $p < 0.03$.

Take Home Simulators

- To provide mechanisms to hone skills through education at home

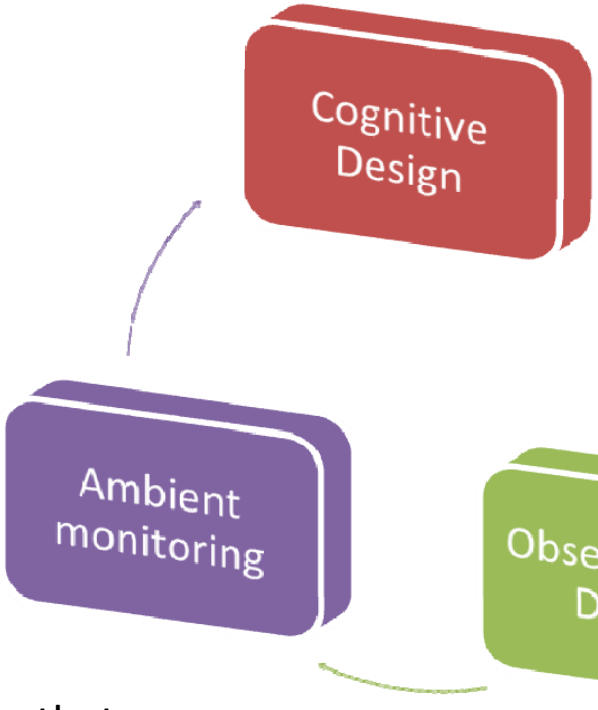


Take Home Simulators

- Re-use of existing resources such as simulation gaming platform has several advantages
- Can provide practice on psychomotor and cognitive skills
- Engaging and fun for trainees
- Several students can study together
- Connectivity proficiency scores can be transmitted to database over the Internet
- Can be deployed anywhere, remote areas as well as developing countries

Methodology For Choosing Exercises

Cognitive task analysis
Suturing->{setting the needle->passing suture->tying}



Adapt gaming scores to our needs

Monitor progress through mechanism that work in an ambient manner

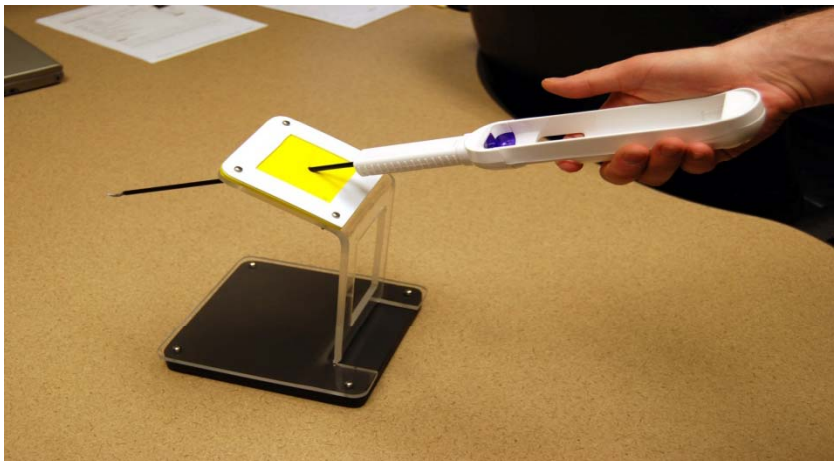
Matching observational Parameters in the real world And virtual world

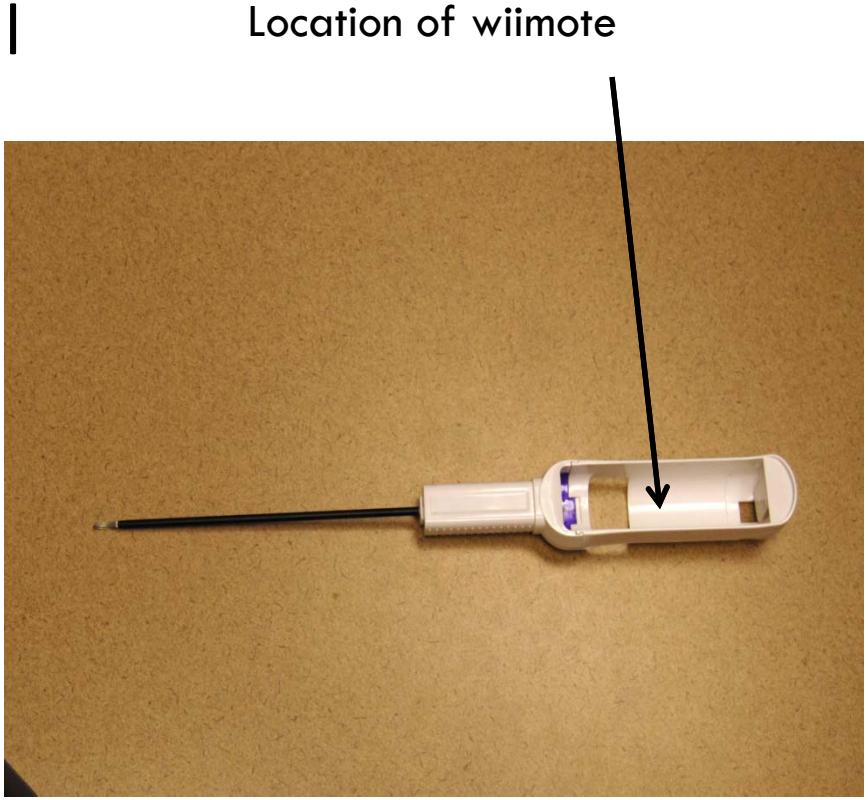
Wii and fine motor skills

- Fine motor skills based games are very suitable
- Very high correlation with basic gestures of surgery
- Quantitatively we found that hand movement acceleration, and joint angles showed 0.78 to 0.91% correlation.
- Cons: doesn't have the fulcrum effect and significant weight.

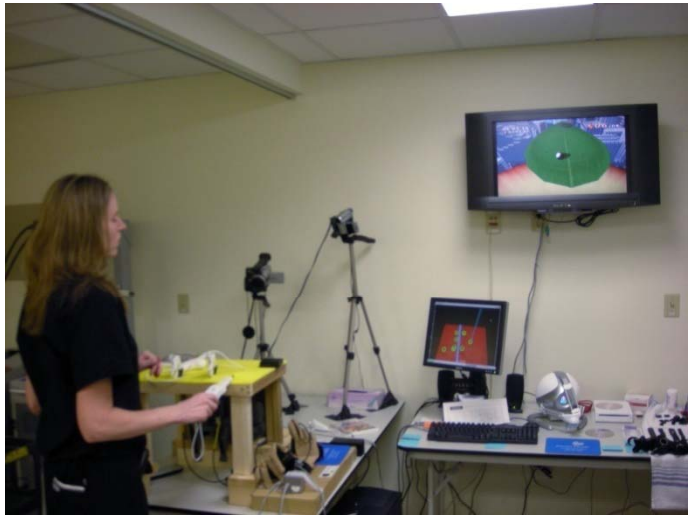
Apparatus

- Gaming Extensions to Wii can be modified for surgical probe based interactions.
- WiiMote Extension
- Movement Constrainer

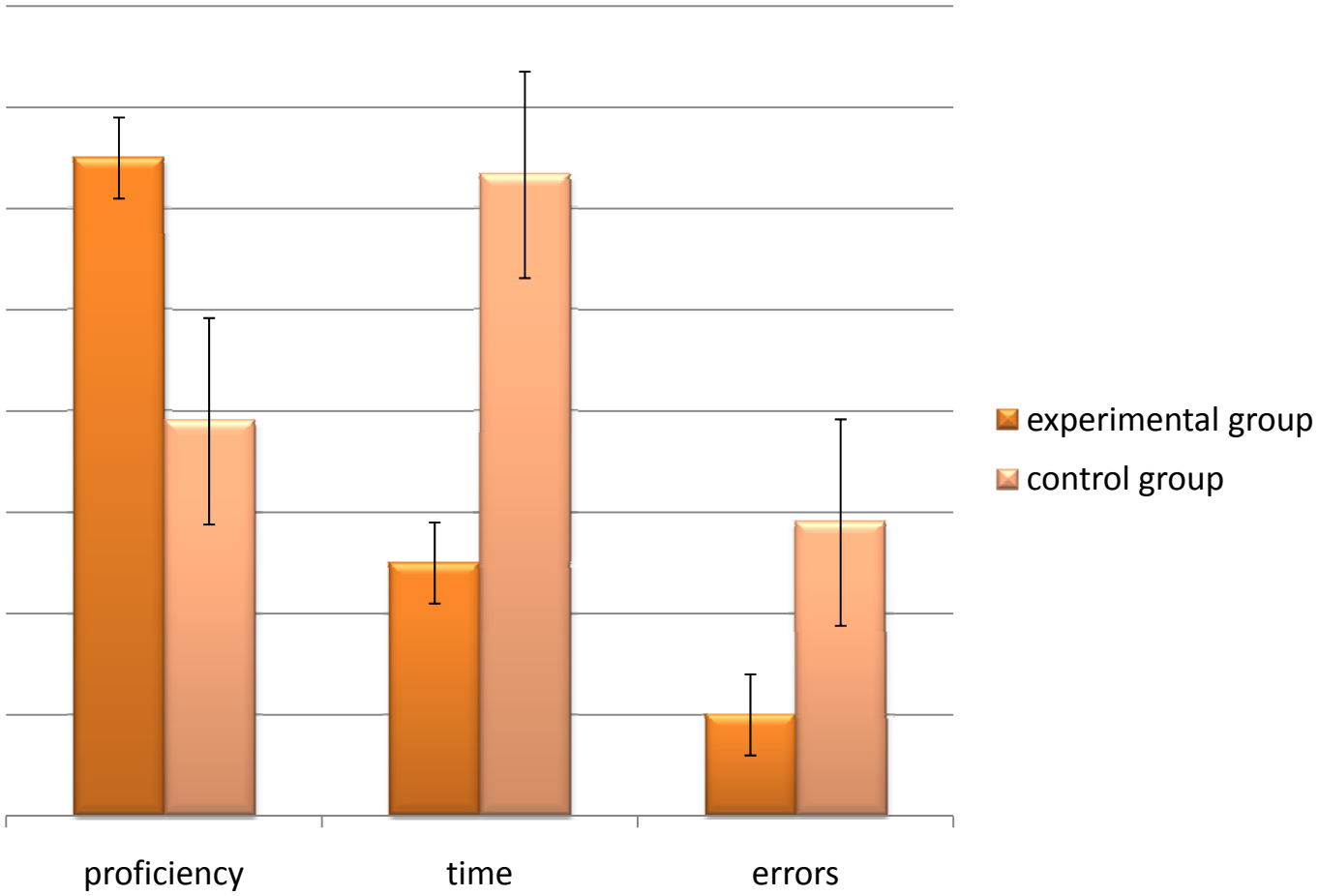




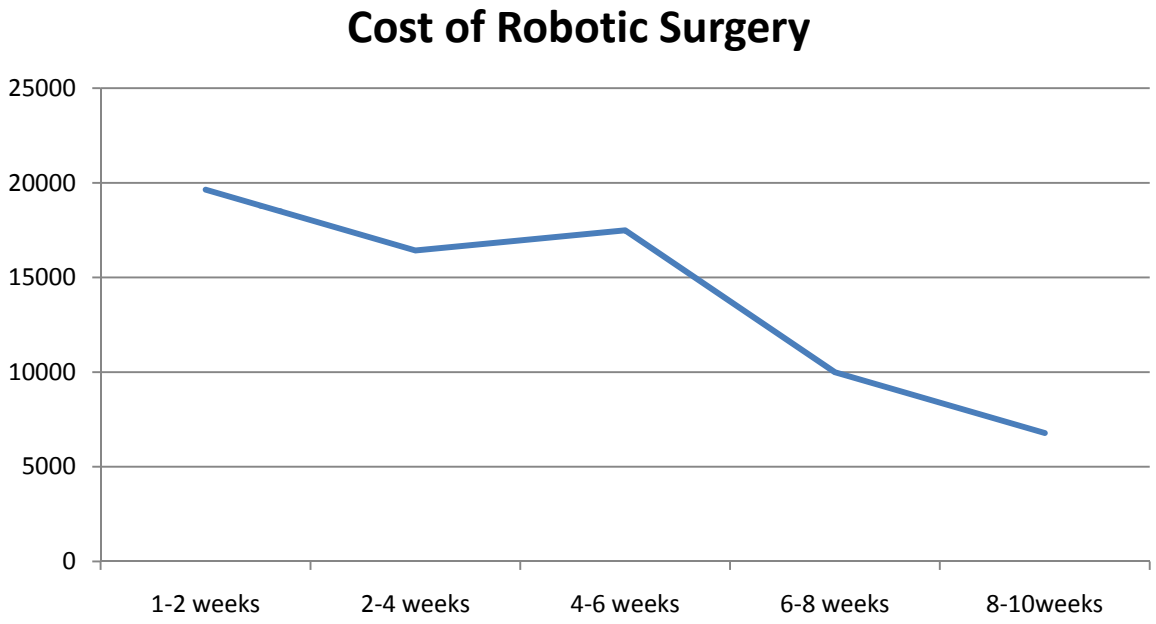
Full System in Action



Study


proficiency
time
errors
experimental group
control group

Cost of surgeons learning robotic surgery in OR

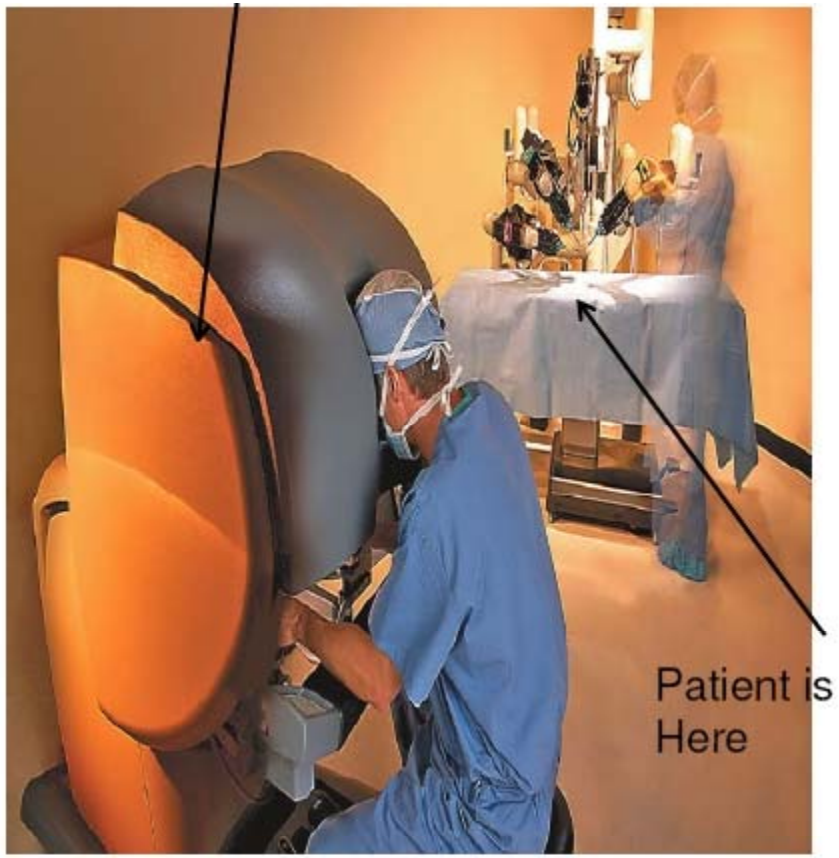


This is over and above mandatory 1 day training by Intuitive@$5000 Per physician

Estimated as $1429 initial cost and $535.50 per 15 minutes

Robotic Surgery Simulator

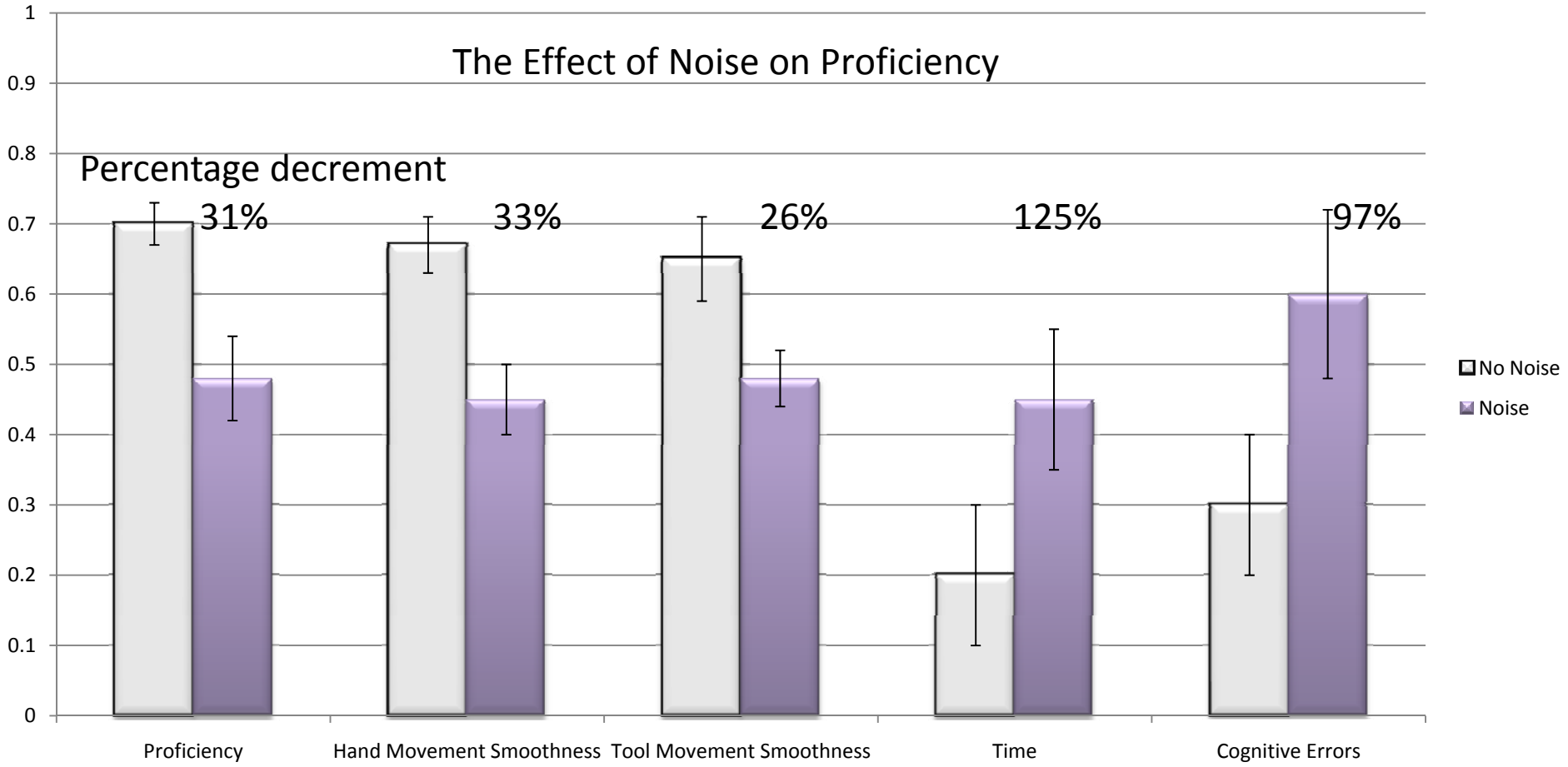
DaVinci Simulator using the Wii

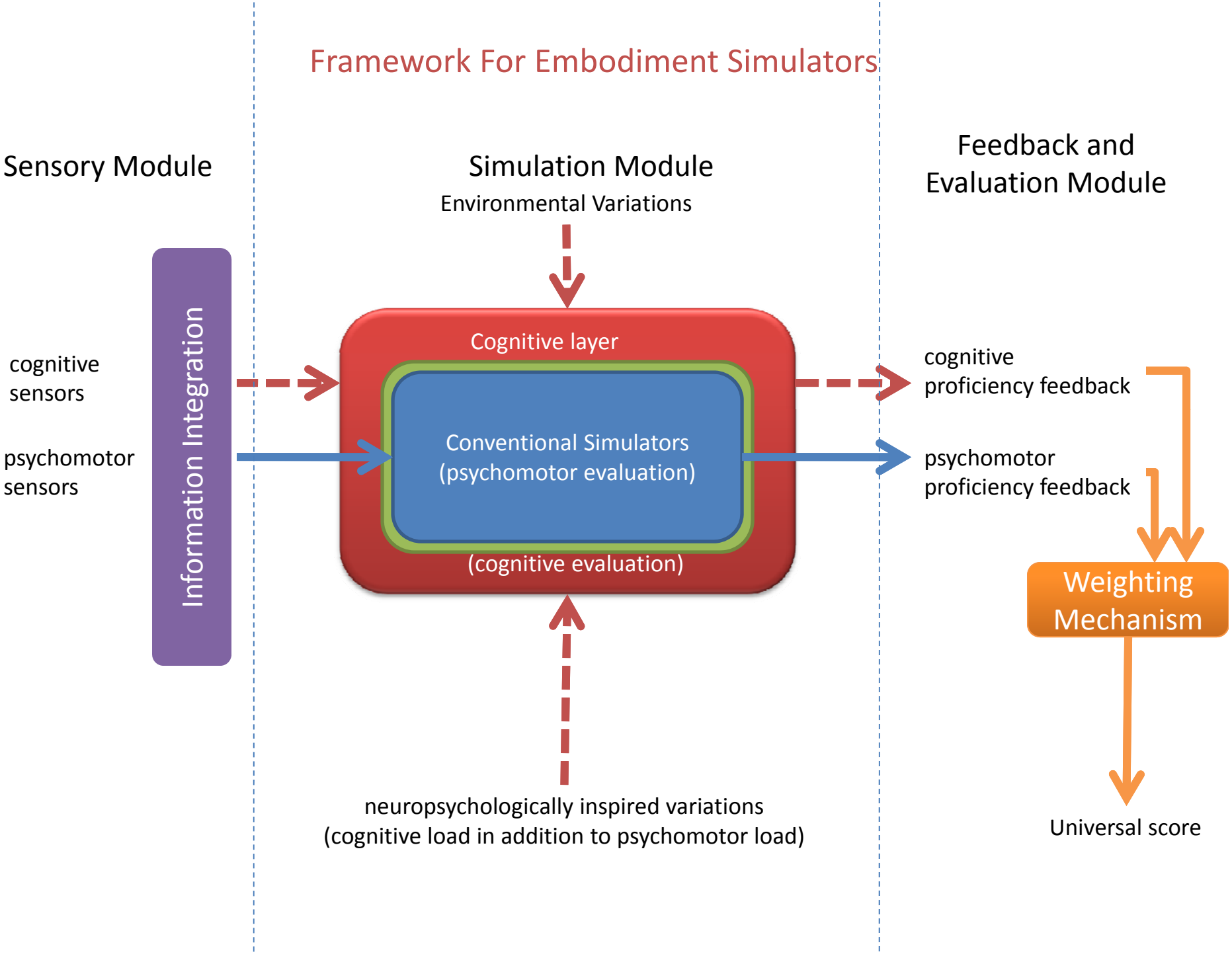


Original Robotic Surgery System

Embodiment Simulators

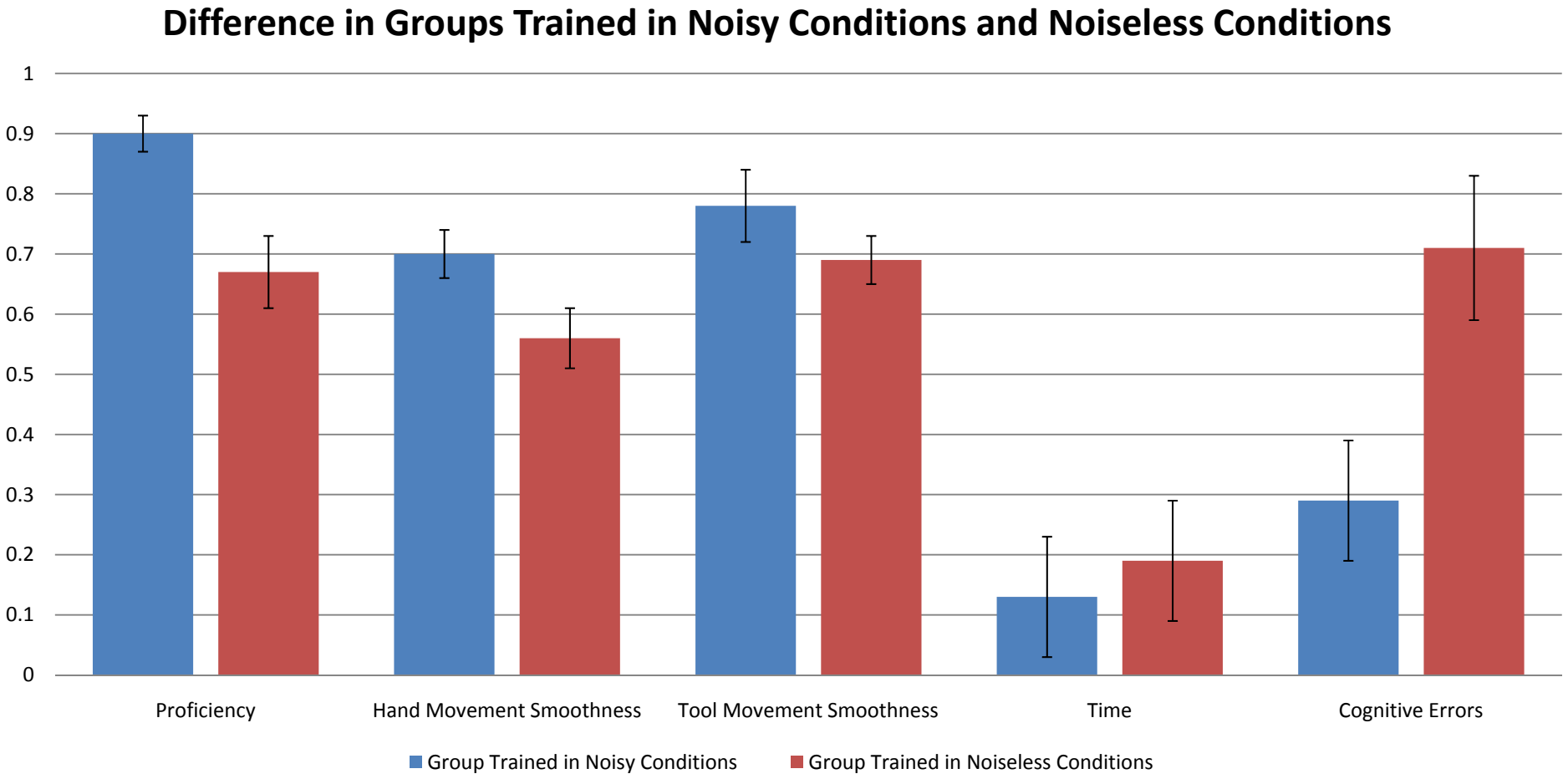
- The statement that learnt psychomotor skills in pristine environments can transfer to real environments is a speculation.




Framework For Embodiment Simulators
Sensory Module
Simulation Module
Environmental Variations
Feedback and Evaluation Module
Information Integration
cognitive sensors
psychomotor sensors
Cognitive layer
Conventional Simulators (psychomotor evaluation)
(cognitive evaluation)
cognitive proficiency feedback
psychomotor proficiency feedback
Weighting Mechanism
Universal score
neuropsychologically inspired variations
(cognitive load in addition to psychomotor load)

Noisy Simulators

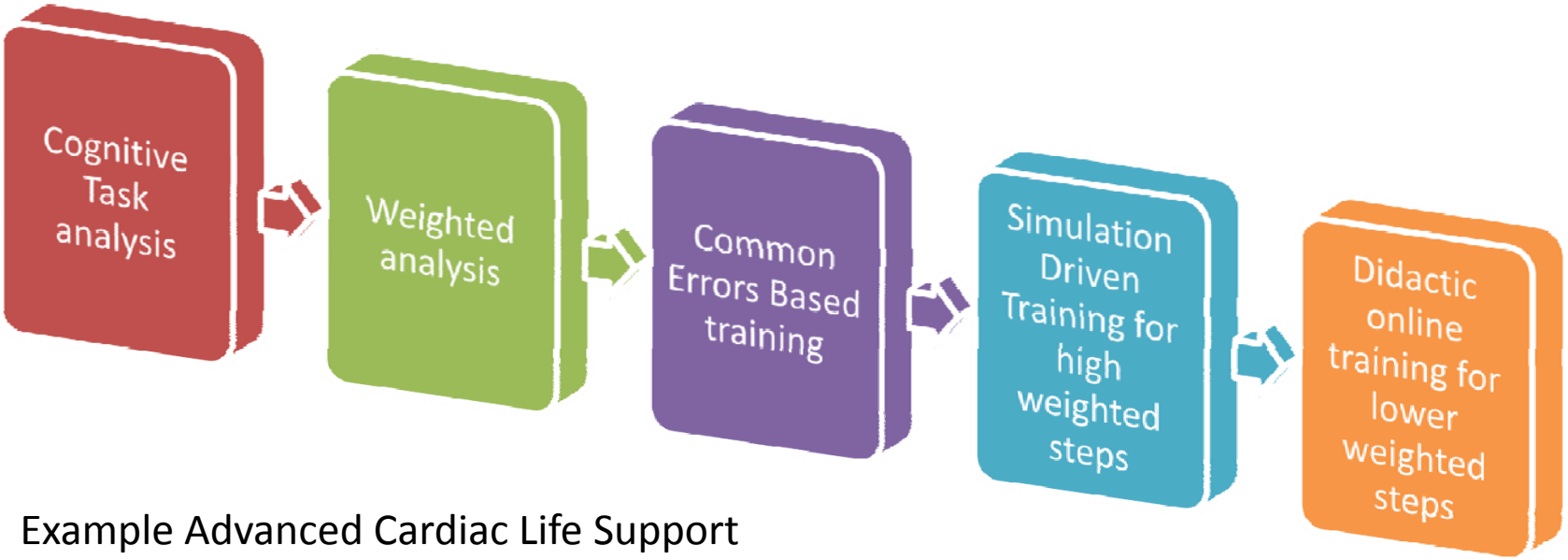
- In addition to cognitive variations added noise to simulations



Integration into Curriculum

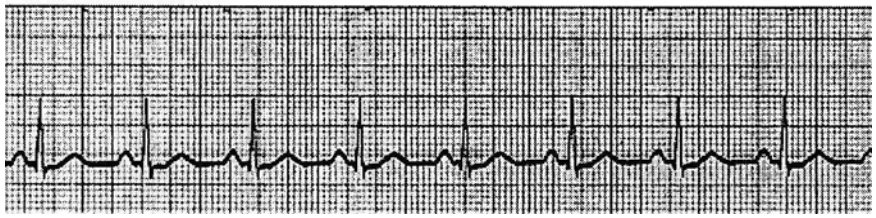
- Simulation cannot be successful in a parallel education model.
- We need a strategy wherein simulation can be integrated into curriculum for residents and medical students.
- Take home simulation helps in reducing overall time required for simulation.
- An additional methodology can help
- In our residency, residents spend a mandatory 1 month training at simulation center where they are also taught basics of research (symbiotic loop)

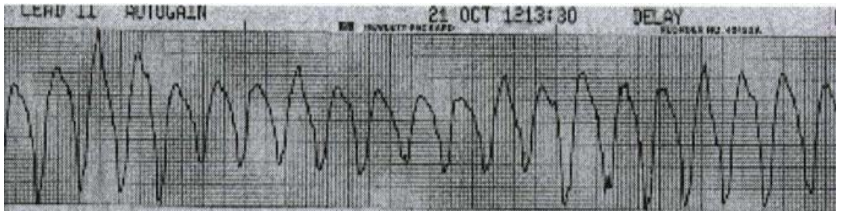
Focusing Simulation Training



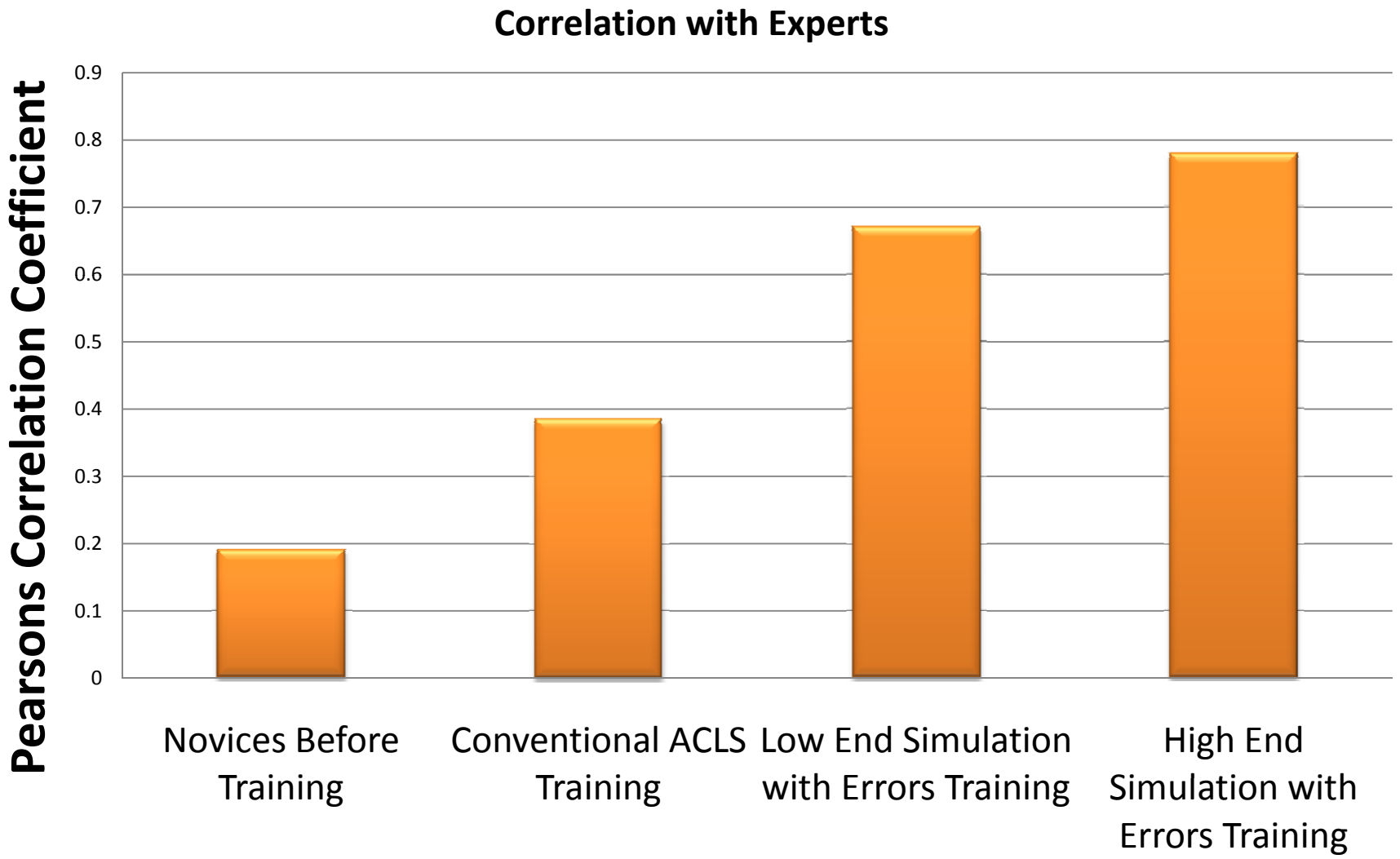
Example Advanced Cardiac Life Support

Training Focused on EKG recognition and errors made in diagnosis.





Errors Training and its Effect



Bringing the real into virtual environments

- A system to monitor real environments and play them back in virtual environments.
- Can capture group activities through RFID sensors, audio analytics, proximity information, process through Hidden Markov Models and Kalman Filters
- Outputs a scripted activity log which can be played back in Virtual Worlds like ActiveWorlds and SecondLife…

http://www.slideshare.net/KanavKahol/virtual-worlds-and-real-world

Virtual Playback and Analysis Tool

Conclusions

An insitu design of simulators addresses the problems of education in an effective manner.

Many of the innovations are basic from technology perspective but have huge impact on the surgical learning.

All the simulators are developed without the generally required graduate student add-on.

Measuring activities in real world is not an option but required to ensure validity.

Partner

Banner Health

http://symbiosis.asu.edu

TATRC PI
$2.2 M
Socially relevant
Telemedicine training
Networks

NSF co-PI
$899,000
A Machine Learning
Approach to Computational
Understanding of Skill
Criteria in
Surgical Training

James S McDonell
Foundation co-PI
Cognitive Complexity
In Critical Care
$5M