April 19, 2018

Master Thesis in Biomedical Engineering

Training in Robot-Assisted Surgery: Design and Evaluation of Adaptive Methods

Andrea Mariani
Edoardo Pellegrini

Supervisor
Elena De Momi

Foreign Supervisor
Peter Kazanzides

Co-Supervisor
Marina Indri

Academic Tutor
Nima Enayati

Academic Year 2016-17
Introduction

Clinical Background: Robot-Assisted Surgery

Robot-Assisted Minimally Invasive Surgery has become adopted in a wide area of surgical interventions

U.S. medical robotic systems market (USDM)

[Source: Grand View Research, Inc.]
Introduction

Clinical Background: Robot-Assisted Surgery

EASIER FOR SURGEONS

Speaker: Andrea Mariani
Introduction

Clinical Background: Robot-Assisted Surgery

SAFER FOR PATIENTS

Faster Overall Recovery Time
No Blood Donation Prior to Surgery
Less Blood Loss
Quicker Return to Normal Activity
Less Pain
Lower Risk for Adverse Side Effects
Shorter Hospitalization Time
Smaller Scars

Speaker
Andrea Mariani
Introduction

Clinical Background: Robot-Assisted Surgery

DRAWBACKS

New Control Modalities

Missing Haptic Feedback

NEED FOR EFFICIENT TRAINING

Speaker Andrea Mariani
Clinical Background: Training in Robot-Assisted Surgery

IDEAL FEATURES

- Surgical Skills Transfer
- Learning Efficiency
- Patient Safety
- Progress Monitoring
Introduction

Clinical Background: Training in Robot-Assisted Surgery

**TRAINING**

**IDEAL FEATURES**

<table>
<thead>
<tr>
<th>Surgical Skills Transfer</th>
<th>Learning Efficiency</th>
<th>Patient Safety</th>
<th>Progress Monitoring</th>
</tr>
</thead>
</table>

**SIMULATION-BASED TRAINING**

- Versatile and cost-effective training environment
- Direct transferability of the acquired skills to the patient-side setting
- Risk reduction since no real patients involved
- Simplified objective performance assessment

[Dawe et al., 2014] [Gaba, 2004] [Enayati et al., 2017]
Several training strategies have been proposed but there exists no training modality that is universally accepted.
Several training strategies have been proposed but there exists no training modality that is universally accepted.

**CURRENT APPROACHES**

**SUBJECTIVE - STATIC TRAINING**

The effective learning occurs when the training is at an appropriate level of difficulty [Guadagnoli and Lee, 2004].

**TRAINING STRATEGY**

- **Training Task**
- **User**
- **Learning Assessment**
Several training strategies have been proposed but there exists no training modality that is universally accepted.

The effective learning occurs when the training is at an appropriate level of difficulty.

**Training Task** -> **User** -> **Learning Assessment**

**PROPOSED APPROACH**

**ADAPTIVE TRAINING**

The effective learning occurs when the training is at an appropriate level of difficulty.
The application of an adaptive physical guidance and the adaptation of the training curriculum to the user’s performances can measurably improve the outcome of the training procedure.

**RESEARCH HYPOTHESIS**

**PROJECT GOALS**

**PRELIMINARY AIM**
- Development of a versatile environment for training studies

**AIM 1**
- Study of an adaptive physical guidance during training

**AIM 2**
- Study of a performance-based adaptive training curriculum
Preliminary Aim

Development of a versatile environment for training studies

AIM 1
Study of an adaptive physical guidance during training

AIM 2
Study of a performance-based adaptive training curriculum

A Framework for Assisted Tele-operation with Augmented Reality
CRAS 2017

N. Enayati, A. Mariani, E. Pellegrini, T. Chupin, G. Ferrigno, E. De Momi
Preliminary Aim

Developing Training Tasks

ISSUES

No Agreed-Upon Motor Learning Definition

Long Study Times

High Variability among Subject Skills and Learning Rate


Speaker Andrea Mariani
Preliminary Aim

Developing Training Tasks

ISSUES

- No Agreed-Upon Motor Learning Definition
- Long Study Times
- High Variability among Subject Skills and Learning Rate

STUDYING TRAINING


ROS

Assisted Teleoperation with Augmented Reality (ATAR)

Speaker Andrea Mariani
Preliminary Aim

Developing Training Tasks

VISUO-MOTOR TASK

FEATURES

- Involve Fundamental Surgical Skills
  - Hand-Eye Coordination
  - Wrist Articulation
  - Instrument-to-Instrument Transfer

- Allow to Measure Data
  - Kinematics and Dynamics Data
  - Metrics
    - Task Specific
    - Task independent

- Adequate Nominal Complexity
  - Nothing To Learn
  - Too Low
  - Too High
  - Cognitive Overload

Speaker: Andrea Mariani

Preliminary Aim

Perform Learning Assessment

Quantification of Training Progression

LEARNING RATE
How FAST the user is learning

IMPROVEMENT
How MUCH the user is learning

BUILDING THE LEARNING CURVE

**Preliminary Aim**

Perform Learning Assessment

---

**LEARNING ASSESSMENT**

**OBJECTIVE SKILL EVALUATION**

Through measuring specific metrics

- **Robotic Devices**
  - Kinematic - Dynamic Data
- **Simulation**
  - VR measures

**AIM 1**

**AIM 2**

---

Aim 1

N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi

Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study

ACCEPTED TO ICRA 2018
Aim 1  Open Issues

**Haptic Guidance**

- **Enhance learning in early phases of complex motor tasks**
  [Marchal-Crespo and Reinkensmeyer, 2008]

**Benificial Aspects**
- Accuracy
- Safety
- Cognitive Load

**Drawbacks**
- Implementation Complexity
- Interference with Real Dynamics

**Past Studies**
- **Detrimental Effects**
  [Winstein et al., 1994] [Tsutsui et al., 2003]
- **Nill Effects**
  [Coad et al., 2017]
- **Positive effects**
  [Feygin et al., 2002] [Crespo et al., 2008]

**Controversial Outcomes**

Speaker  Andrea Mariani
Aim 1  Open Issues

Enhance learning in early phases of complex motor tasks

- Accuracy
- Safety
- Cognitive Load

Drawbacks
- Implementation Complexity
- Interference with Real Dynamics

Interest in Learning Improvement

Robotic Assistance

Haptic Guidance

Past Studies

ON-OFF ASSISTANCE

NO ADAPTIVITY

Marchal-Crespo and Reinkensmeyer, 2008

N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018
Aim 1
Open Issues

HAPTIC GUIDANCE

REHABILITATION FIELD

LEARNING BENEFIT

INFORMATION

PERFORMANCE IN PRACTICE

DRAWDACK

Dependency on Assistance

Guidance Hypothesis

Slacking Hypothesis

Task Functional Difficulty

Hypothesis

FUNCTIONAL TASK DIFFICULTY

Assessment by Performance Measures

Skill Level

ASSESSED BY

PERFORMANCE MEASURES

ADAPTED TO KEEP

Drawback

Modulation to avoid voluntary control minimization

Level of Assistance

Optimal Challenge Point (OCP)

Basic Principle

There exists an optimal amount of information that maximizes learning.

Schmidt RA, Bjork RA, 1992


Squeri V, Basteris A, Sanguineti V, 2011

Guadagnoli MA, Lee TD, 2004

[Enayati A, M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
Aim 1  
Research hypothesis

RESEARCH HYPOTHESIS

The application of a performance-based adaptive physical guidance following the assistance-as-needed framework positively affects the training procedure

[Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, *Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study*, Accepted To ICRA 2018]
Aim 1  Methods

Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018

EXPERIMENTAL SETUP

ROBOT ASSISTANCE-AS-NEEDED METHOD

APPLIED TO THE TRAINING OF

COMPLEX BIMANUAL VISUOMOTOR TASK

HARDWARE

dVRK MASTER CONSOLE
(Intuitive Surg)
GeForce GTX 980 Ti GPU
(Nvidia Corp.)

SOFTWARE

ATAR

Steady Hand Task

Execution of the Studied Virtual Reality Task (Non-Assisted)

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
Aim 1 Methods

**TASK METRICS**

- **TIME**
  - TOTAL
  - RMS
  - MAX

- **TRANSLATION ERROR**
  - DISTANCE BETWEEN THE RING CENTER AND THE WIRE

- **ORIENTATION ERROR**
  - ANGLE OF THE ROTATION (AXIS AND ANGLE REPRESENTATION) TAKING THE RING TO ITS IDEAL ORIENTATION

- **NORMALIZATION**
  - $x_{repetition}^* = \text{sat}(0, \frac{x_{best} - x_{repetition}}{x_{best} - x_{worst}}, 1) \in [0, 1]$

**OVERALL PERFORMANCE = AVERAGE**

---

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, *Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study*, Accepted To ICRA 2018]
Aim 1  Methods

16 NON-MEDICAL PARTICIPANTS

**CONTROL GROUP**

- NO ASSISTANCE
- ACQUIRED FIRST
- 2 SESSIONS PER DAY (Morning and Afternoon)
- 8 REPETITIONS PER SESSION (Average duration: 10 mins)

**EXPERIMENTAL GROUP**

- ADAPTIVE ASSISTANCE
- TILL LEARNING CURVE PLATEAU

NON-MEDICAL PARTICIPANTS

[16]

CONTROL GROUP

EXPERIMENTAL GROUP

8

8

ACQUISITION PROTOCOL

8

8

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
### Aim 1: Methods

#### Assistance Modulation

**Normalized Assistance Intensity**

- Modulate the assistance on the basis of past performances to keep the optimal challenge point.

**Assistance as Needed Framework**

\[
\text{Assistance} = \alpha \times f(e)
\]

**Scaled by**

- \( \alpha \)

**Proportional to**

- \( f(e) \)

**Current Error**

- \( T_c: [p_c, q_c] \)

**Desired Pose**

- \( T_d: [p_d, q_d] \)

**Viscoelastic Active Constraint**

\[
\begin{align*}
    f &= -K_T (p_d - p_c) - B_T \dot{p}_c \\
    \tau &= -K_R [q_c^* q_d]_{rpy} - B_R \omega
\end{align*}
\]

---

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, *Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study*, Accepted To ICRA 2018]
Aim 1  Methods

**ASSISTANCE MODULATION**

\[ f, \tau \in \mathbb{R}^3 : \text{force and torque} \]
\[ \omega \in \mathbb{R}^3 : \text{Current angular rate} \]
\[ \mathbf{p}_x : \text{Position vector in } \mathbb{R}^3 \]
\[ \mathbf{q}_x : \text{Unit quaternion in } \mathbb{R}^4 \]

**TABLE I PARAMETERS OF THE IMPLEMENTED AC**

<table>
<thead>
<tr>
<th></th>
<th>(K_T)</th>
<th>(B_T)</th>
<th>(K_R)</th>
<th>(B_R)</th>
<th>(f_{\text{max}})</th>
<th>(\tau_{\text{max}})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000</td>
<td>30</td>
<td>0.03</td>
<td>4</td>
<td>4N</td>
<td>0.03</td>
</tr>
<tr>
<td>N/m</td>
<td>N.s/m</td>
<td>N.m/rad</td>
<td>N.m.s/rad</td>
<td>N.m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(K_T, K_R\): Translational and Rotational elastic coefficients

\(B_T, B_R\): Translational and Rotational viscosity coefficients

**VISCOELASTIC ACTIVE CONSTRAINT**

\[ f = -K_T (\mathbf{p}_d - \mathbf{p}_c) - B_T \dot{\mathbf{p}}_c \]

\[ \tau = -K_R [\mathbf{q}_c^* \mathbf{q}_d]_{\text{rpy}} - B_R \omega \]

\([N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
**Aim 1: Methods**

**ASSISTANCE MODULATION**

**NORMALIZED ASSISTANCE INTENSITY**

\[ \alpha \times f(e) \in [0, 1] \]

**ASSISTANCE AS NEEDED FRAMEWORK**

Modulate the assistance on the basis of past performances to keep the optimal challenge point.

---

[Enayati, A. M., Okamura, A., Mariani, E., Pellegrini, M., Coad, G., Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
Aim 1 Results and Discussion

NORMALIZED ASSISTANCE INTENSITY, $\alpha$

[Graph showing normalized assistance intensity across training sessions for different subjects.]

DECREASING STEPWISE SHAPE SESSION BY SESSION

ADAPTIVITY TO THE USER’S INTER AND INTRA SESSION PERFORMANCES

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, *Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study*, Accepted To ICRA 2018]
Aim 1 Results and Discussion

LEARNING CURVES

PERFORMANCE COMPARISON BETWEEN THE TWO GROUPS

[Image of a graph showing learning curves for two groups, with annotations: 10 SESSIONS TO ACHIEVE PROFICIENCY, AVERAGE PERFORMANCE INCREASE, PERFORMANCE VARIABILITY REDUCTION INTRA AND INTER SUBJECTS.]

[Note: The graph shows normalized overall performance against repetition, with a line indicating average assistance intensity.]

N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
Aim 1 Results and Discussion

LEARNING CURVES

PERFORMANCE COMPARISON BETWEEN THE TWO GROUPS

[Image of learning curves showing performance comparison between null subjects and assisted subjects.]

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
Aim 1  Results and Discussion

LEARNING CURVES

METRICS ANALYSIS

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
Aim 1  Results and Discussion

LEARNING CURVES

METRICS ANALYSIS

[Image showing learning curves for different metrics over training sessions, indicating performance improvement over time for various groups.]

BASELINE ASSESSMENT

NO STATISTICALLY SIGNIFICANT DIFFERENCE

[Image showing statistical analysis: Kruskal-Wallis Test. DEPENDENT VARIABLES: Performance metrics. INDEPENDENT FACTORS: Training groups.]

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, "Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study," Accepted To ICRA 2018]
Aim 1

Results and Discussion

LEARNING CURVES

METRICS ANALYSIS

AT ASSISTANCE REMOVAL

7TH SESSION

STATISTICALLY SIGNIFICANT DIFFERENCE ONLY FOR TIME

[N. Enayati, A. M. Okamura, A. Mariani, E. Pellegrini, M. Coad, G. Ferrigno, and E. De Momi, Robotic Assistance-as-Needed for Enhanced Visuomotor Learning in Surgical Robotics Training: An Experimental Study, Accepted To ICRA 2018]
Aim 2

A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi

**Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study**

ACCEPTED TO EMBC 2018

---

**PROJECT GOALS**

<table>
<thead>
<tr>
<th>PRELIMINARY AIM</th>
<th>AIM 1</th>
<th>AIM 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of a versatile environment for training studies</td>
<td>Study of an adaptive physical guidance during training</td>
<td>Study of a performance-based adaptive training curriculum</td>
</tr>
</tbody>
</table>

---

**ADAPTIVE LOGIC**

- Training Task
- User
- Learning Assessment

---

CARRIED OUT AT:

**JOHNS HOPKINS UNIVERSITY**

Speaker: Edoardo Pellegrini
Aim 2  Open Issues

MENTOR DIRECTION

- STATIC
- SUBJECTIVE
- HIGH COSTS

SELF DIRECTION

- RELY ON THE USER’S SELF ASSESSMENT
- LACK OF CONSISTENCY

[Davis et al., 2006]

TRAINING CURRICULUM

SIMULATORS

SHIFT TOWARDS

[MacDonald et al., 2003]
Aim 2  Research Hypothesis

An **adaptive training curriculum** allows to reach better final performances compared to a self-managed training

[RESEARCH HYPOTHESIS]

**An adaptive training curriculum allows to reach better final performances compared to a self-managed training**

[Speaker] Edoardo Pellegrini

[Reference] [A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, *Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study*, Accepted To EMBC 2018]
Aim 2  Methods

Elena De Momi, DEIB

[Image]

TASK POOL

ELEMENTARY TASKS

TASK 1  TASK 2  TASK 3  TASK 4  TASK 5

SKILL 1  SKILL 2  SKILL 3  SKILL 4  SKILL 5

...  

COMPLEX TASKS

TASK 1  TASK 2

SKILL 1  SKILL 2  SKILL 3  SKILL 4  SKILL 5

...  

FUNDAMENTAL SURGICAL SKILLS

[ A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study, Accepted To EMBC 2018 ]

Speaker  Edoardo Pellegrini  23
Aim 2  Methods

**EXPERIMENTAL SETUP**

**COMPLEX TASKS**
- STEADY HAND TASK
- DEPTH PERCEPTION
- INSTRUMENT TO INSTRUMENT EXCHANGE

**ELEMENTARY TASKS**
- WRIST ARTICULATION
- HAND-EYE COORDINATION

**HARDWARE**
- dVRK MASTER CONSOLE (Intuitive Surg)
- Xeon Processor E5-1620 v2 (Inter Corp.)

**SOFTWARE**
- ATAR

**ATAR**

**SKILL DECONSTRUCTION LIST**
[Dulan et al., 2012]

[A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, *Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study*, Accepted To EMBC 2018]

**Speaker** Edoardo Pellegrini
Aim 2 Methods

EXPERIMENTAL SETUP

STEADY HAND TASK

SAME ELEMENTARY SKILLS

SECOND COMPLEX TASKS

AIM
TEST SKILL TRANSFER

HARDWARE

dVRK MASTER CONSOLE
(Intuitive Surg)
Xeon Processor E5-1620 v2
(Inter Corp.)

SOFTWARE

ATAR

[Speakers: Edoardo Pellegrini]

[Text: 24]

[Ref: A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study, Accepted To EMBC 2018]
Aim 2 Methods

**METRICS**
- Depth Error AVG
- Time
- Position Error AVG
- Orientation Error AVG
- Object Drops

**NORMALIZATION**

**COMPLEX TASK**

\[ S_i = \frac{\sum \alpha_j m_j}{\sum \alpha_j} \in [0,1] \]

**ELEMENTARY TASK**

**OVERALL PERFORMANCE**

\[ P = \frac{\sum \beta_j m_j}{\sum \beta_j} \in [0,1] \]

**SKILL RELATED PERFORMANCE**

\[ P = \text{avg}(S_i) \in [0,1] \]

Aim 2  Methods

ACQUISITION PROTOCOL

12 NON-MEDICAL PARTICIPANTS

CONTROL GROUP

EXPERIMENTAL GROUP

N=6

N=6

SELF-MANAGED

ADAPTIVE

[A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study, Accepted To EMBC 2018]

Speaker  Edoardo Pellegrini
Aim 2 Methods

**ACQUISITION PROTOCOL**

**SINGLE SESSION**

- **START**
  - BASELINE ASSESSMENT
  - **CT**

- **45 MINUTES**
  - TRAINING
  - **CT** + **ET_i**

- **END**
  - TESTING
  - **CT** + **CT**

**SELF-MANAGED**

- **CONTROL GROUP**
  - EXPERIMENTAL GROUP
  - **ADAPTIVE**

**LEGEND**

- **CT** = COMPLEX STEADY HAND TASK
- **ET_i** = iTH ELEMENTARY TASK
- * = SKILL TRANSFER EVALUATION

---

[A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, *Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study*, Accepted To EMBC 2018]

---

Speaker  Edoardo Pellegrini  27
Aim 2 Methods

EXPERIMENTAL GROUP TRAINING

3 TRAINING SUBSLOTS OF 15 MINUTES

CT ET – ET – ET – ET – ET ...

CT ET – ET – ET – ET – ET ...

CT ET – ET – ET – ET – ET ...

TRANING SUBSLOT

CT ELEMENTARY SKILLS EVALUATION PERFORMANCE ADAPTIVE LOGIC ET PERFORMANCE IF TIME>15MIN

MINIMIZE SKILL GAPS

Legend
CT = COMPLEX TASK
ET = ELEMENTARY TASK

[Adapted from A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: A Pilot Study, Accepted To EMBC 2018]
Aim 2

Results and Discussion

TRAINING TASKS

- Average number of task repetitions

- Control Group: 10
- Experimental Group: 20

Total Number of Tasks

- Experimental Group: 24
- Control Group: 13

p = 0.009

Reasons

- Object Transfer
- Wrist Articulation
- Hand-Eye Coordination
- Depth Perception
- Complex Task

Benefits

- Optimize time with the simulator

Statistical Analysis

Wilcoxon Rank Sum Test

Dependent Variables: Performance measures
Independent Factors: Training groups

Reference:

[A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study, Accepted To EMBC 2018]
Aim 2 Results and Discussion

OVERALL PERFORMANCE

PERFORMANCE VARIABILITY

AVERAGE PERFORMANCE

BOTH THE GROUPS

PERFORMANCE IMPROVEMENT

STATISTICAL ANALYSIS
Wilcoxon Rank Sum Test

DEPENDENT VARIABLES - Performance measures
INDEPENDENT FACTORS - Training groups

BEFORE – AFTER TRAINING

CONTROL GROUP

EXPERIMENTAL GROUP

* STATISTICAL SIGNIFICANCE

p = 0.002

p = 0.31

[A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, *Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study*, Accepted To EMBC 2018]

Speaker Edoardo Pellegrini
Aim 2 Results and Discussion

OVERALL PERFORMANCE

BEFORE – AFTER TRAINING

PERFORMANCE DIFFERENCE BETWEEN THE 2 GROUPS

STATISTICAL ANALYSIS

Wilcoxon Rank Sum Test

DEPENDENT VARIABLES - Performance measures

INDEPENDENT FACTORS - Training groups

[Statistical results and interpretation]

THE ADAPTIVE TRAINING ALLOWED TO OBTAIN HIGHER FINAL PERFORMANCES

[References]

[Statistical analysis details]

[Graph showing performance comparison before and after training]
Results and Discussion

SKILL PERFORMANCE

AFTER TRAINING

Experimental Group
- HIGHER PERFORMANCES IN ALL THE SKILLS

<table>
<thead>
<tr>
<th>S</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.04</td>
</tr>
<tr>
<td>2</td>
<td>0.004</td>
</tr>
<tr>
<td>3</td>
<td>0.009</td>
</tr>
<tr>
<td>4</td>
<td>0.002</td>
</tr>
</tbody>
</table>

- LOWER VARIABILITY BOTH INTER AND INTRA SKILL

Control Group

BIGGEST GAP IN THE OBJECT TRANSFER

TRAINING SCHEDULE

[Statistical Analysis: Wilcoxon Rank Sum Test]

DEPENDENT VARIABLES - Performance measures
INDEPENDENT FACTORS - Training groups

[A. Mariani, E. Pellegrini, N. Enayati, P. Kazanzides, and E. De Momi, Design and Evaluation of a Performance-based Adaptive Curriculum for Robotic Surgical Training: a Pilot Study, Accepted To EMBC 2018]

Speaker: Edoardo Pellegrini
Aim 2

Results and Discussion

SKILL PERFORMANCE

AFTER TRAINING

Experimental Group

- HIGHER PERFORMANCES IN ALL THE SKILLS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object Transfer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist Articulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand-Eye Coordination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth Perception</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Task</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.04</td>
<td>0.004</td>
<td>0.009</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Control Group

- BIGGEST GAP IN THE OBJECT TRANSFER

TRAINING SCHEDULE

[Statistical Analysis: Wilcoxon Rank Sum Test]

[Dependent Variables: Performance measures]

[Independent Factors: Training groups]

Speaker: Edoardo Pellegrini
Aim 2 Results and Discussion

**SKILL TRANSFER**

**SKILL TRANSFER TASK**

AFTER TRAINING

**SKILL TRANSFER**

**EXPERIMENTAL GROUP PERFORMAANCE**

**CONTROL GROUP PERFORMANCE**

* USERS WHO UNDERWENT THE ADAPTIVE TRAINING BETTER LEARNT THE ELEMENTARY SKILLS

> p = 0.04

[Control Group](#) [Experimental Group](#)

---

**STATISTICAL ANALYSIS**

Wilcoxon Rank Sum Test

DEPENDENT VARIABLES - Performance measures

INDEPENDENT FACTORS - Training groups

---

**EXPERIMENTAL GROUP**

**PERFORMANCE**

**CONTROL GROUP**

**PERFORMANCE**

---


---

**Speaker** Edoardo Pellegrini

---

POLITECNICO MILANO 1863
Conclusions

Did the experimental studies test the research hypotheses?

**AIM 1**

- Both non-assisted and assisted groups achieved similar performances at the end of the training
- Subjects who received assistance achieved high performance in terms of completion time faster than the non-assisted subjects did

**AIM 2**

- The final performances of the experimental users undergoing the adaptive training were significantly higher
- Their skill learning featured more uniformity and higher end points compared to the control group

Speaker Edoardo Pellegrini
Adaptive strategies have shown to be promising in improving the outcomes of the simulation-based training in robot-assisted surgery.

**Conclusions**

**FUTURE WORKS**

- **AIM 1**
  - DIFFERENT TASKS
  - AUGMENTED REALITY
  - STUDY ON RESIDENTS
  - WIDER STUDY POPULATION

- **AIM 2**
  - MULTIPLE SESSIONS
  - MENTORED TRAINING
Thanks for your attention

Any question?