Cost-Efficient Laparoscopic Haptic Trainer based on Affine Velocity Analysis.

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To cite this version:

Charles Barnouin, Benjamin de Witte, Richard Moreau, Arnaud Lelevé, Xavier Martin. Cost-Efficient Laparoscopic Haptic Trainer based on Affine Velocity Analysis.. Surgetica 2017, Nov 2017, Strasbourg, France. hal-01563262

HAL Id: hal-01563262
https://hal.archives-ouvertes.fr/hal-01563262
Submitted on 4 Feb 2019

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INTRODUCTION

- Learning minimal invasive surgery (MIS) skills is young surgeons’ major concern.
- Cognitive load elicited by simulators’ use and trainees’ spatial abilities seem to impact efficient learning process(1).
- Objectives: design a basic skill training simulator which objectively evaluate trainees’ level.
- Use of Affine velocity(2-3) as assessment variable.

METHODS

Step 1 - Cognitive conception
- Observation and analyses of surgeons in situ
- Inclusion of literatures’ recommendations

Step 2 - Simulator conception
- Use of materials enabling haptic feedback and developing a VR environment (Phantom Omni, CHAID, laparoscopic devices...)

Step 3 - Simulator validation
- Define assessment variables to evaluate the trajectory:
  - Time taken to complete the level
  - Number of errors (collisions)
  - Affine Velocity

WHAT IS AFFINE VELOCITY

Relation between geometry and kinematic first shown in 2D drawing: 
\[ v = v_K K^{-1/3} \]
- With the curvature \( K \)

New power law for 3D movement:
\[ v = v_K K^{\alpha} \]
- With the torsion \( \tau \)
- \( \alpha \) and \( \beta \) are exponents that depend of the studied movement

WHAT IS AFFINE VELOCITY

Logarithmic linearization to find \( \alpha \) and \( \beta \) for laparoscopic gesture:
\( \alpha = -0.048 \), \( \beta = -0.0026 \)

RESULTS

Panel of 77 subjects separated initially into 4 groups:
- Expert surgeon: more than 100 interventions
- Intermediate: between 5 and 20
- Unexperienced intern (BSS): witnessed but never performed
- Novice

<table>
<thead>
<tr>
<th>Group</th>
<th>Intern</th>
<th>Expert</th>
<th>Intermediate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert</td>
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<tr>
<td>Intermediate</td>
<td>P&lt;0.05</td>
<td>0.43</td>
<td>-</td>
</tr>
<tr>
<td>Novice</td>
<td>P&lt;0.05</td>
<td>P&lt;0.05</td>
<td>P&lt;0.05</td>
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</tbody>
</table>

Statistical test Kruskal and Wallis on affine velocity (above) can separate every groups but Experts and Intermediates, whereas collision alone could also not separate Novices from Unexperience Interns.

PCA with Expert and Intermediate fused with variables Collision, Time, and Affine Velocity

CONCLUSION

- A cognitive analysis of MIS enables to design a reliable and valid simulator.
- Affine velocity is a valid tool and another objective variable to evaluate a trainee skill on his trajectory.
- Once a certain level of skill is reached, it becomes harder to differentiate individuals.
- As feedback about skill level is displayed, the simulator should be effective in learning, this needs however to be confirmed by future investigations.

REFERENCES