Force-based Assessment of Skill in Minimally Invasive Surgery

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**Background and Motivation**

**Minimally Invasive Surgery (MIS)**

The fulcrum effect at the entry point:
- Reverses hand motion;
- Increases friction
- Significantly reduces dexterity, and
- Considerably degrades the sense of touch.

These limitations result in new perceptual-motor relationships that require training to overcome.

- Up to 7,000 deaths occur in Canada every year due to preventable surgical errors.
- Simulator training is effective if performance feedback is provided.
- Current performance measures rely on time and/or instrument or hand motion.
- It is difficult to relate these measures to task execution and safety.

**Force Sensing in Minimally Invasive Surgery**

The objective of this study is to evaluate the usefulness of force information during skills assessment and training or during surgery.

A set of laparoscopic instruments was developed capable of measuring position and tool-tissue force information in all directions.

**Experimental Methods**

**Hypotheses:**

1. A performance metric based on applied forces correlates better with experience level than time.
2. Visually providing force feedback will have an effect on performance.

Experiments were performed using the sensorized instruments in a laparoscopic training box.
A computer was used to record, calibrate and display the force and position data.

A complex procedure was performed composed of 5 tasks:
- Task 1: Palpation
- Task 2: Cutting
- Task 3: Manipulation
- Task 4: Suturing
- Task 5: Tying a surgeon’s knot.

Visual force feedback was provided as force bars that increased in size and changed colour (green, yellow, orange, and red).

Feedback was randomly provided in four levels:
- None
- Grasping force only
- Cartesian force only
- Both grasping and Cartesian forces.

**Experimental Design**

30 subjects performed the experiments a total of 4 times (17 novices, 13 experts).

The experiment was designed as a repeated measures study with feedback (2 factors at 2 levels) as a within-subjects factor and experience level as a between subjects factor.

<table>
<thead>
<tr>
<th>Basic</th>
<th>Detailed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice n = 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (n = 6)</td>
<td>No medical background, e.g., Engineers</td>
<td></td>
</tr>
<tr>
<td>2 (n = 6)</td>
<td>Medical students</td>
<td></td>
</tr>
<tr>
<td>3 (n = 5)</td>
<td>PGY 2-3 and surgeons with no MIS training</td>
<td></td>
</tr>
<tr>
<td>4 (n = 2)</td>
<td>PGY 4-5 with training</td>
<td></td>
</tr>
<tr>
<td>5 (n = 5)</td>
<td>Follows training</td>
<td></td>
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<tr>
<td>Expert n = 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 (n = 6)</td>
<td>Expert surgeons</td>
<td></td>
</tr>
</tbody>
</table>

Experience level was further divided into 6 different levels. A Spearman’s Rho correlation between experience and various performance measures was evaluated.

Performance measures included:
- Task completion time
- Maximum force
- Average force
- Force integral
- Force derivative
- High force ratio (% of time above 10 N)
- A measure that combines force and position

**Results**

The effect of visual feedback was minimal. Only two measures in three different tasks showed a significant difference.

Spearman’s Rho correlations were significant for all of the measures.

Stronger correlations were found for force-based measures or combined measures that those found for time.

**Conclusions and Future Work**

- Applied forces may be used in the development of MIS performance metrics. Performance metrics based on applied forces, and on a combination of force and position, correlate better with experience level than task completion time.
- Visually providing force feedback had minimal effect on performance. Only two measures were significantly affected by the availability of visual force feedback.
- Future work includes a second experiment to verify the performance measures proposed.