Construct Validity for the UCLA Laparoscopic Training System (LTS)

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Background: This study aims to establish the construct validity of new Laparoscopic Training Simulator (LTS) developed at UCLA. The system was developed due to the increasing demand for Minimally Invasive Surgery (MIS) coupled with the difficulty associated in training surgeons in the use of MIS techniques with traditional apprenticeship models. In addition to training issues, there exists an immediate need for an objective assessment of Minimally Invasive Surgery (MIS) skills and techniques required to ensure safe and high quality treatment as previously established [1]. While currently available training systems have been used they are slow in educating new surgeons and they do not provide an objective assessment. The new system developed UCLA-LTS [2] addresses these very issues by combining the simplicity of the traditional training box with the advances in computer simulation technology to both train and to assess skill level.

Methods: The current study focuses on the construct validity that evaluates whether the UCLA-LTS system can distinguish different skill levels. We converge on the differences for the kinematic performance metrics, time to completion, path length, and acceleration at the instrument tip [2], between experienced surgeons and novice trainees. To illustrate the advantages of the UCLA-LTS system we compare the performance scores of test subjects with two levels of skills, expert (n=4) and novice (n=25). A set of three different training tasks, previously validated in other studies [3], with progressively increasing difficulty were performed in sequential order by all test participants. The "peg transfer", Fig-1(a), consists of picking up a rubber piece located on a peg with one instrument; transfer it to the 2nd instrument, which is subsequently placed on the other peg. An increasingly more difficult task, "pass the rope", Fig-1(b), consists of passing a rope from the right hand instrument to the left hand instrument and reverse by grabbing it at specific points marked in one inch intervals. Finally, a "cap the needle" test, Fig-1(c), requires the subjects to grab the needle with the right hand instrument while the left hand instrument grabs a cap and places the needle in the cap.

***Statistical Analysis*:** The study uses a t-Test to evaluate the differences between the two groups, and box plots to show the distribution for each variable. We require a P-value of at least 0.05 for statistical significance.

***Materials*:** The UCLA-LTS, described previously [2] is a modular system consisting of a traditional laparoscopic training box combined with state of the art DC electromagnetic motion tracking system, with the sensors directly integrated into the instruments. These sensors provide real-time tracking of the spatial positions of the instruments, visually represented in a 3-D animated space using computer graphics. A desktop PC collects all the motion sensing data, and provides the visual feedback.

***Results*:** Based on the data collected, Construct validity of the UCLA-LTS was completed. Test data supporting this includes individual kinematical parameters that demonstrate novice test subjects require, on the average about twice to three times as long to perform a given task, Fig-2. In addition to temporal length scales, the instrument tip travels about three times further for novice users. More importantly, the volume defined by movement of the instrument tip is significantly larger for the novice subjects, reflecting an increased risk to injury due to unintended collisions with surrounding anatomy. Other highlighted data includes a relatively flat learning curve for the expert subject whereas the novice subjects' experience a sharp increase in capabilities following the first 5-6 test runs before if begins to level out. These findings are consistent with observations of previous studies [3]. In addition to these findings, we observed significant performance differences between the left hand and the right hand for the novice subjects, as compared to the experts, Fig-3. Statistical measure of performance for the expert group, a randomly selected novice and the other entire novice group in Table-1 clearly differentiates between the experts and the novice.

***Conclusion*:** This study establishes the construct validity of the UCLA-LTS. Kinematics based parameters are employed in the assessment of performance as a means to both automate the scoring process, but more importantly to provide an objective measure to the otherwise subjective, observation based scoring of MIS training. This system thus can be used to both train novice surgeons as well as assess the skill levels of surgeons. Current work to be presented includes evaluation of the expedited learning curve to educate novice surgeons on MIS procedures.

Key words: Minimally Invasive Surgery, MIS, laparoscopy, education, surgical skills, objective assessment, and kinematics for instrument tips.

1. Rosser, J.C., et al, Objective Evaluation of a Laparoscopic Surgical Skill Program for Residents and Senior Surgeons. Arch Surg, 1998. 133(6): p. 657-661.
2. Nistor, V., et al. Immersive training and mentoring for laparoscopic surgery. in Nanosensors, Microsensors, and Biosensors and Systems 2007. 2007. San Diego, California, USA: SPIE.
3. Jourdan, I.C., et al., Stereoscopic vision provides a significant advantage for precision robotic laparoscopy. British Journal of Surgery, 2004. 91(7): p. 879-885.

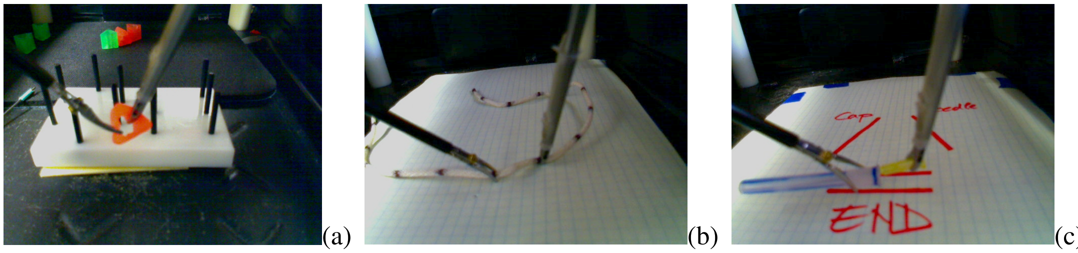

Fig-1, Training tests for the evaluation of performance scores (a) “peg transfer”: (b) “rope pass”; (c) “needle cap”

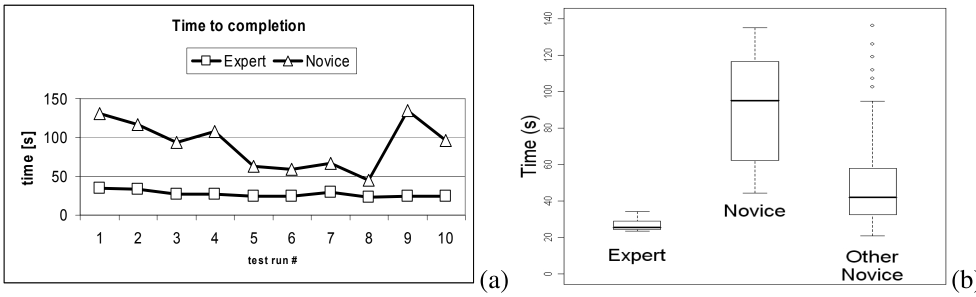

Fig-2. “Time to completion” performance metric. The experts’ learning curve is almost flat for the 10 test runs (a), whereas the novice shows a sharp slope for the first 5-6 test runs. Towards the end of the run, usually the novice trainee gets fatigued and the time to complete the task increases. A novice trainee takes more than 3 times as long to perform the same task (b), and more significantly the error distribution is about 10 times as much as for the expert. For the entire novice group the distribution of “time to completion” is a lot more compact than compared to the individual trainee (b)

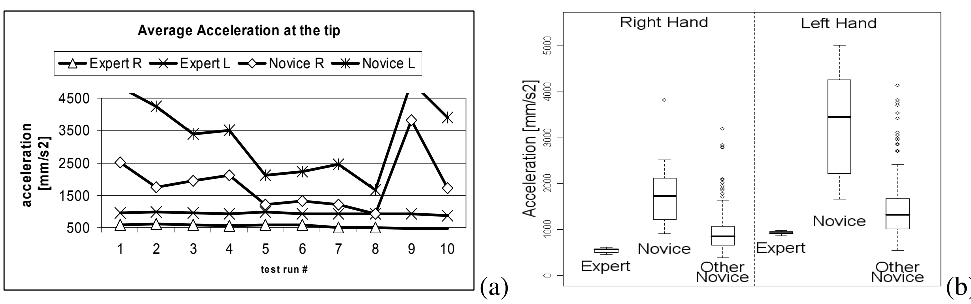

Fig-3. A good indication of the motor skill is the acceleration as experienced at the tip of the instrument. We can see a significant (> 3x) difference between the expert and the novice. We observed large differences of skill between the dominant and non-dominant hand for the individual novice as well as the entire novice group.

		EXPERT GROUP	*INDIVIDUAL NOVICE*		*NOVICE GROUP*	
PERFORMANCE METRICS		Mean (SD)	Mean (SD)	P-value	Mean (SD)	P-value
Time to completion [s]		27.1 (3.9)	91.3 (31.7)	0.001	47.3 (22.3)	<0.001
Path length [mm]	Right hand	869.5 (80.4)	2566.4 (914.0)	0.002	1455.1 (986.2)	0.001
	Left hand	863.1 (45.4)	2904.8 (942.5)	<0.001	1365.2 (551.5)	<0.001
Acceleration [mm/s^2]	Right hand	545.7 (54.40	1849.3 (843.6)	0.009	1178.1 (1763)	<0.001
	Left hand	933.2 (31.7)	3336.6 (1180.9)	0.001	1462 (696)	<0.001

Table-1. presents statistical measure of performance for the expert group, versus a randomly selected novice individual, and versus the entire novice group. These kinematical performance metrics clearly show with a high degree of statistical significance, measurable differences in psychomotor skill as measured by these metrics between the expert group, the individual novice as well as the entire novice group.