A Feasibility Study for the Validation of the Virtual Reality Motor-Skills Simulator

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Introduction

Virtual reality simulators have been demonstrated to be a useful and valid motor skills training instrument for laparoscopy surgery.[1-3] The Virtual Reality Motor Skills Simulator (VRMSS) is a low cost virtual reality distributed computer training system designed to teach fine-motor skills needed in performing laparoscopic surgery.[4] Endoscopic and microscopic formats are also utilized.

VRMSS trains fine motor skills by implementing 3D graphics and haptics (force-feedback) in a virtual environment. VRMSS displays beadlike objects that the user must move between cups within a 3D field of view. Complexity is varied by changing hand use, i.e., non-dominant or bimanual, with or without wrist rotation. A foot pedal is used in the microscopic format for zooming. Environmental factors, including depth of field, decreased exposure, and obstacles, are also introduced to increase difficulty. All actions are objectively recorded and a score is generated.

The following describe technical aspects of VRMSS:

- VRMSS uses an off-the-shelf desktop computer and Phantom Omni (Sensable Technologies, Woburn, MA) haptic devices.
- VRMSS is built on the open source SPRING real-time surgical simulation system and can function in either a standalone or a distributed sever/client based model.[5]

Tools and Methods

The study was designed to assess whether the VRMSS system can both train and measure motor skills used in laparoscopic, microscopic, and endoscopic surgery. Performance improvements were expected in repeated similar tasks and performance decrements were expected as difficulty of the tasks increased. Data were collected at the 2006 Medicine Meets Virtual Reality annual meeting,

Quantitative metrics on speed, accuracy and economy of motion were recorded for ten tasks, i.e., five task difficulty levels each performed twice.

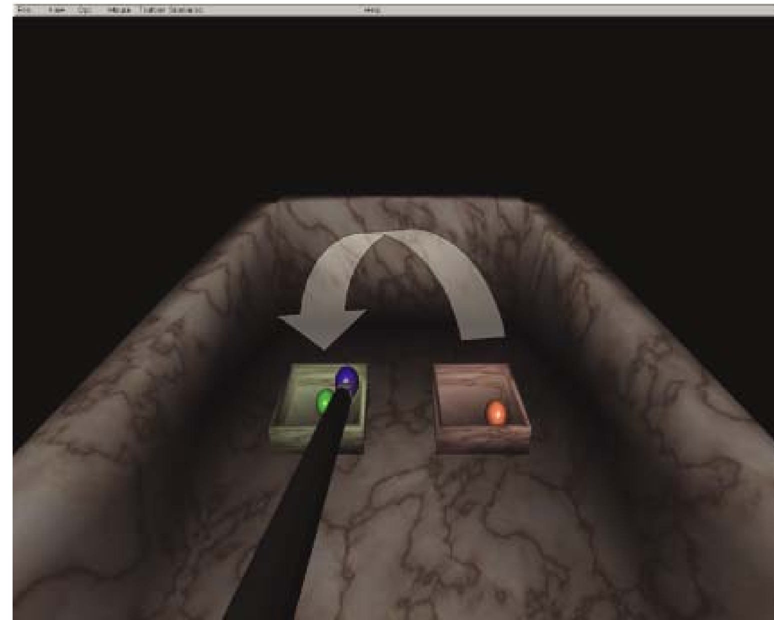

Figure 1. Basic Training (Level 1 difficulty)
Tasks 1 and 2: Environment for grasping and transfer skills involving dominant hand, task is to move bead to adjacent cup
Tasks 3 and 4: Environment for grasping and transfer skills involving non-dominant hand, task is to move bead to adjacent cup

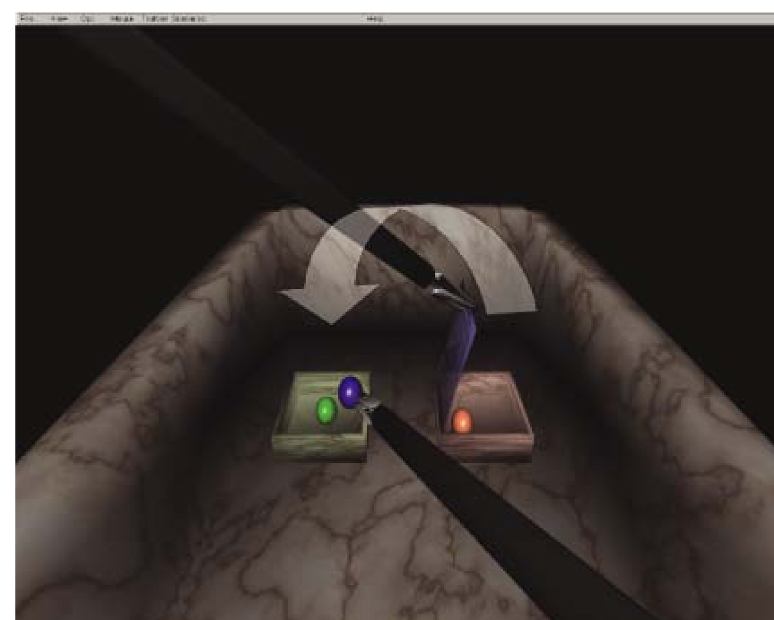

Figure 2. Basic Bimanual Training (Level 2 difficulty)
Tasks 5 and 6: Open hinge with hand and cross over and move bead to adjacent cup with other hand

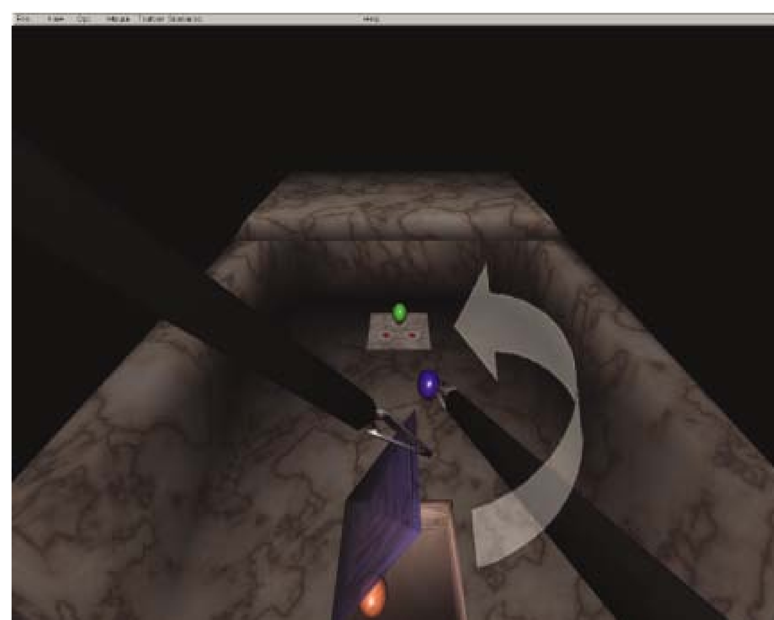

Figure 3. Basic Microscopic Training (Level 3 difficulty)
Tasks 7and 8: With narrowed surgical field to limit instrument movement, task is to open hinge with hand and move bead from forward cup to backward cup with other hand

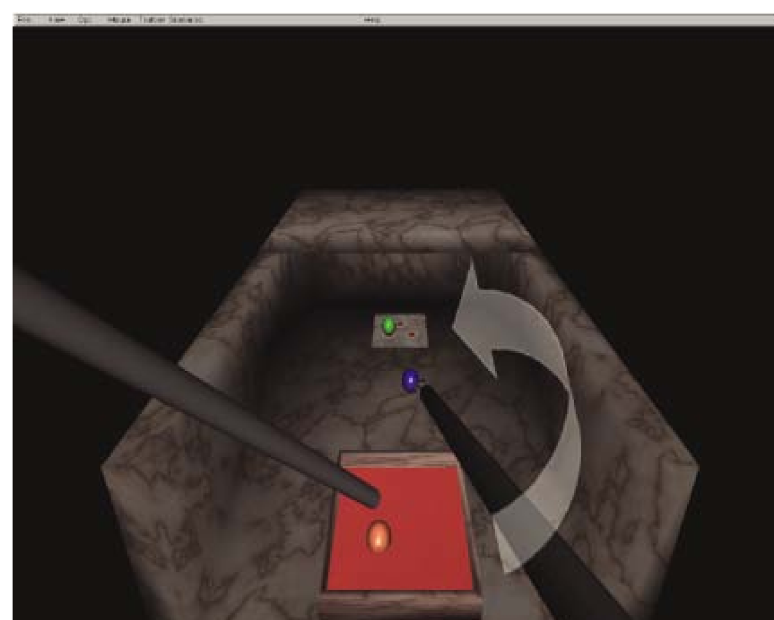

Figure 4. Bimanual Microsopic Training with Suction (Level 3 difficulty)
Tasks 9: With narrowed surgical field to limit instrument movement, task is to open hinge with hand and move bead from forward cup to backward cup with other hand

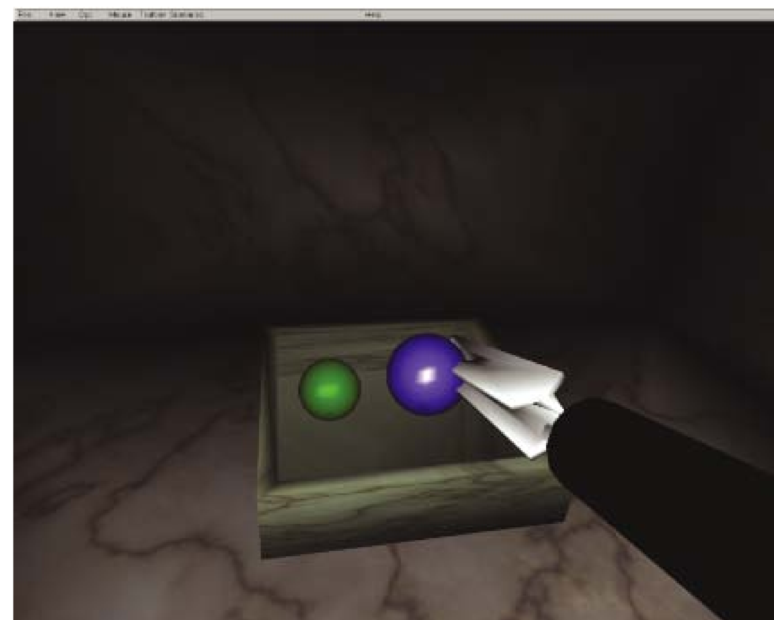

Figure 5. Bimanual Endoscopic Training (Level 3 difficulty)
Tasks 10: Task is to use endoscope with one hand and move bead from forward cup to backward cup using the other hand. Limited lighting requires moving endoscope and laparoscope in tandem

Statistical Analysis

Data were collected from 16 participants. Performance measures included the total time duration for task completion, number of errors committed, and economy of hand movement. The experimental design was a 5 X 2 repeated measures completely crossed factorial. The two variables were Task Difficulty (5 levels) and Task Repetition (2 levels).

Results

Each data set was analyzed using a 5 (Task Difficulty) x 2 (Task Repetition) repeated measures analysis of variance. All three data sets failed to meet sphericity assumptions. Therefore, multivariate F statistics (Pillai's Trace) are reported here. For time to complete each task, main effects for task difficulty and task repetition were statistically significant. For the number of errors made while completing each task, the main effect for task difficulty was statistically significant. For hand economy, main effects for task difficulty and task repetition were statistically significant (see Table 1 for details). All other main effects and interactions were non-significant.

Table 1. MANOVA for VRMSS Performance Measures

		F	df	p
Time to Compete Task	*Task Difficulty*	45.051	4/12	< .001
	Task Repetition	16.072	1/15	< .001
Number of Errors	*Task Difficulty*	6.750	4/12	< .001
Hand Economy	*Task Difficulty*	26.354	4/12	< .001
	Task Repetition	5.036	1/15	< .001

Discussion and Conclusion

The objective of this study was to assess user performance of the VRMS system. The results demonstrated that all three measures, i.e., speed, accuracy and economy of motion, were sensitive indicators of performance. Also, the scoring system provided an objective measure of performance. The system is flexible, in that multiple different scenarios can be implemented, with dynamic user feedback, and objective performance measurement. Further evaluation of VRMSS will include both studies in clinical outcomes and the cognitive processes of how virtual trainers improve skills.

References:

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