Medicine Meets Virtual Reality
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Validation Of Virtual Reality To Teach And Assess Psychomotor Skills In Laparoscopic Surgery: Results From Randomised Controlled Studies Using The MIST VR Laparoscopic Simulator.

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ABSTRACT

Objective assessment of surgical technique is currently impossible. A virtual reality simulator for laparoscopic surgery (MIST VR) models the movements needed to perform minimally invasive surgery and can generate a score for various aspects of psychomotor skill. Two studies were performed using the simulator: first to assess surgeons of different surgical experience to validate the scoring system; second to assess in a randomised controlled way, the effect of a standard laparoscopic surgery training course. Experienced surgeons (> 100 laparoscopic cholecystectomies) were significantly more efficient, made less correctional submovements and completed the virtual reality tasks faster than trainee surgeons or non-surgeons. The training course caused an improvement in efficiency and a reduction in errors, without a significant increase in speed when compared with the control group. The MIST VR simulator can objectively assess a number of desirable qualities in laparoscopic surgery, and can distinguish between experienced and novice surgeons. We have also quantified the beneficial effect of a structured training course on psychomotor skill acquisition.

INTRODUCTION

Laparoscopic surgery is difficult to perform and extensive training is necessary to master the skills to operate safely[1]. Although technical expertise is only one of many factors which determines outcome from surgery, failure in the past to address the issue of training in psychomotor skills has become more obvious with the advent of laparoscopic surgery. The hand-eye co-ordination required to operate within the constraints of a two-dimensional image on a video monitor involves skills that are unfamiliar to most surgeons[2]. It has been estimated that some 10% of surgeons lack the visuo-spatial skills necessary to perform this type of surgery[3].

Practice on patients is no longer acceptable and a large number of courses for surgical trainees in all disciplines of minimal access surgery have been developed[4]. Tasks include simple transfer of small inanimate objects between containers up to highly complex tasks such as practising laparoscopic suturing on animal tissue. Up to now, the only assessment possible has been a subjective rating by the instructors of the trainees. It is widely regarded as an unsatisfactory method, prone to bias and variability[5]. The only absolutely objective method of measuring performance has been to record the time taken to complete a task[6]. Although good surgeons tend to perform procedures fairly quickly, using speed as a goal for surgical training is not ideal. This study aims to analyse laparoscopic movements in virtual reality in order to produce objective measurements of factors other than speed which can be used to distinguish between good and bad laparoscopic technique.

PURPOSE OF THE WORK

There are three main aims to the study:

1. To develop a reliable and feasible method to assess laparoscopic psychomotor skills on a MIST VR simulator.
2. To validate this scoring system by comparing surgeons of different laparoscopic experience on the MIST VR simulator.
3. To quantify the effect of a standard laparoscopic training course on MIST VR simulator score

METHODS

All the subjects were assessed on a virtual reality laparoscopic surgery simulator. The Mist VR system used for the trials was based on a PC running Windows 95. The PC was configured with a Pentium 133 MHz processor, 32 MB of RAM, a 1.6 GB hard drive, a Mattrox Mystique 4MB video card and a 21- inch monitor. The laparoscopic interface was a standard Immersion Corporation unit, with the addition of a foot pedal for the diathermy tasks. The trials ran Mist VR version 1.2 which currently utilises the WorldToolKit Version 6 and Microsoft Direct 3D Version 3 graphics libraries. Frame rates averaged around 15 fps and did not drop below 10 fps during the evaluations. The simulator and the tasks were described in detail at MMVR 1997.

Two tasks were chosen for detailed analysis: A simple task that involved picking up a virtual ball, placing it in a box and releasing it; a complex task which required participants to hold a target still while the other hand burns off subtargets by using a foot pedal to simulate surgical electrocoagulation. The x,y,z co-ordinates for both virtual instrument tip positions were recorded approximately every 0.05 - 0.1 seconds (depending on screen refresh rates). The kinematic data were re-sampled to ensure regular time stamping of 0.05 seconds, extrapolating to recalculate tip positions. The data were then filtered using a fourth order 1.5Hz Butterworth filter. Path length, path velocities and distance to target profiles were analysed to calculate:

1. Efficiency of movement (actual path length / ideal path length)
2. Number of submovements (Number of velocity peaks)
3. Errors (Number of movements away from the target)
4. Time taken to complete the virtual task.

Thirty subjects (experienced laparoscopic surgeons with > 100 cases (n=10), trainee surgeons (n=10) and non-surgeons (n=10)) were recruited for the validation study. All subjects were given identical tuition on the MIST-VR simulator to control for the limited cognitive skills required to perform the tasks and to familiarise them with the equipment. Six tasks which demanded different co-ordination skills were given in a progressive and identical sequential order. The final complex virtual task which involved

two-handed co-ordination and use of a foot pedal to simulate diathermy was used for the assessment. The scores for the repetitions were averaged and the groups compared.

To assess the effect of a training course, ten junior surgeons attending a Royal College of Surgeons of England basic surgical skills course were recruited. All subjects had assisted in laparoscopic procedures but never performed any laparoscopic surgery. On the first day of the course, all 10 subjects were assessed on the same simple virtual task. On the following day, 5 subjects were re-assessed after the skills training course. The course involved extensive hands-on training on standard closed box tasks developing simple hand-eye co-ordination manipulating laparoscopic instruments to dissect, cut, clip and transfer inanimate objects. The remaining 5 were used as a control group to correct for the learning curve of the MIST VR simulator itself, and were re-tested before any hands-on training. Both groups had identical exposure to the Mist VR simulator. The Mann-Whitney *U* test was used for non-parametric analysis.; $p < 0.05$ was considered statistically significant.

Table 1. The effect of previous laparoscopic experience on performance in VR

Mean ± SD Complex task	EXPERIENCED SURGEONS	TRAINEE SURGEONS	NON-SURGEONS
EFFICIENCY (path ratio)	2.3 ± 0.3	3.3 ± 1.3	3.6 ± 1.0
ERRORS (past pointing)	4.8 ± 0.8	6.3 ± 2.3	7.3 ± 2.2
SUB - MOVEMENTS	10.4 ± 3.4	15.9 ± 4.4	18.5 ± 6.1
TIME TAKEN (seconds)	13.7 ± 2.6	19.3 ± 5.4	21.9 ± 6.7

Significance (Mann Whitney U)	Experienced Vs Trainees	Experienced Vs Non-surgeons	Trainees Vs Non-surgeons
EFFICIENCY (path ratio)	$p < 0.04$	$p < 0.01$	NS
ERRORS (past pointing)	NS	$p < 0.01$	NS
SUB - MOVEMENTS	$p < 0.02$	$p < 0.01$	NS
TIME TAKEN (seconds)	$p < 0.02$	$p < 0.01$	NS

Table 2. The effect of a training course on performance in VR

Mean ± SD Simple task (1)	TRAINED	UNTRAINED	Significance Mann Whitney U
EFFICIENCY (path length ratio)	2.8 ± 0.7	3.5 ± 0.9	$p < 0.02$
ERRORS (past pointing)	2.3 ± 1.1	3.6 ± 1.1	$p < 0.02$
SUB - MOVEMENTS	8.4 ± 2.6	10.3 ± 2.4	n.s
TIME TAKEN (seconds)	9.3 ± 2.3	10.4 ± 2.1	n.s

RESULTS

1. Effect of previous laparoscopic experience on performance in virtual reality

Experienced surgeons performed significantly better in virtual reality than trainee surgeons on efficiency ratio (2.3 vs 3.3 ($p<0.04$)), number of submovements (10.4 vs 15.9 ($P<0.02$)) and time to complete task (13.7 vs 19.3 seconds ($p<0.02$)). There was no significant difference in the number of errors made (4.8 vs 6.3. As shown in *Table 1* experienced surgeons performed better than non-surgeons on all 4 criteria ($p<0.01$), but there was no significant difference between trainees surgeons and non-surgeons. There was a large variation in ability in the inexperienced groups with some trainees scoring as well as the best experienced surgeons for efficiency and errors (*Fig.1*).

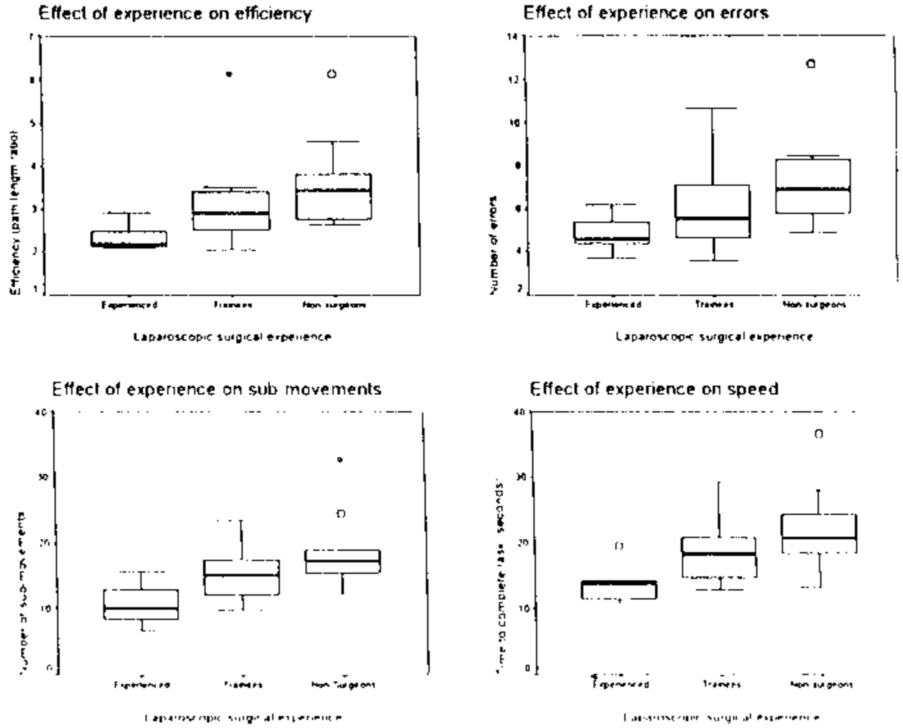
2. Effect of the training course

As shown in *Figure 2* both groups were well matched on the first assessment. On the second assessment the trained group were more efficient than the untrained group (2.8 vs 3.5 ($p<0.02$)) and made less errors (2.3 vs 3.6 ($p<0.02$)). There was a small reduction in the number of submovements (8.4 vs 10.3) and time taken (9.3 vs 10.4 seconds) but this did not reach significance (*Table 2*)

CONCLUSION

The MIST VR simulator offers an opportunity to assess a surgeon's technical expertise in laparoscopic surgery. By tracking the movement of the instruments and correlating that with the virtual tasks, a detailed analysis of how well the task has been completed, rather than simply how quickly it has been done, can be produced.

Figure 1. The effect of experience on psychomotor skill assessed on a complex MIST VR task (task 6)

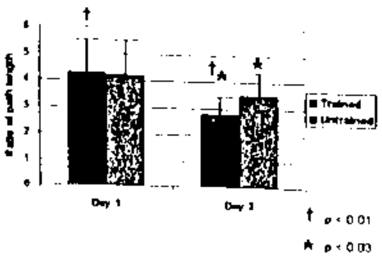


This study has demonstrated that experienced surgeons outperform trainee surgeons by measurable, objective criteria on a virtual reality simulator. Moreover, a randomised controlled study has shown that a Royal College of Surgeons approved course has taught juniors to make less errors and to operate more efficiently than their untrained contemporaries, without a significant decrease in time to complete the tasks.

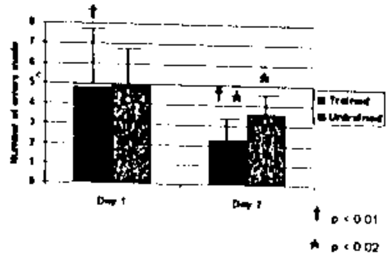
An unbiased method of measuring psychomotor skill in laparoscopic surgery could guide training by providing detailed and constructive feedback and could identify those who require additional training before being allowed to operate on patients.

... a training course on psychomotor skill asssessed on a simple MIST VR task (task 1)

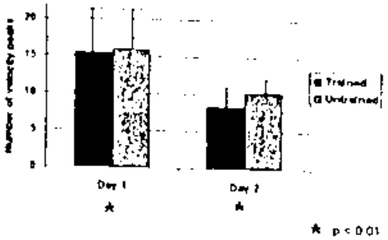
Effect of training on efficiency



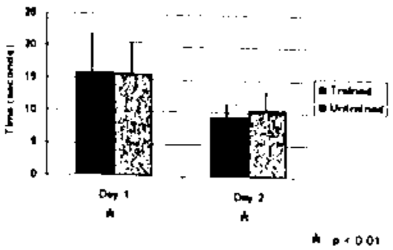
Effect of training on errors



Effect of training on sub-movements



Effect of training on speed



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3D and 4D atlas system of living human body structure

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Abstract. A reference system for accessing anatomical information from a complete 3D structure of the whole body "living human", including 4D cardiac dynamics, was reconstructed with 3D and 4D data sets obtained from normal volunteers. With this system, we were able to produce a human atlas in which sectional images can be accessed from any part of the human body interactively by real-time image generation.

1. Preface

A human atlas from which both accessing morphological and anatomical information can be readily accessed in a 3D format would provide powerful tool for both clinical medicine and basic medical research. The advent of a number of medical imaging techniques which produce 3D images have increased the demand for such a these 3D atlas for medical education. Our aim is to produce a database of living human anatomy based on 3D structure and 4D dynamics obtained by non-invasive measurement techniques such as MRI.

In 1986, we developed a "3D Human Atlas", which was intended for use with a personal computer [1]. However, personal computers at that time were not powerful enough to handle complicated human 3D structures. We could only install very simple human models in the system, despite the very detailed anatomical information obtained from serial MRI data sets. As a result, the system was only useful for basic education. Recent advances such as high-speed graphic work stations and a network system, have made it possible to construct a more comprehensive 3D atlas.

We have also tried to re-make our 3D atlas system by applying these devices [2]. Recently, according to the growth of imaging diagnosis with 3D imaging and progress in computer graphics, the development of a 3D human atlas has been attempted by many investigators, not only the enormous Visible Human Project [3-6] and the Voxel Man [7], but also the work of many resarchers who are creating a human atlas system using high speed graphic workstations and multi - media systems. New ways to observe human anatomy, such as virtual endoscopy and surgery rehearsal are also being developed by applying these digitalized human body data [8-11].

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