THE EFFECTS OF COGNITIVE DISTRACTION ON PERFORMANCE OF LAPAROSCOPIC SURGICAL TASKS

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Running Title: Cognitive Distraction in Laparoscopic Tasks

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ABSTRACT

Hypothesis: To quantify the effects of cognitive distraction on surgical task performance in residents and medical students using a laparoscopic surgical simulator.

Design: Within-subjects design.

Setting: A surgical skills laboratory.

Participants: Thirteen surgical residents and medical students volunteered for the study.

Interventions: Subjects performed six tasks on the Minimally Invasive Surgical Trainer – Virtual Reality (MIST-VR), under two different conditions (distracted and undistracted). Task order remained the same for all subjects, but the order of distraction was counterbalanced. In the distracted condition, distractions consisted of mental arithmetic problems posed sequentially so that subjects were continually distracted.

Main Outcome Measures: Time to task completion, surgical errors committed, economy of motion, and overall performance score were generated by the MIST-VR program software. Arithmetic error was not a factor in the overall performance score.

Results: Time to task completion was significantly greater when subjects were distracted. This was true for all six tasks performed. Overall score and economy of motion were negatively affected by distraction but the effect did not reach a level of statistical significance. There was no effect of distract on surgical errors.

Conclusions: Cognitive distraction appears to negatively influence the performance of laparoscopic surgical tasks by increasing task completion time. Further study is required to determine what the effects would be on experienced surgeons and actual surgical outcomes.

INTRODUCTION

Common sense would suggest that a surgeon's peak performance can be affected by noise and other distracting activities in the operating room environment. In fact, the operating room is a noisy and dynamic environment; sounds from phones, pagers, patient monitors, surgical equipment, background music, and conversation can be as high as 80-85 dB[1,2]. However, even though noise is an environmental pollutant, it has been shown that surgeons' performance on a surgical task simulator is not affected by loud noise (80-85 dB) or background music[3]. Furthermore, music has been shown to lower autonomic reactivity and increase speed and accuracy of a subtraction task for surgeons in a controlled environment, compared to no music at all[4]. Therefore, a more likely candidate distractor for surgeons may well be of the cognitive type – when they are pressed to answer questions about a patient on another floor, make a scheduling decision, or predict the timing of their current operation. In fact, a survey of orthopedic surgeons revealed they viewed "full focus" and "distraction control" to be important factors in attaining an excellent outcome[5]. Research on the impact of distraction on performance has largely been limited to measuring the effects of distraction on purely cognitive tasks (i.e., memorization or reading comprehension tasks)[6,7,8,9] or purely motor ones (i.e., walking on a treadmill or finger-tapping)[10,11,12]. These studies have successfully demonstrated performance decrements in various cognitive and motor tasks when a cognitive distraction was imposed. One study specifically compared the effects of using a secondary cognitive task to distract subjects while performing a primary cognitive task and found that the effect of a secondary cognitive task was similar to the effect of lorazepam (a depressant) use concurrent with primary task performance[9]. Laparoscopic surgery, however, is a complex task likely involving both motor and cognitive functions and utilizing multiple areas of the brain concurrently. This study aims to determine the effects of cognitive distractions on laparoscopic surgical task performance, using the Minimally Invasive Surgical Trainer – Virtual Reality (MIST-VR), a validated surgical training simulator[13].

MATERIALS AND METHODS

Thirteen medical students and surgical residents were recruited for this study. The study was approved by the hospital Institutional Review Board. All subjects had been previously trained once on the MIST-VR and were given an opportunity to watch the "demo" for each task before the experiment.

Subjects completed one trial each of six simulated laparoscopic surgery tasks on the MIST-VR in both distracted and undistracted conditions. For a description of tasks, see Table 1. The order of tasks remained the same for all subjects, but the order of distraction was counterbalanced. During each trial where subjects were distracted, the experimenter posed a series of arithmetic problems (e.g., What is 11 x 14?) to be solved without external aid. The difficulty level of these arithmetic problems was kept at a medium level to ensure sufficient loading of surgeons' cognitive resources, yet not too difficult to prevent performance. This would also serve to confirm our assumption that laparoscopic surgery requires cognitive functions in addition to motor skills. As soon as one problem was solved and reported verbally by the subject, another was posed so that subjects were continually distracted. If a problem was answered incorrectly, the participant was asked to "try again". The question was repeated when a subject appeared to stop working on the arithmetic problem. The number of errors committed and the number of problems solved were recorded for each task but did not figure into the performance score. Spontaneous comments or questions by subjects were answered as briefly as possible.

Measurements of performance were tracked and recorded by the MIST-VR software program. They were time to task completion, number of errors committed, economy of motion and an overall performance score. Single factor ANOVAs were conducted on each performance measure for all six tasks. The level of statistical significance was set at $p=0.05$.

The study was performed in the Surgical Skills Research Laboratory in a hospital, an environment that is relatively quiet but not immune to the sounds of passersby, overhead announcements, and phones ringing. This environment was the same for all subjects, no unusual amounts of noise or other distractions were noted.

RESULTS

We found a significant increase in the time to task completion for all six tasks in the distracted condition compared with the undistracted condition (See Figure 1 and Table 2). Analysis of the economy of motion (see Figure 2) and overall score (see Figure 3) data for all tasks showed a clear trend towards poorer performance when subjects were distracted. However, the decrement failed to reach a level of statistical significance (set at $p < 0.05$). This trend was reflective of the percent change calculated between distracted and undistracted trials for all performance parameters. Examination of the data for distracted vs. undistracted time showed a 30-40% change in time to task completion. Economy of motion showed a clear but modest increase of 15-25%, depending on the task. Overall score had a widely variable difference for different tasks, from 20-40%. Post-Hoc analysis was conducted to determine if more complicated or more difficult tasks showed a greater effect than simpler ones, but the task type did not appear to consistently influence the decrement caused by distraction. Errors (as predetermined by the MIST-VR software) did not show a consistent variation based on the presence or absence of distraction.

DISCUSSION

It would seem to be self-evident that surgeons would perform best when they are allowed to fully concentrate on an operation without being distracted. However, given the time pressures and busy practices of today's surgeons and hospitals, such an environment would be an unusual luxury. In fact, it is routine in most operating rooms for the surgeon or assistants to be interrupted several times to answer questions, make a decision on an unrelated matter, or to predict the timing or schedule of his or her day. Even within an operating team, attending physicians often teach by using the Socratic method. This questioning creates not only a purely auditory distraction, but a cognitive one as well. The operator must think about the answer while simultaneously thinking about the case at hand, and continuing the motor task of operating.

Previous research has demonstrated the negative effects of cognitive distraction on performance of cognitive and motor tasks. This study looked at virtual reality laparoscopic surgical simulation tasks that combine motion and cognition, designed to replicate the levels of cognitive and motor demands in surgical procedures. A number of studies have validated the MIST-VR as a useful tool for training surgeons and surgical residents[13-20], and additional work has shown that the MIST-VR system successfully discriminates between skill levels and thus may be used for analysis of surgical skills[21-24].

Our results showed a clear difference between distracted and undistracted task performance. However the magnitude and consistency of the difference varies with the performance parameter that was measured. Time proved to be the parameter most sensitive to the influence of distraction – all tasks showed a statistically significant increase in task time when subjects were distracted. Our observations suggested that this was because participants would pause their surgical task briefly when they were given a cognitive distraction. According to Baddeley's multiple resource model in information processing[25], our results suggest that the arithmetic problem was competing with the laparoscopic task for cognitive resources, confirming our assumption that laparoscopic tasks require cognitive functions in addition to motor functions. This result is similar to that observed in a study of students who attempted to complete homework while watching television[7]. In that British study, homework performance suffered because students paused to look at the TV and then continued work. Our scores for economy of motion also suffered when participants were distracted –because the pause is an inefficient motion or because tools are rarely held completely still during such pauses. The overall score is comprised of these parameters (plus a score for errors) so it is not surprising that the overall score showed a decrement during distracted tasks as well.

Surgical errors, as calculated by the MIST-VR software program, were also measured but did not show a consistent or significant increase when subjects were distracted. We hypothesize that this, too, was the result of the subjects' tendency to pause work while solving their arithmetic problem. Though a pause took time and was inefficient, movements occurring during such a pause were slight and no errors were recorded. In addition, it did not appear that the shifting of attention back and forth in and of itself led to errors. This was in contrast to the result of other studies, which showed that a distraction that caused an attention shift led to increased errors in performance of both cognitive[8] and motor[10,12] tasks.

While a clear trend towards worsening performance was observed in the distracted condition, only the time parameter showed a statistically significant difference. There was a 30-

40% increase in task completion time in the distracted vs. undistracted condition, compared with only a 15-20% increase in distracted vs. undistracted economy of motion score (the results for overall score were variable, with a 20-40% difference, and not all tasks reaching statistical significance). Because the trend is so clear but the percent change is small, we believe that enrolling additional subjects will allow us to increase the power of our study.

One of the limitations of this study is the fact that there was only one level of difficulty in the cognitive distraction. Graded levels of cognitive difficulty are needed to fully represent the range of distractions a surgeon faces in the OR. Further studies are also needed to determine the cumulative effect of all distractions in the operating room, especially given the beneficial effect of background music[4]. Even if surgical task performance is worse, it remains to be seen if there would be an actual effect on surgical outcomes. Furthermore, experienced and expert surgeons should be studied, as it is entirely possible that experienced surgeons are better able to "block out" distracting factors in the environment.

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TABLES

Table 1. Description of Tasks using the MIST-VR.

Task Abr.	Task Name	Task Description
AP	Acquire-Place	Target is grasped with a tool and placed in a box
WI	Withdraw-Insert	Target is grasped with a tool, touched with the opposite tool, and then held in a steady position inside a box while the second tool is withdrawn from the screen, reinserted, and touches the target again.
DT	Diathermy	A cautery tool (with foot pedal) is used to cauterize a stationary target
MD	Manipulate-Diathermy	Target is grasped with a tool and held in place while the other tool touches the target, is withdrawn, and then is used to cauterize the target while it is being held steady within a box by the other hand.
SS	Stitch Start	A needle is grasped and a suture is placed through tissue at a specified location
HSK	Half Square Knot	A needle is grasped and a single-throw knot is tied using an intracorporeal technique

Table 2. Effect of cognitive distraction on task performance.

	AP	WI	DT	MD	SS	HSK
Time (sec)						
Distracted	18.2	24.9	31.8	54.8	188	219
Undistracted	12.3	16.8	19.7	37.1	126.4	129.2
p-value	0.005	0.0028	0.00028	0.015	0.02	0.02
% change	32	33	38	32	33	41
Economy of motion						
Distracted	6.7	5.1	6.2	4.8		
Undistracted	5.4	4.1	4.6	4.1		
p-value	0.25	0.12	0.025	0.27		
% change	19	20	26	15		
Score						
Distracted	32	37.7	51.7	116	209.2	239.5
Undistracted	26.1	29.7	32.2	91.3	141.2	143.98
p-value	0.2	0.1	0.001	0.1	0.01	0.029
% change	18	21	38	21	33	40
Errors						
Distracted	7.6	9.2	56.5	13.7	21.2	20.5
Undistracted	8.4	9.8	50.1	7.9	14.8	14.8
p-value	0.8	0.9	0.6	0.2	0.08	0.3

LEGENDS OF FIGURES

Figure 1. Distracted vs. undistracted task completion times. All task completion times were greater for distracted compared to undistracted tasks. All differences were statistically significant at a $p < 0.05$.

Figure 2. Distracted vs. undistracted economy of motion score. Lower score indicates better performance. Suturing tasks (SS and HSK) did not record data on economy of motion. A trend was present suggesting worse performance when subjects were distracted.

Figure 3. Distracted vs. undistracted overall score. Lower score indicates better performance. Overall score is a combination of task time, number of errors, and economy of motion. A trend towards worse performance when subjects were distracted was observed.

Figure 4. Distracted vs. undistracted total errors. Lower score indicates better performance. There was no clear indication of a difference in performance as a function of distraction.

FIGURES

Figure 1

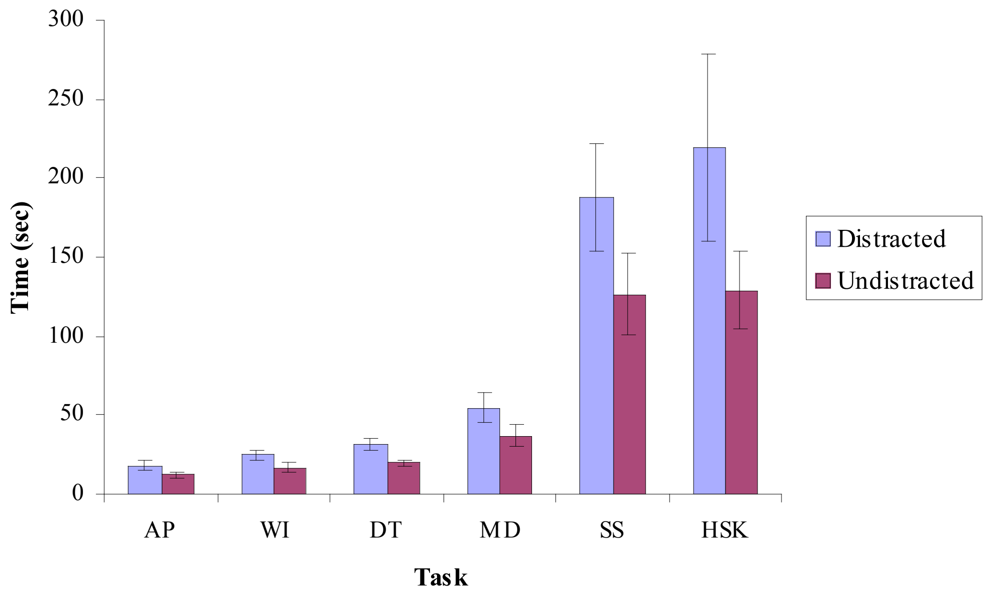


Figure 2

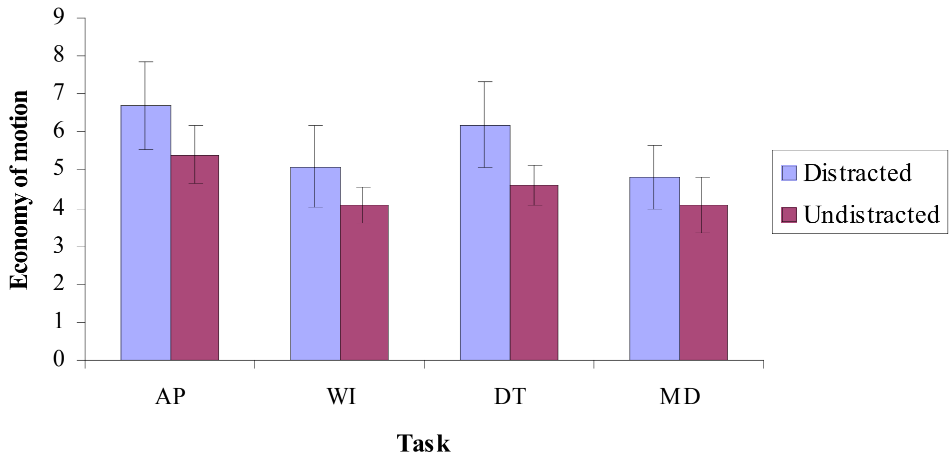

9
8
7
6
5
4
3
2
1
0
Economy of motion
AP
WI
DT
MD
Task
Distracted
Undistracted

Figure 3

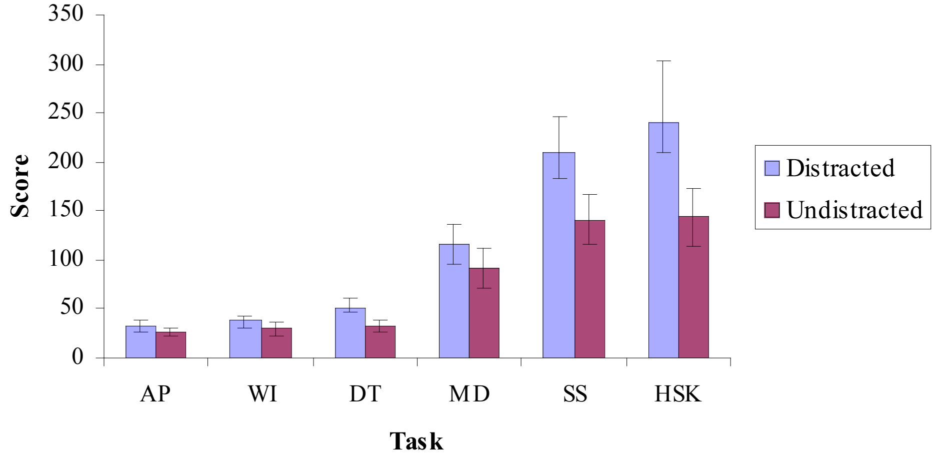
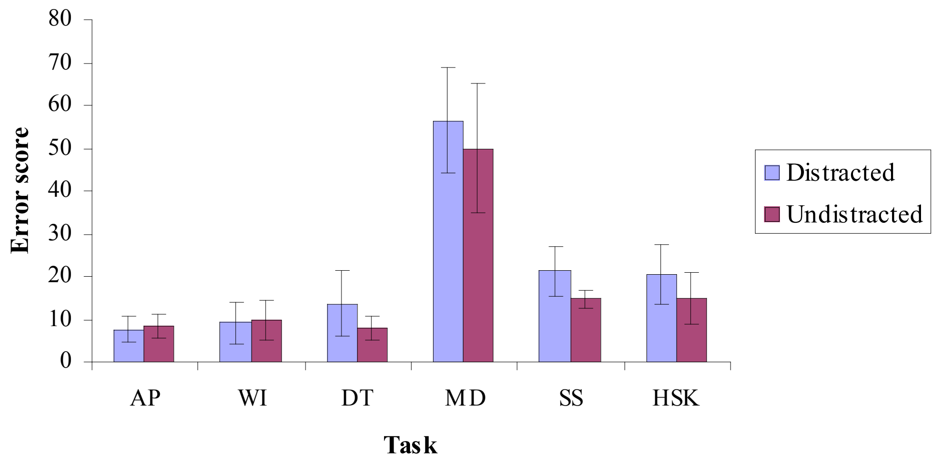

350
300
250
200
150
100
50
0
Score
AP
WI
DT
MD
SS
HSK
Task
Distracted
Undistracted

Figure 4



80
70
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50
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30
20
10
0
Error score
AP
WI
DT
MD
SS
HSK
Task
Distracted
Undistracted