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Objective Assessment of Laparoscopic Skills: Dual-Task Approach

Adam T. Meneghetti, MD, MHSc[1], George Pachev, MD[1], Bin Zheng, MD[1], Ormond Neely Panton, MD[1], and Karim Qayumi, MD[1]

Abstract

Background. Assessment of surgical performance is often accomplished with traditional methods that often provide only subjective data. Trainees who perform well on a simulator in a controlled environment may not perform well in a real operating room environment with distractions. This project uses the ideas of dual-task methodology and applies them to the assessment of performance of laparoscopic surgical skills. The level of performance on distracting secondary tasks while trying to perform a primary task becomes an indirect but objective measure of the surgical skill of the trainee. **Methods.** Nine surgery residents and 6 experienced laparoscopic surgeons performed 3 primary tasks on a laparoscopic virtual reality simulator (camera position, grasping, and cholecystectomy) while being distracted by 3 secondary tasks (counting beeps, selective responses, and mental arithmetic). Completion time and error rates were recorded for each combination of tasks. **Results.** When performed separately, time to completion and error rates for primary and secondary tasks were similar for learners and experts. When performing the tasks simultaneously, learners had more errors than experts. Error rates increased for learners when distracting tasks became more difficult or required more attention. Expert surgeons maintained consistent error rates despite the increasing difficulty of task combinations. **Conclusions.** The use of dual-task methodology may help trainers to identify which surgical trainees require more preparation before entering the real operating room environment. Expert surgeons are capable of maintaining performance levels on a primary task in the face of distractions that may occur in the operating room.

Keywords

simulation, skills assessment, dual task, surgical education

Introduction

Assessment of surgical-technique performance is often accomplished with the use of traditional methods (supervisor/observer evaluation with checklists, global rating scales, timing, review of outcome quality, etc).[1] Unfortunately, most of these assessment tools involve subjective analyses or qualitative data. Increasingly, surgical trainees are being evaluated using virtual reality simulators and computer records of performance that can provide more objective assessments of performance, such as number of errors and time to completion.[2] However, a trainee who performs well on a simulator that is in a controlled environment may not perform well in a real operating room environment. Part of this discrepancy is likely due to the distractions and stresses that are commonly found in the operating room.[3] Phone calls, pagers, equipment malfunctions, and time pressures are just some of the distractions that are present, which are not normally present in a skills lab or simulator environment.[4,5] Thus, the trainee has not attained mastery of the technique to allow for a consistently safe performance. An assessment method to distinguish between apparently safe and really safe will result in more focused training, less errors in practice, increased patient safety, and targeted remediation.

One way to address the construction of an assessment method that meets the needs outlined above is to use the achievements of dual-task methodology from human factors and psychology research. The conceptualization of dual-task methodology was started by Kahneman and Tversky[6] and was later developed in the works of others.[7-9] The fundamental assumptions of this methodology include the following: (*a*) cognitive resources for performing a task are limited; (*b*) the level of performance of a task depends on the amount of resources allocated to

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performance; (*c*) when more than 1 task is performed, the tasks compete for the limited resource pool; and (*d*) the degree of competition between the tasks is reflected in the level of performance of the tasks—if resource limits are exceeded by the joint task demands, performance on both (or, on 1 of the tasks, in the case of selective allocation of resources) will deteriorate. The degree to which the tasks interfere with each other depends on the degree to which they compete for the resource supply.

This project uses the ideas of dual-task methodology and applies them to the assessment of performance of laparoscopic surgical skills. Surgical trainees were asked to perform a primary task (on a surgical simulator) while at the same time they were distracted with secondary tasks that must also be completed. The ability of the trainees to perform successfully will depend on their ability to cope with demands of the 2 tasks. The more skillful they are in surgery, the better they will be able to cope with the increased demands introduced by the secondary (distracter) tasks. Thus, the level of performance on the secondary tasks becomes an indirect but objective measure of the surgical skill of the trainee.

Materials and Methods

Participants

Nine general surgery residents of varying skill level (R1 to R6) and 6 experienced laparoscopic surgeons working at Vancouver General Hospital volunteered for the study at the Centre of Excellence for Simulation Education and Innovation (CESEI), University of British Columbia. The study was approved by the Institutional Behavior Research Ethics Board.

Tasks and Measures

The participants were asked to perform 3 surgical tasks (primary tasks) on a SurgicalSim virtual trainer. These tasks were chosen from the tasks preprogrammed on the simulator and included the following:

Task A: Positioning a 30° laparoscope on a target with one hand and grasping the target with the other hand

Task B: Grasp an object with one hand and dissect tissue with a hook in the other hand

Task C: Laparoscopic cholecystectomy

Performance measures on the primary tasks were time to completion (in seconds) and total number of errors. These were recorded by the SurgicalSim trainer.

Three auditory-stimulus tasks (secondary tasks), requiring verbal response, were designed and administered via a laptop PC using the software package E-Prime V. 2.0, a product of Psychology Software Tools, Inc. These tasks included the following:

Task 1: Counting "beeps" (CB)—1, 2, 3, or 4 beeps were administered in rapid succession and the participant had to respond by stating the number of beeps they heard.

Task 2: Selected response (SR)—Participants heard a number from 1 to 10 and had to respond with the following number if they heard an odd number or the preceding number if the stimulus was an even number.

Task 3: Mental calculations (MC)—Participants heard a number from 1 to 10 and had to add it to or subtract it from a "starting" number (depending on whether they heard an even or an odd number).

The performance measures for the secondary tasks included reaction time from stimulus completion to voice onset for response (automatically recorded by the software) and error rates (number of errors divided by the number of stimuli). For this latter measure, the value of each response was entered on the computer by a research assistant and was scored automatically by the software.

Procedure

Each participant went through a sequence of 5 blocks of 3 trials. The order of blocks was the same but the order of trials within a block was random. The first block consisted of performing each of the 3 secondary tasks alone, while observing the animated tutorial for 1 of the primary tasks. For the CB and SR tasks, the order of stimuli was selected randomly by the computer and included 27 stimulus administrations. The MC task in this block consisted of 32 stimuli, 4 iterations of 8 stimulus sequences. For each task, the first 10 administrations were omitted when calculating the mean reaction time and error rate.

Values of the dependent measures in this block were used as baseline to control statistically for individual differences in speed and accuracy. This block was followed by a block of performing the 3 primary tasks alone, and then, by 3 blocks of concurrent task performance containing all primary–secondary task combinations in a random order. Two-minute breaks between blocks allowed participants to rest and the researcher to set up the next block. Overall, the procedure took between 1 and 1.5 hours to complete.

Analyses

Descriptive statistics were used to describe the distributions and performance curves of both groups for each of the

Table 1. Primary Task Alone, Concurrent Performance, and Overall Means (Standard Deviations) for Learners and Experts by Dependent Measure

	Learners			Experts		
	Alone	Dual	Overall	Alone	Dual	Overall
Time to completion (in seconds)						
Task A	204 (78)	192 (102)	194 (90)	293 (75)	269 (201)	276 (138)
Task B	204 (50)	140 (39)	156 (33)	223 (76)	171 (37)	184 (46)
Task C	351 (171)	279 (164)	297 (163)	350 (133)	244 (69)	270 (80)
Number of errors						
Task A	5.67 (2.88)	10.72 (10.41)	9.38 (8.33)	9.00 (7.07)	13.00 (11.20)	10.50 (9.24)
Task B	13.11 (14.28)	8.15 (5.92)	9.39 (7.69)	14.83 (9.95)	11.78 (4.38)	12.54 (5.61)
Task C	31.44 (22.64)	21.41 (18.70)	23.92 (19.15)	30.83 (19.75)	20.00 (10.27)	22.71 (12.54)

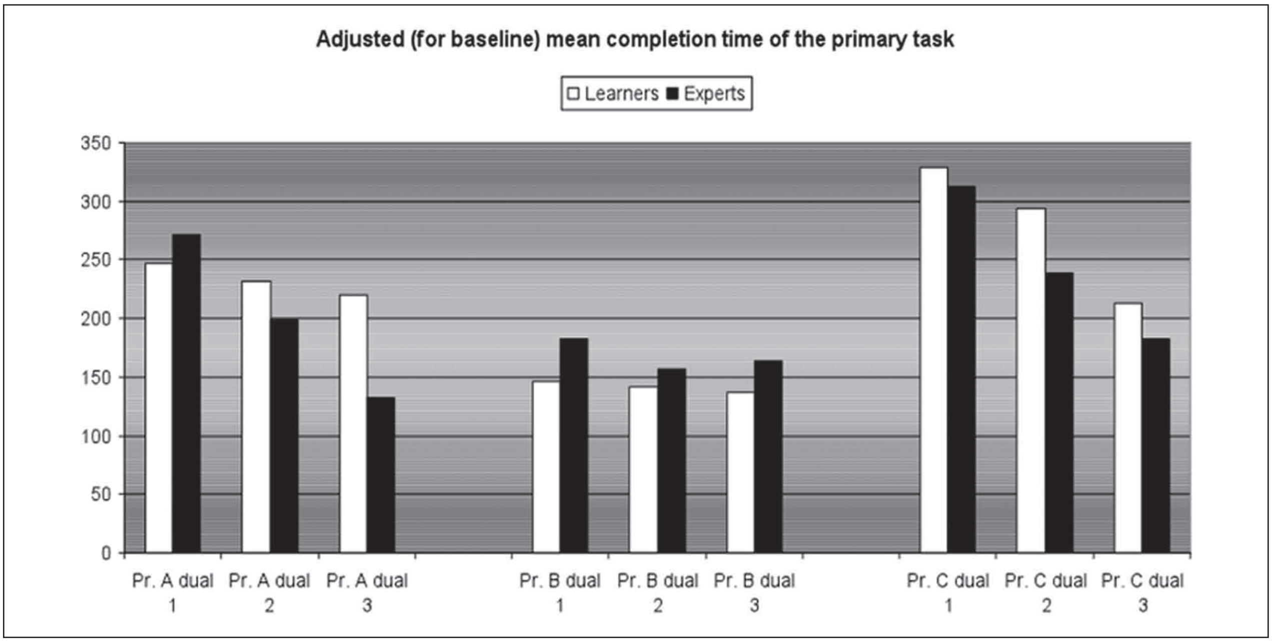

Figure 1. Time (seconds) to complete the 3 primary tasks (Pr A, Pr B, and Pr C) while distracted by secondary tasks

study blocks. Inferential analyses were carried out in the context of multivariate analyses of variance and covariance with Hotteling T criterion used for the “beginners” and “experts” between-group comparisons.

Results

A total of 9 general surgery residents were recruited. Six expert laparoscopic surgeons were also recruited. All participants completed the primary and secondary tasks.

Primary Task Performance

Table 1 displays summary statistics for primary task performance. There was no significant difference in time to completion or number of errors for the primary tasks between learners and experts. The laparoscopic cholecystectomy primary task required the longest time to complete and resulted in the most errors for learners and experts (see Figure 1).

It should be noted that the 3 attempts of the primary task in dual-task conditions are represented here with the mean of the 3 trials. This masks the “practice” effects in primary task performance and results in lower values on the dependent variables. Analyses of performance by order of task administration revealed similar “learner curves” for learners and experts, with increase in time to completion and error rates in the first concurrent performance trial and steady improvement in the next 2 concurrent performance trials.

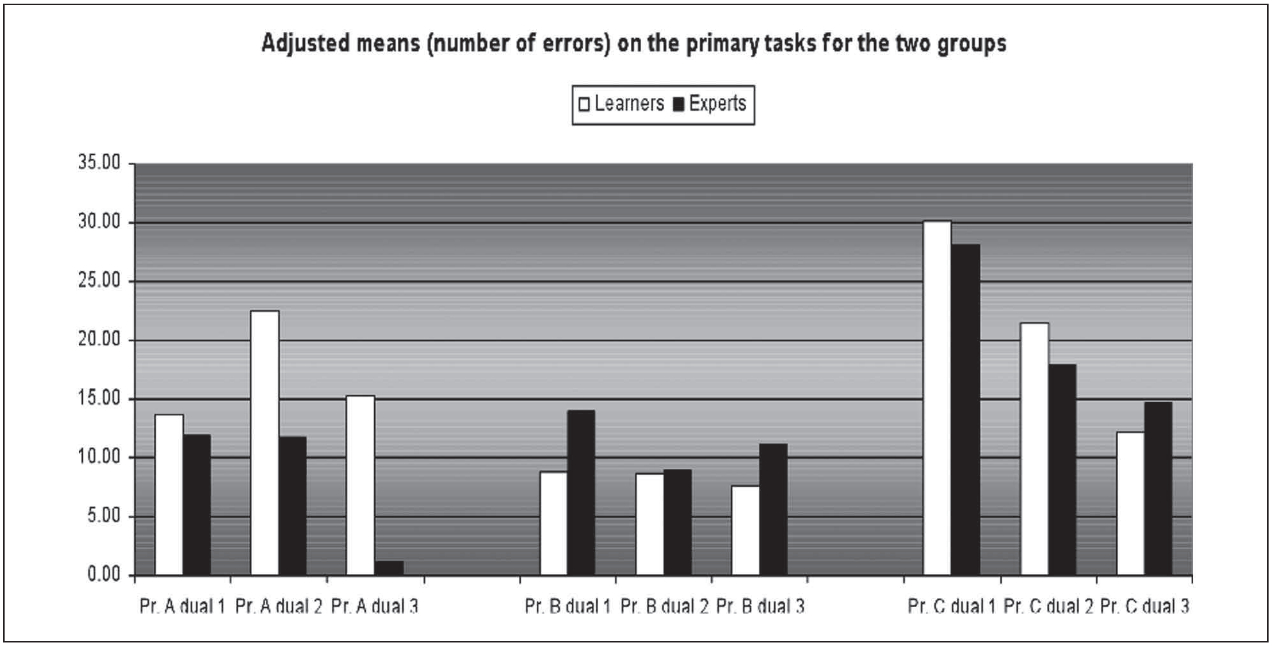

Figure 2. The number of errors made in the 3 primary tasks (Pr A, Pr B, and Pr C) while distracted by secondary tasks

Secondary Task Performance

There was no significant difference in time to completion for secondary tasks between learners and experts (Figure 2). As the secondary tasks increased in complexity from counting beeps to mental calculations, the response time increased for learners.

Table 2 lists the basic descriptive statistics for the reaction-time measure on the secondary task. Comparisons between the 2 groups, for all secondary tasks and in all secondary task conditions, failed to detect significant differences between the groups. Given the large intersubject variability, though, a proper estimate requires statistical accounting for differences in baseline performance. The test of the hypothesis was thus conducted in the context of multivariate analysis of covariance, with the respective baseline measure serving as covariates. The analyses of covariance revealed significant effects for the selected response secondary task and the scope-positioning primary task-combination, SR + A, $F(2, 8) = 6.92$ $P < .05$, and for the mental calculation in combinations with A, and C, $F(2, 8) = 8.28$, $P < .05$; $F(2, 12) = 12.21$, $P < .01$, respectively. MC + B combination was marginally significant, $P = .06$ (see Figure 3).

Analyses of the error-rate-dependent measure followed a similar sequence. Table 3 lists the statistics of the 2 groups' performance across the secondary tasks and their conditions. Overall, error rates were highest in all primary tasks when the distraction was counting beeps ($P < .05$). Within-group performance seemed to follow different patterns for learners and experts: the latter tended to maintain steady error rates for all combinations of exercises; there was less variation in their performance when compared with the learners. Learners, on the other hand, tended to increase the error rates in concurrent performance conditions, strongly expressed in their performance levels for the "counting beeps" task.

The analyses of covariance revealed significant effects for the counting beeps secondary in combination with scope-positioning and gall bladder removal primary task combinations, CB + A, $F(1, 7) = 15.25$, $P < .05$, and CB + C, $F(1, 7) = 7.68$, $P < .05$, respectively. No significant differences were detected by the selected-response secondary task. Mental calculation in combination with the gall bladder removal task yielded a marginally significant difference, $F(1, 8) = 3.87$, $P = .085$ (see Figure 4). All differences were in the hypothesized direction: experts committed fewer errors.

Discussion

The operating room is a stressful environment that requires attention to details by the surgical team to avoid errors. Unfortunately, there are often many distractions that occur such as pagers, phone calls, equipment issues, and so on.[10-12] Surgical trainees usually practice skills in a skills lab prior to coming to the operating room. The skills lab has the advantage of being a controlled environment with limited distractions. However, trainees who perform well in the skills lab may not perform as well in the real operating room because of the added stressors and distractions.[13]

Table 2. Secondary Task Performance (Reaction Time Measure, ms) for the 2 Groups on All Secondary Task Combinations

	Learners				Experts			
Tasks	N	Mean	SD	Adj. Mean*	N	Mean	SD	Adj. Mean*
Counting beeps (CB)								
CB task alone	9	1418	307		6	1241	158	
CB + primary A	7	1968	230	1906	3	1744	585	1889
CB + primary B	9	1821	331	1781	6	1599	341	1658
CB + primary C	9	1843	514	1804	6	1734	386	1793
Selective response								
SR task alone	9	1571	461		6	1684	244	
SR + primary A	7	2227	342	2236	3	1905	436	1885
SR + primary B	9	2304	556	2338	6	2191	495	2141
SR + primary C	9	2283	621	2327	6	2234	526	2167
Mental calculations								
MC task alone	9	1627	369		6	1988	493	
MC + primary A	7	2661	385	2736	4	2426	672	2294
MC + primary B	9	2316	504	2437	6	2423	543	2240
MC + primary C	9	2343	390	2407	6	2374	287	2278

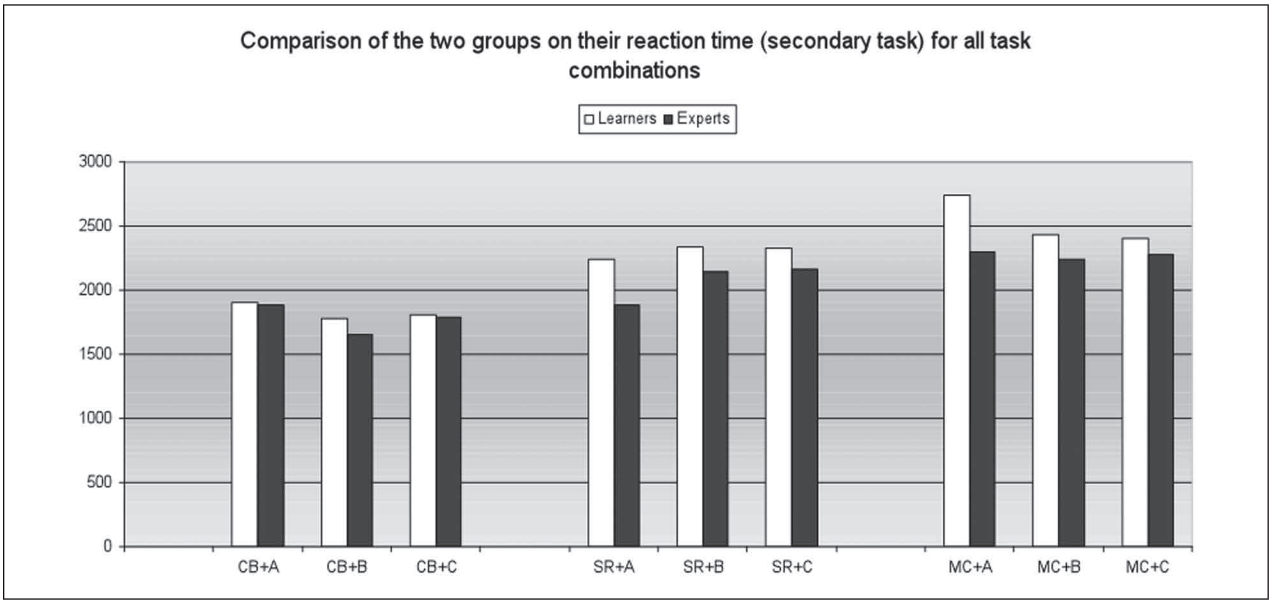

Figure 3. Reaction time (ms) to complete the 3 secondary tasks while performing primary tasks
Abbreviations: CB, counting beeps; SR, selective response; MC, mental calculation.

There are many studies looking at the effect of noise or other stressors on performance in the operating room.[14-17] In this study, we looked at the use of dual-task methodology to assess surgical trainees performing laparoscopic exercises on a virtual reality simulator. Participants were asked to perform a primary task while concurrently having to deal with a secondary task. The ability of the trainee to successfully complete the primary task is determined in part by their ability to cope with the secondary task. By increasing the difficulty level of the secondary task, an indirect objective assessment is made of the surgical trainee, as to how they might perform in a more realistic environment such as the operating room.

In this study, error rates for learners and experts increased when the distracting secondary tasks were introduced. The time to complete the tasks was similar for learners and experts; however, the number of errors that occurred differed significantly. Expert surgeons were able to maintain consistently low error rates no matter what type of distraction was encountered. Learners, instead, were not

Table 3. Secondary Task Performance (Error-Rate Measure) for the 2 Groups on All Secondary Task Combinations

	Learners				Experts			
Tasks	N	Mean	SD	Adj. Mean*	N	Mean	SD	Adj. Mean*
Counting beeps (CB)								
CB task alone	9	0.09	0.08		6	0.10	0.07	
CB + primary A	7	0.18	0.07	0.19	3	0.06	0.07	0.03
CB + primary B	9	0.13	0.09	0.14	6	0.12	0.07	0.08
CB + primary C	9	0.15	0.07	0.17	6	0.08	0.06	0.03
Selective response								
SR task alone	9	0.07	0.09		6	0.09	0.05	
SR + primary A	7	0.09	0.08	0.09	3	0.06	0.02	0.06
SR + primary B	9	0.07	0.08	0.08	6	0.08	0.06	0.05
SR + primary C	9	0.11	0.08	0.10	6	0.08	0.05	0.04
Mental calculations								
MC task alone	9	0.03	0.05		6	0.06	0.06	
MC + primary A	7	0.05	0.04	0.06	4	0.08	0.09	0.06
MC + primary B	9	0.09	0.10	0.09	6	0.09	0.08	0.08
MC + primary C	9	0.10	0.08	0.14	6	0.07	0.06	0.05

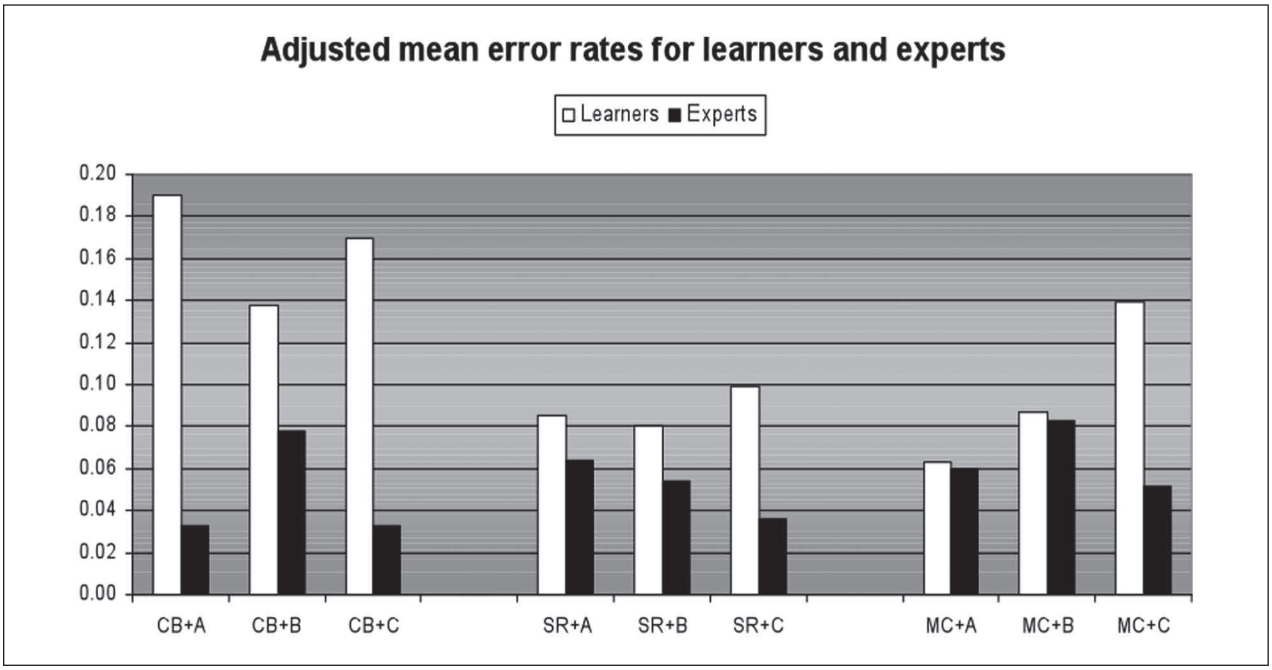

Figure 4. Error rates in the 3 secondary tasks while performing primary tasks
Abbreviations: CB, counting beeps; SR, selective response; MC = mental calculation.

able to cope as well with the distractions and this resulted in higher error rates. Hsu et al demonstrated similar findings.[18]

The secondary task that resulted in the most errors was the counting beeps task. The beeps were created using a laptop software program, and the beeps were administered rapidly. The participant had to carefully listen in order to determine the correct number of beeps and this is likely why the error rates were highest with this task. The most challenging primary task appeared to be the laparoscopic cholecystectomy exercise. This task required the most resources from participants in terms of hand–eye coordination, and as a result, when secondary distracters were introduced it resulted in the highest error rates.

One challenge to the dual-task approach is to design a task combination that allows for the sensitive detection of available resources. One obvious requirement is that responses to the 2 tasks should have different channels. If one and the same channel were used, the observed performance deterioration will be attributed to response interference rather than to processing resources. In the case of surgery as a primary task, the response channel for the secondary task should not involve any use of hands. A number of other requirements have been established empirically. These have been succinctly summarized by Damos[19]: (*a*) use of 2 physically separated stimuli results in more interference than using 2 superimposed or 1 shared stimulus, (*b*) performance decrement is larger when the stimulus modalities for the primary and secondary tasks are different, and (*c*) performance decrement is larger with stimuli that are not related and not predictable (ie, avoid sequence patterns of stimuli that can be learned easily by the subjects). In this project, we took into account these requirements when developing the primary and secondary tasks by having tasks of increasing difficulty (counting beeps to mental arithmetic). We also randomly administered the distracting tasks to avoid predictability.

Another challenge to the application of the dual-task approach for assessing resources has been the confounding effect of individual differences. Some participants may be fast to start with, whereas others may always respond slowly, so that different participants will have different baseline performance levels of the secondary tasks. To control for these differences, participants were asked to perform the secondary tasks alone until they reached a plateau of performance. This plateau then acted as the baseline for each individual participant.[20]

The goal for future studies will be to determine which types of distracters will work best as secondary tasks in order to maximize the effect on the cognitive resources of the trainee. If the approach to assessment is valid, then surgical trainees at different levels of mastering a specific surgical technique will exhibit levels of performance on the secondary task that parallel their levels of mastery. In addition, the use of dual-task methodology may help trainers to identify which surgical trainees require more preparation before entering the operating room environment.

Declaration of Conflicting Interests

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