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The authors declare no conflicts of interest

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All authors were involved in the design of the study. AM and AA conducted the study with analysis by AM and MSJW. Following interpretation of the data by all authors, the manuscript was prepared by MSJW with critical appraisal and final approval by all authors.

A standardised training tool to assess laparoscopic image navigation task performance in novice camera assistants

Background: A number of tools for assessing task performance of the laparoscopic have been described, but few focus on the acquisition and assessment of the attainment of proficiency in novice laparoscopic camera assistants. Our aim was to develop a simulated objective assessment tool for a novice camera assistant.

Materials & Methods: A 10-cycle image navigation task tool was developed. This involved a series of 360 degree clockwise and anti-clockwise rotation manoeuvres of a 30 degree laparoscope along its shaft, focusing on a predefined geometric target on a 45 degree fixed slope in a laparoscopic box trainer. The tasks were to simultaneously maintain neutral horizon, optimum distance and centring. Task accuracy and time to completion were assessed objectively at 3-second intervals on an unedited video recording.

Results: 29 novice medical students were assessed. Novices improved mean total error and task completion time (1st vs. 5th cycle, mean errors 15.4 vs. 8.4, p=0.048; mean task time 158.1 vs. 92.9 seconds, p=0.04). This improvement continued until the task cycle was completed (6th vs. 10th cycles, 7.9 vs. 6.2, p=0.01; 91.9 vs. 76.6 seconds, p<0.0001). There was a significant decrease in centring errors (5.2 vs. 2.4, p=0.001) and horizon (4.8 vs. 2.3, p=0.004), when comparing the 1st versus 5th task cycle. It took 6 cycles for optimum distance to achieve significance (5.4 vs. 3.3, p=0.023).

Conclusions: Using our assessment tool, novices achieved an objective proficiency-gain curve for laparoscopic camera navigation tasks. There was improvement in errors related to maintaining horizon, optimum distance and centring. Mean task completion time also decreased. This tool could be used as an additional means of assessment and training in novice surgical trainees.

Keywords: proficiency-gain curve, surgery, laparoscopy, training, simulator, camera assistant, surgical education

Introduction

Great attention has been paid to the assessment of task performance and the attainment of surgical proficiency. Proficiency may be defined as the knowledge and ability to execute a procedure well (1). The proficiency-gain (or learning) curve has been described for a variety of procedures and refers to the point at which a surgeon performs a procedure consistently well and with a good outcome (2-4).

To date, little attention has been paid to the proficiency-gain curve of the laparoscopic camera assistant. In laparoscopic surgery, the ability to perform a procedure proficiently is dependent upon the knowledge and skills of the surgeon, and the attainment of an optimal visual field to compensate for the loss of tactile feedback and depth perception as compared to open surgery (5). An adequate visual field requires an experienced camera assistant, and by deduction there is also a proficiency-gain curve for the camera assistant. By convention, the role of the camera assistant falls to the most junior member of the team. Surgical trainees are expected to act as camera assistant with little prior knowledge or experience in this role. With such a pivotal role, the task of the camera assistant should not be underestimated.

Previous studies in this area have examined the use of both 0 and 30 degree laparoscopes, the use of simulated models versus box trainers in both simulated environments and in a real life theatre setting, using both novices and experts (6-10).

Our aim was to develop a standardised lab based training tool using a box trainer and study its effects on laparoscopic image navigation task performance in novice camera assistants.

Materials and methods

Twenty nine medical students with no previous experience in laparoscopic surgery were recruited voluntarily and informed consent was obtained. 5 experts (consultant surgeons with laparoscopic experience) undertook the same task for comparative purposes. Local ethical approval was granted. Participants watched an orienting 15 minute audio-visual demonstration, with 5 minutes to familiarise themselves with the equipment prior to commencing the task.

The aim was to simultaneously maintain optimal distance, horizon and centring of a laparoscopic image in a timely manner.

<u>Setup</u>

A laparoscopic box trainer (Body Torso, Pharmabiotics Ltd, UK) was used throughout. A 30 degree laparoscope (Karl Storz, Germany) was used with light source, cable and attached to a 23-inch LCD monitor (Karl Storz, Germany). The monitor was marked with a horizontal red band, dividing the screen into equal halves. A marker (point M) was attached to the central point of the screen. Table height and monitor distance were standardised.

A stationary geometric target (15×15 cm^2) on a 45 degree slope was fixed to the floor of the box trainer (Figure 1). The target had an 8mm circle (point A) in the centre and intercepting diagonal lines to mark the centre of the target. Two horizontal double lines (2mm apart), through the centre of point A (line D) were used to demarcate horizon, with two circles (B) 2.75 cm apart from point A and two squares (H) 5.5 cm from point A (Figure 1) to define optimum viewing distance. The target was specifically designed to facilitate objective assessment of the three primary aims

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of the study, i.e. the ability to keep the image centred while maintaining the horizon and distance unchanged during the manoeuvring of the laparoscope as detailed below.

Using a fixed trocar point, the laparoscope was inserted into the box trainer by a member of the research team and the neutral position obtained.

Tasks

The task started at the neutral position, defined as; horizon parallel to ground, light nozzle at 12 o'clock, point A superimposed on point M such that the horizontal double lines on the target were equidistant between the horizontal red band on the screen, with B in the periphery and H not seen.

A cycle required rotation of the laparoscope by rotating the light cord nozzle 360 degrees clockwise, then counter clockwise back to the neutral position (cycle 1). This was repeated 10 times for the novice cohort and 5 times for the expert cohort. All tasks were completed continuously on the same day for both novices and experts.

During each cycle the task was to superimpose point A on to the centre of point M, whilst maintaining horizon by not deviating from outwith the double horizontal lines and optimum viewing distance by keeping the two circles in the periphery, with the squares not seen. No verbal cues were given after the commencement of the task.

Assessment and definition of endpoints

The task was recorded digitally, and analysis performed at 3 second intervals at a later date by a single researcher (AM). Centre and horizon markings were reproduced on the television screen when analysing the recordings. Total errors were counted for each task cycle. Endpoints are displayed in figure 2 and defined as:

1. *Centring* – point M deviated from the perimeter of point A on the target by >20mm.

2. *Horizon* – when the red band on the monitor deviated outwith the horizontal double lines (D) on the target.

3. *Distance* – when either circle (B) was not seen (target too close), or squares (H) were seen (target too far away).

4. *Time* – in seconds to complete each task cycle.

Statistical analysis was performed by IBM SPSS 21 statistical software. Student's t test was used. A p-value <0.05 was accepted as statistically significant.

Results

The novice cohort committed a total of 2633 errors. Of these, 1614 (61.3%) were in the first 5 cycles versus 1019 (38.7%) in the last 5. The most common error was in optimum navigation distance (1011, 38.4%), followed by centring (860, 32.7%) and maintaining horizon (762, 28.9%).

Mean total errors (Table 1) improved between cycles 1 to 5 (15.4 vs. 8.4, p=0.048) and 6 to 10 (7.9 vs. 6.2, p=0.01). Task completion time (Table 1 and Figure 3) reduced between cycles 1 to 5 (158.1 vs. 92.9 seconds, p=0.0001) and 6 to 10 (91.9 vs. 76.6 seconds, p=0.001). The mean completion time for each cycle in the novice group was 102 seconds per cycle, which equates to approximately 17 minutes to complete all ten cycles of the task.

Mean centring errors improved (5.2 vs. 2.4, p=0.001), as did horizon error (4.8 vs. 2.3, p=0.004) between cycles 1 to 5 (Figures 4 & 5). An improvement in mean optimum navigation distance was achieved after 6 cycles (5.4 vs.3.3, p=0.023) and is seen in Figure 6. When comparing cycles 6 to 10 there were no significant differences in centring, horizon or optimum distance.

The expert cohort also demonstrated improvement in task completion (139.2 seconds cycle 1 versus 93.2 seconds cycle 5, p=0.043, Figure 7). Mean centring (2.4 vs. 2.2, p=0.155), horizon (4.2 vs. 1.8, p=0.068) and optimising distance (4.6 vs. 2.4, p=0.066) also improved in this cohort between cycles 1 to 5 but failed to reach significance (Table 2).

When comparing our novices to experts, novices improved task completion time and became comparable with experts, but with a greater number of errors. There was

some inconsistency in the assessment of horizon errors, with novices on occasion better than experts.

Discussion

We describe an objective, standardised training tool to assess the proficiency gain of novice camera assistants. Our study focused on the simultaneous assessment of the three key elements of obtaining an optimum view of the surgical field with a laparoscope i.e. centring, maintenance of horizon and optimum distance. The assessment tool was standardised on a stationary target using a thirty degree angled laparoscope, thus requiring more complex manoeuvres to maintain an optimal view.

Our novices completed a series of tasks designed to replicate the requirements of a laparoscopic camera assistant in the operating theatre. Overall task completion time reduced with each cycle, with a reduction in mean total errors. Further, individual error subtypes improved as the task progressed. The proficiency gain curve was steepest in the first to fifth cycles (Table 1 and Figures 3-6).

A trainee performing a surgical task acquires knowledge and skills over a period of time. Each procedure has its own proficiency-gain curve, and proficiency improves as the trainee becomes more familiar with the procedure. The gradient of the curve varies and reflects the complexity of the task and inherent aptitudes of the trainee. However, a fundamental component of laparoscopic surgery is the skill of the camera assistant. The assistant is required to project an optimal image of the surgical field on to the monitor, and the camera assistant has traditionally received no formal training in this pivotal role.

The three key tasks that are essential to the projection of an adequate image need to be performed simultaneously; centring of the image, maintenance of horizon and optimum viewing distance. Task efficiency is hampered significantly if the camera

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assistant lacks the expertise to make a series of simultaneous, anticipatory adjustments to the field of view as the surgeon proceeds with the operation.

Our study differs from many of the previously reported tools for the assessment of laparoscopic camera assistant performance. We used a novel target design, with thirty degree laparoscopes in a box trainer with no verbal feedback after task orientation was complete. Our target was purposely designed to be stationary in order to mimic many surgical procedures (such as dissection of Calot's triangle) where the surgical target is in a relatively fixed position for the duration of the procedure. Having a stationary target also enabled greater standardisation, with the assessment of complex manoeuvres.

Franzeck *et al* (2012) compared centring and horizon using 30 degree laparoscopes using simulators (Lap Mentor™ and ProMis™) and conventional theatre based laparoscopic camera training. They reported no significant difference in the simulator or theatre based cohorts, but simulator based training was more time efficient (6).

Both Ganai *et al* (2007) and Korndorrfer *et al* (2005) compared simulator training models in porcine models at baseline and end of the study (7, 8). Those who underwent simulator based training were more efficient.

Both Stefanidis et al (2007) and Shetty et al (2012) reported studies that could discriminate between surgeons with varying levels of laparoscopic experience and overall training level (9, 10). Stefanidis *et al* compared EndoTower™ and the Tulane video-trainer, whereas Shetty *et al* used the LapSim VR simulator.

Cost is the main obstacle to the mainstream use of virtual reality based assessment tools. Surgical trainees prefer box trainers to software based simulators as they are

more realistic, with better face validity and equivalent to real life laparoscopy in the operating room with use of identical equipment (11). Novices gain the most from simulator based training (12), and assessment should form an integral part of any surgical training curriculum (13).

Our results demonstrate that novice camera assistants develop a proficiency-gain curve and that our video-trainer tool can demonstrate this curve. Mean task completion time reduced with a synchronous reduction in errors related to centring, horizon and maintaining optimum distance.

The limitations of our study are that we employed novice medical students to complete the tasks. We did compare their performance to those of experts (consultant surgeons) as a control. Our findings may not therefore truly reflect the findings of surgical trainees and a further study is recommended in this area. The validity of our training tool would be improved if replicated on surgical trainees at the start of their career (6-8). Our training tool was specifically designed to mimic the real life skills required of a camera assistant. The findings are yet to be replicated in a theatre environment or proven to make a difference to performance in the operating theatre and should form the basis of a future study. Our study has not fully defined the point on the learning curve where a camera assistant can be defined as competent. We have however demonstrated the rapid improvement in the key skills required of a camera assistant after task orientation, and significant gains were made by the fifth cycle when assessing centring and horizon and by the sixth cycle for optimum distance. Additional studies would be required to determine the number of cycles required to determine at what point competence or proficiency is attained, and also assess for retention of developed skills after a period of time. Further, our study fails to take into account other factors that would affect the attainment of an optimal view of the

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surgical field such as instrument collision, or indeed surgeon preference (some prefer a wider view, others opt for a closer view). Therefore, our study describes an evaluation tool for the technical skills required to navigate a 30 degree laparoscope. The methodology for assessing errors in our study was robust but time consuming. In future studies we would envisage that identification and analysis of errors would be performed rapidly by a virtual reality platform. Our training tool could be used as an aid to assess the development of surgical trainees as they develop proficiency as novice camera assistants. Incorporating our training tool into the training curriculum of novice camera assistants would be reproducible, and logistically feasible in the majority of laparoscopic centres. Advanced scrub practitioners could also be assessed in a similar fashion, as part of a competency based assessment.

Disclosures

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more realistic, with better face validity and equivalent to real life laparoscopy in the operating room with use of identical equipment (11). Novices gain the most from simulator based training (12), and assessment should form an integral part of any surgical training curriculum (13).

Our results demonstrate that novice camera assistants develop a proficiency-gain curve and that our video-trainer tool can demonstrate this curve. Mean task completion time reduced with a synchronous reduction in errors related to centring, horizon and maintaining optimum distance.

The limitations of our study are that we employed novice medical students to complete the tasks. We did compare their performance to those of experts (consultant surgeons) as a control. Our findings may not therefore truly reflect the findings of surgical trainees and a further study is recommended in this area. The validity of our training tool would be improved if replicated on surgical trainees at the start of their career (6-8). Our training tool was specifically designed to mimic the real life skills required of a camera assistant. The findings are yet to be replicated in a theatre environment or proven to make a difference to performance in the operating theatre and should form the basis of a future study. Our study has not fully defined the point on the learning curve where a camera assistant can be defined as competent. We have however demonstrated the rapid improvement in the key skills required of a camera assistant after task orientation, and significant gains were made by the fifth cycle when assessing centring and horizon and by the sixth cycle for optimum distance. Additional studies would be required to determine the number of cycles required to determine at what point competence or proficiency is attained, and also assess for retention of developed skills after a period of time. Further, our study fails to take into account other factors that would affect the attainment of an optimal view of the

surgical field such as instrument collision, or indeed surgeon preference (some prefer a wider view, others opt for a closer view). Therefore, our study describes an evaluation tool for the technical skills required to navigate a 30 degree laparoscope. The methodology for assessing errors in our study was robust but time consuming. In future studies we would envisage that identification and analysis of errors would be performed rapidly by a virtual reality platform. Our training tool could be used as an aid to assess the development of surgical trainees as they develop proficiency as novice camera assistants. Incorporating our training tool into the training curriculum of novice camera assistants would be reproducible, and logistically feasible in the majority of laparoscopic centres. Advanced scrub practitioners could also be assessed in a similar fashion, as part of a competency based assessment.

Disclosures

Drs. Alam, Wilson, Tang, Tait and Alijani have no conflicts of interest or financial ties to declare.

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Table 1

Variable	Centring error		Horizon Error		Distance error		Total error		Task time (second)	
Task cycle	mean	p value	mean	p value	mean	p value	mean	p value	Mean	p value
1	5.2	0.001	4.8	0.004	5.4	0.057	15.4	0.048	158.1	0.0001
5	2.4		2.3		3.6		8.4		92.9	
6	2.4	0.155	2.1	0.594	3.3	0.102	7.9	0.01	91.9	0.0001
10	2.2		2		2		6.2		76.6	

Table 1: Task cycle completion time and errors (novices)

Table 2

Variable	Centring error		Horizon Error		Distance error		Total error		Task time (second)	
Task cycle	mean	p value	mean	p value	mean	p value	mean	p value	Mean	p value
1	2.4	0.7	4.2	0.068	4.6	0.066	11.2	0.043	139.2	0.043
5	2.2		1.8		2.4		6.4		93.2	

Table 1: Task cycle completion time and errors (experts)

Figure 1

15 x 15 cm square paper

AB distance: 2.75 cm
AH distance: 5.5cm
D= double line through centre A and parallel and devides square into an equal upper and lower half

D

H
B
A= centre
B
H

Transverse line D (black)will be superimposed by the single transverse line (red colour)drawn through the centre point M on the monitor screen and this will assess the orientation / horizon of the image field.

Figure 1: The target task design

Figure 2
Click here to download high resolution image

Centring errors

Horizon errors

Optimum navigation distance errors
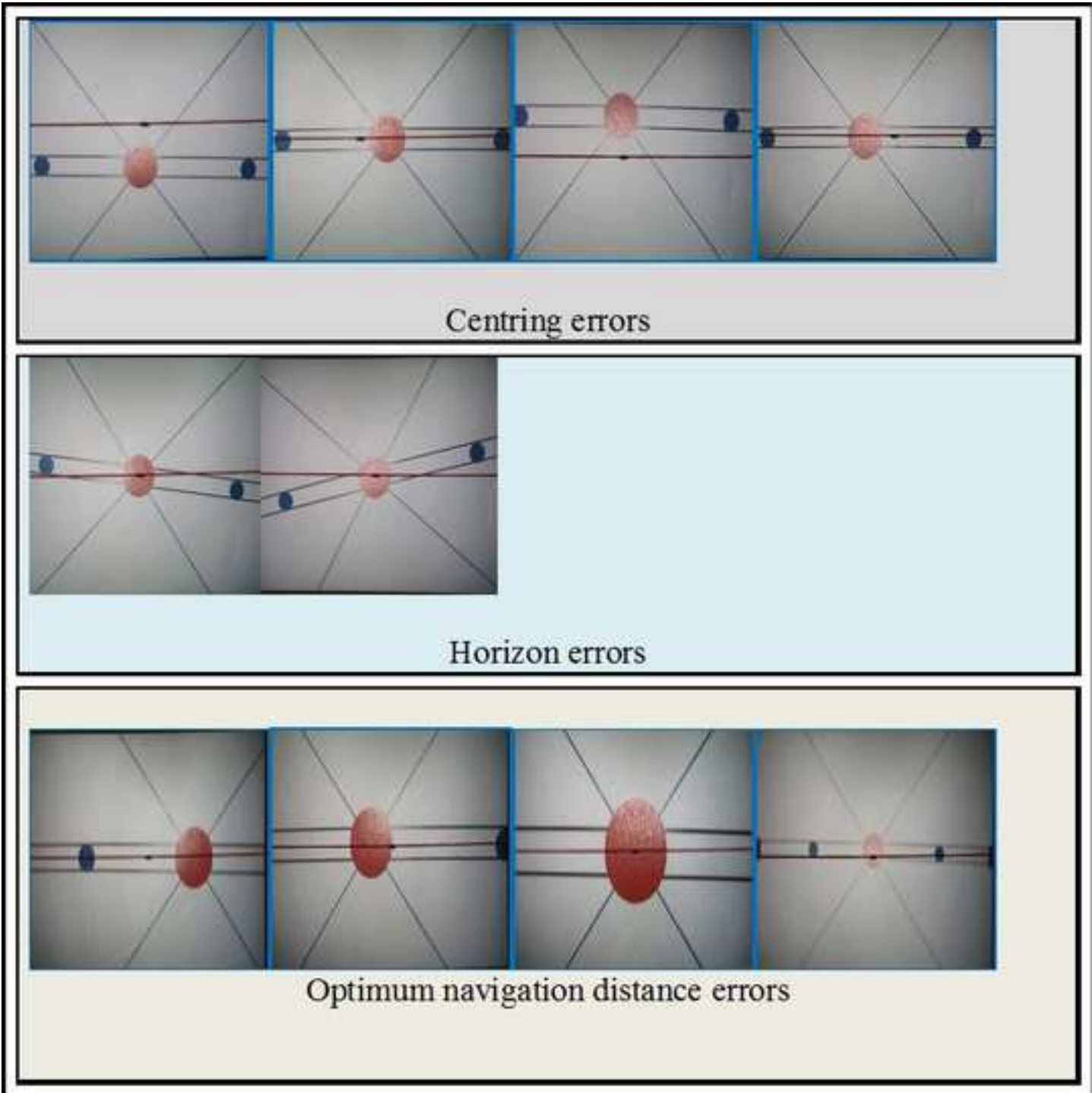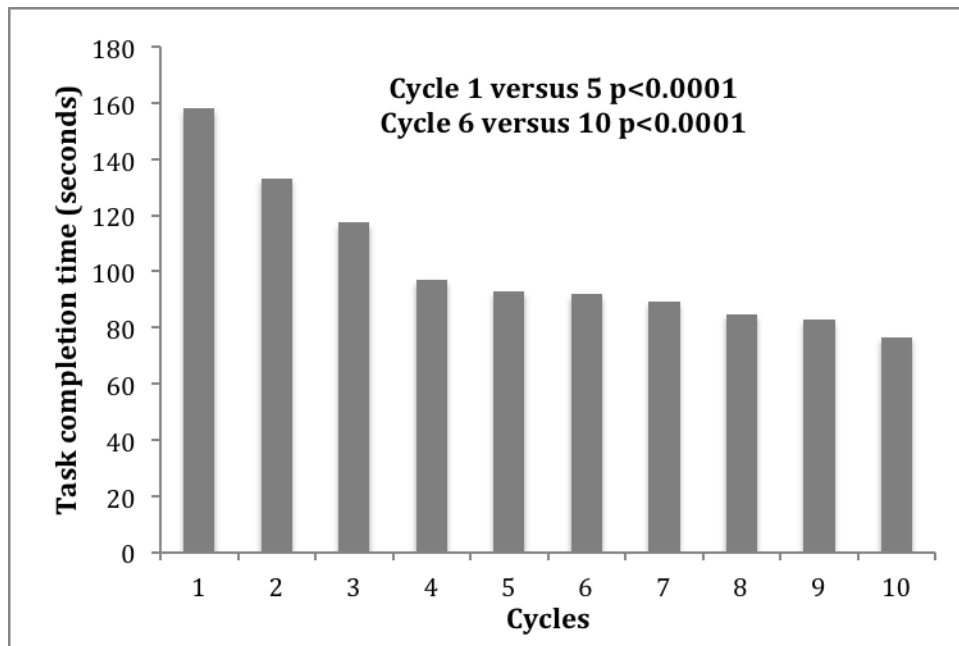
Figure 3

Figure 3: Task completion time results (novices)
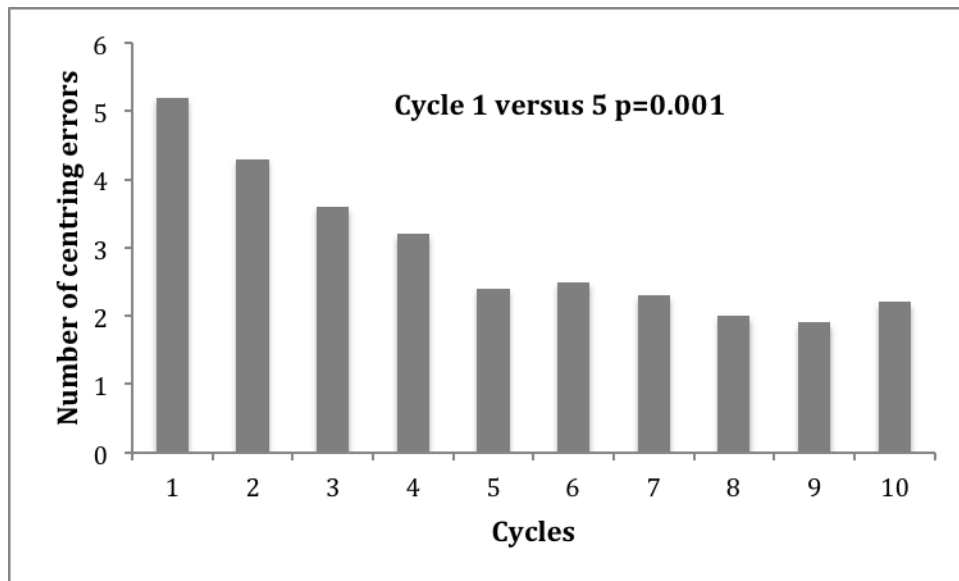
Figure 4

Figure 4: Centring errors (novices)
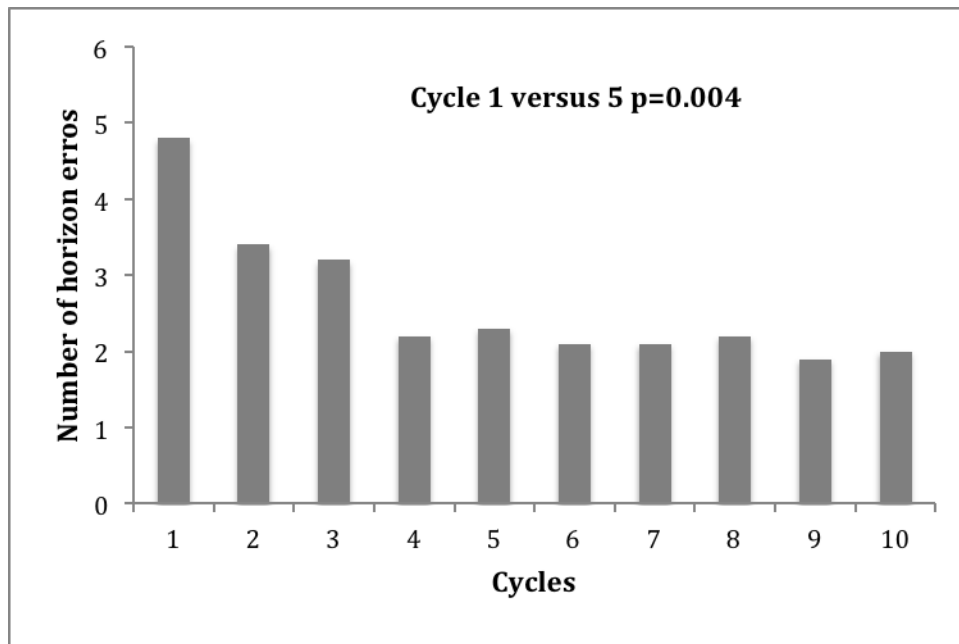
Figure 5
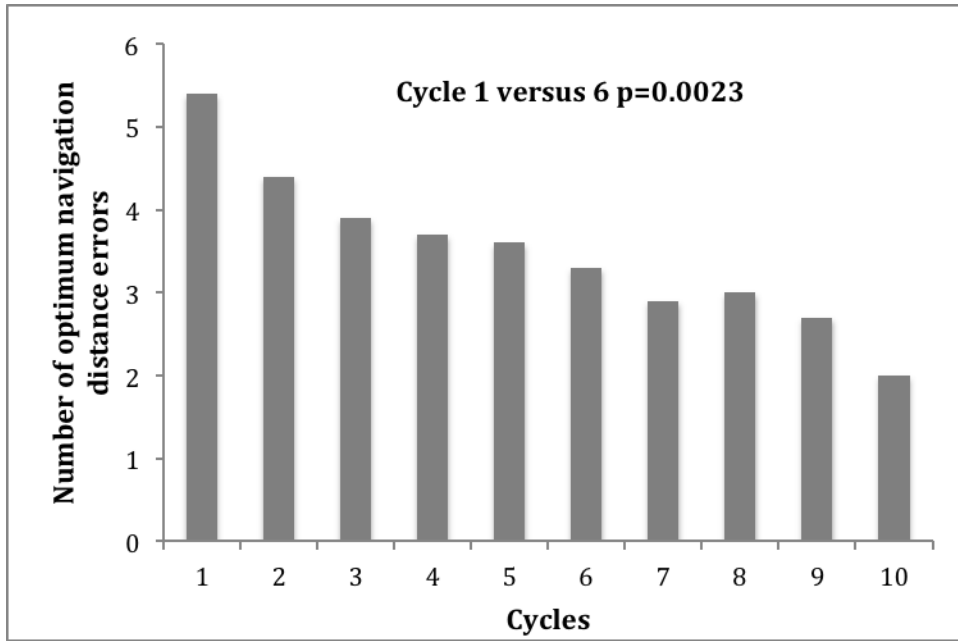

Figure 5: Horizon errors (novices)

Figure 6

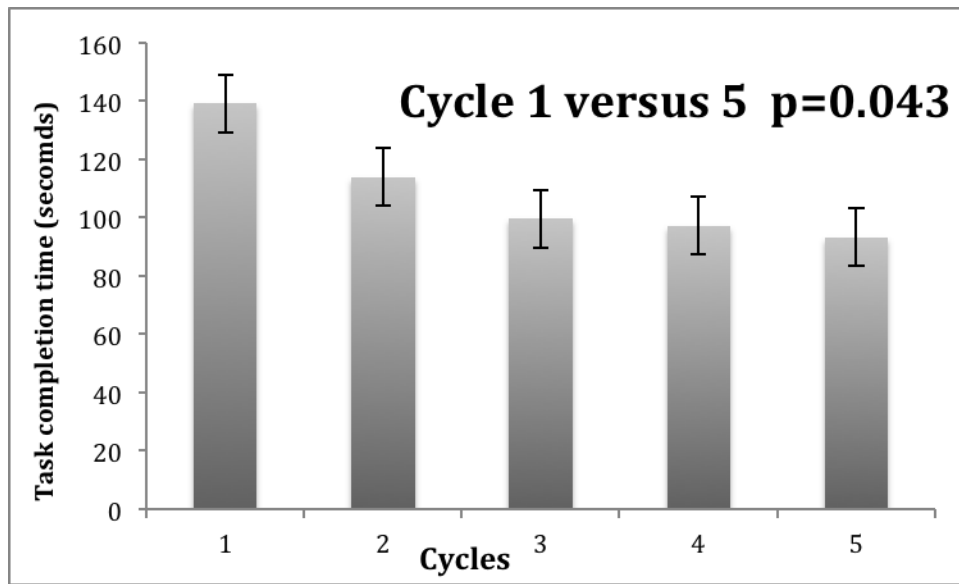Figure 6: Number of errors for optimum navigation distance (novices)

Figure 7

Figure 7: Task completion time results (experts)