1-1-2012

The evaluation of fundamental ability in acquiring minimally invasive surgical skill sets

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The Evaluation of Fundamental Ability in Acquiring Minimally Invasive Surgical Skill Sets

A thesis submitted to the Royal College of Surgeons in Ireland, in fulfillment of the requirements for the degree of Medical Doctorate (Surgery)

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Candidate Thesis Declaration

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Acknowledgements

Supervisors

Mr. Paul Neary

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Additional Mentors

Professor Sean Tierney

Professor Arthur Tanner

Mr. Brian Lane

Mr. Sean Carroll

Ms. Dara O'Keeffe

Ms. Eva Doherty

Statistician

Dr. Borislav Dimitrov

In Acknowledgement of their Generous Support

Mr. Hazem Hseino

Mr. Kieran Ryan

Mr. Derek Young

Ms. Emer Pyke

Mr. Donncha Ryan

Ms. Siobhan O'Keeffe

Ms. Paula Mansell

Ms. Caroline McGuinness

Mr. Anthony Whelan

In Acknowledgement of their Time & Effort

All the Medical Students

Basic Surgical Trainees

Higher Surgical Trainees who participated

Special Acknowledgement

Gemma & Gerard Nugent

Edward, David, Fergal, Killian & Melinda

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List of Abbreviations

MIS	Minimally Invasive Surgery
NOTES	Natural orifice transluminal endoscopic surgery
EVAR	Endovascular aneurysm repair
EWTD	European working time directive
CPD	Continuing professional development
CAS	Competence assurance structures
PBPT	Proficiency based progression training
DAT	Differential aptitude test
VR	Virtual reality
VIST	Vascular Intervention Simulation Trainer
RCSI	Royal College of Surgeons in Ireland
TCD	Trinity College Dublin
BST	Basic surgical trainee
HST	Higher surgical trainee
NSTC	National surgical training centre
PicSOr	Pictorial surface orientation test
TAIS	The attentional and interpersonal style inventory
OGD	Oesophagogastroduodenoscopy
ERCP	Endoscopic Retrograde Cholangiopancreatography
OSATS	Objective structured assessment of technical skill
MCQ	Multiple choice questions

Abstract

Background: Minimally invasive surgery (MIS) is an evolving area of surgery which is becoming more main-stream. However, when compared to the traditional open surgical approach MIS techniques have been demonstrated to be associated with a longer learning curve for the trainee surgeon.

Aim: The overall objective of this thesis was to investigate and evaluate those factors that could influence the length of the learning curve and the capacity of a trainee to become a proficient minimally invasive surgeon.

Materials & Methods: We evaluated three different areas; psychometric aptitude (visual spatial, depth perception & psychomotor), personality traits and non-technical skills (musical ability, playing sport & video games) and how these factors impacted on the surgical novice, junior and senior trainees ability to perform in both basic minimally invasive skills (laparoscopy, endoscopy & endovascular) and more advanced skills (laparoscopic colectomy) in a simulated setting.

Results: The results demonstrated that there is a relationship between psychometric aptitude and MIS performance. This association was greatest in frequency and most consistent amongst the surgical novices with its effect decreasing with increasing surgical experience. However, the results also demonstrated that in trainees with significant surgical experience psychometric aptitude was associated with performance in an advanced MIS task (laparoscopic colectomy). Certain personality traits were also found to be associated with MIS performance (distractibility, confidence & energy). Finally, musical ability in particular was found to have the greatest association with MIS performance in contrast to the other non-technical skills measured.

Conclusion: We have shown that certain attributes influence the learning curve and the fundamental ability of the trainee surgeon in MIS techniques. These findings have relevance in the design of training curricula and when ensuring the optimum learning pathway for the individual trainee.

Chapter One

Introduction

1.1 Minimally Invasive Surgery

Surgery is ever evolving. Nowhere has this been more evident than in the field of minimally invasive techniques. Minimally invasive surgery (MIS) is a term that encompasses a variety of interventional and diagnostic techniques including, laparoscopy, therapeutic and diagnostic endoscopy and endovascular procedures. Recent years have seen progression in all of these areas. There has also been development in the area of robotic technology and we have been introduced to the newest surgical concept - natural orifice transluminal endoscopic surgery (NOTES).

The boundaries are continually being pushed further with the ideal being a procedure that results in very minimal scars (for example single incision laparoscopy) or no visible scars (NOTES). These concepts are currently the latest great challenge facing the pioneering techniques of minimally invasive surgery.

The idea of minimal intervention is not a novel phenomenon. The history of modern endoscopy is relatively young dating back no more than 130 years, but is roots stretch back much further. Minimally invasive techniques can be traced back to the ancient Greek's, Chinese and Indian medicine. Hippocrates (460 -375 BC) is credited with the earliest recorded reference to a procedure that resembled an endoscopic examination of the rectum (Gordon, 1993).

1.2 A Brief History of Minimally Invasive Surgery

1.2.1 The History of Endoscopy

Endoscopy is defined as the exploration of any cavity of the body with a viewing instrument for diagnosis or treatment (Lau et al, 1997). The pace at which endoscopy developed was initially slow. Its progression relied heavily on the technical advances available at the given period in time. Endoscopy demonstrated that a minimally invasive approach was feasible and desirable in terms of a reduced morbidity and mortality. The development of endoscopy laid down an important foundation for future minimally invasive techniques. In particular, the technology and instrumentation that were designed for endoscopy formed the cornerstones of modern laparoscopic surgery.

The first description of a form of an endoscopic procedure was by Hippocrates in 460 – 375 BC. The next recording of an attempted endoscopic technique was by Aranzi, in 1585. He used a flask of water to direct sunlight into the nasal cavity for examination. However there were no further advancements in the field of endoscopy until the 1800's.

In 1806, Philip Bozzini, a German urologist, built an instrument from aluminium. He designed it initially to examine the genitourinary tract. Candle light was used to illuminate the instrument which had concave mirrors on the inside to reflect light onto the area to be visualised. He called his invention the "Lichtleiter". It was also used to examine the rectum, mouth and vocal cords. In the 1850's, a French surgeon, Desormeaux modified the Lichtleiter. He improved the light source by using a combination of alcohol and turpentine to intensify and strengthen the flame (Ozkara & Watson, 1992). He also coined the term "l'endoscopie". As a result of his contribution Desormeaux is often known as the father of endoscopy.

The modification of the Lichtleiter led to an expansion in the uses of endoscopy. One of the first oesophagogastroscopies was performed on a sword swallower by Kussmaul in 1868. Nitze is credited with developing the first usable cystoscope in 1877. He increased magnification by using a series of lenses. He was also the first to place the light source inside the organ of interest to aid visualisation.

However it was Thomas Edison's invention of the filament globe or light bulb in 1879 that allowed the endoscope to progress greatly. Prior to this the light source in endoscopy was quite poor and often there was a risk of causing thermal injury to the patient. Mikulicz in 1880 incorporated Edison's filament globe into the end of the endoscope giving the world the first practical gastroscope. The image quality was now much improved. The use of electricity improved the understanding of human physiology. Pathologies of living organs could now be visualised with clarity. Another important development improving visualisation was the incorporation by Mikulicz in 1881 of a 30 degree angle onto the lower third of the scope. This to a certain extent made the endoscope semi-flexible. Prior to this point all scopes were rigid, open tubes which made viewing the target organ difficult and limited.

The success of using endoscopy in the setting of upper gastrointestinal medicine encouraged the development of instruments to examine the lower gastrointestinal tract. In 1895, Howard Kelly designed and demonstrated the use of a rigid scope to examine the sigmoid. Given the nature of the anatomy of the colon there was no real progression in colonoscopy until the introduction of the flexible scope. As a result the first colonoscopy wasn't carried out until 1965 in Italy (Provenzale & Revignas, 1969). This was followed by the first snare polypectomy by Shinga in 1969. This heralded a new era in therapeutic minimally invasive procedures.

Following 1880, there were no further major developments in endoscopy for another 70 years. In 1930 Heinrich Lamm, a gynaecologist demonstrated that fine threads of glass fibres could be bundled together to act as a light conduit (Sircus, 2003). These bundles had a novel property - it was possible to flex them without a loss of light transmission. This became known as fibreoptic technology. Although they were an important discovery they weren't used in endoscopy until the 1950's.

Hopkins invented a new rod lens optical system in 1954 with the result that the image transmitted was much improved (Berci & Forde, 2000). Hopkins demonstrated his new flexible scope at a meeting in Holland but it wasn't accepted until Hirschowitz published his historic article in 1958. Basil Hirschowitz was the first to apply this new technology with success. He famously demonstrated its usage by performing an oesophagogastroscopy on himself before going on to perform the same procedure on a patient. The benefits of this new flexible technology were quickly recognised. They included greater patient comfort and therefore greater time to perform the scoping and increased safety for the patient. These factors allowed an expansion in the ways in which endoscopy was employed in both a diagnostic and therapeutic capacity.

The first scope using a camera was designed in 1989 by Lange and Melzing. They used a roll of film which was placed at the distal end of the endoscope. Up to 50 exposures could be taken during an examination of the upper gastrointestinal tract. This technology advanced until the invention of the closed camera which incorporated a charge coupled device chip onto the scope. This allowed the video image to be transmitted to a television monitor. The invention of television coupled with the camera brought with it many advantages to the endoscopist. It allowed an enlarged image to be seen by both eyes. Several team members could see it simultaneously. Overall this allowed for better teaching and assisting.

Alongside the many advances made in optics and visualisation there were other core changes to the endoscope. These included the ability to steer the tip of the instrument via controls and the use of channels to insert instruments for intervention. Endoscopy continues to progress with newer inventions such as ultrasonic endoscopy and self-propelled capsule endoscopy. Therapeutic endoscopy also continues to evolve with procedures such as transanal microsurgery and natural orifice transluminal endoscopic surgery (NOTES) becoming an exciting reality. NOTES surgery is the current aspiration for endoscopic technology. The advancements in endoscopic technology in recent years have allowed this new form of surgery to progress.

1.2.2 The History of Laparoscopy

Laparoscopic surgery owes much of its history to the development of endoscopy. Its main use initially was as a diagnostic tool by gynaecologists. However the development of the video camera and the introduction of laparoscopic cholecystectomy led to a revolution in general surgery. Laparoscopy has changed the modern field of general surgery more drastically and rapidly than any other surgical milestone.

The Greek words "lapara" meaning the soft part of the body between the ribs, hip, flank and loin and "skopein" meaning to look at or survey were combined to give "laparoscopy", which is otherwise known as key-hole surgery. Jacobaeus, a Swedish surgeon, in 1910 was the first to introduce the term in work he published on the descriptions of the human peritoneal, thoracic and pericardial cavities (Hatzinger et al, 2006). The first report of visualisation of the peritoneal cavity was by the German physician, Kelling in 1902. He performed the procedure on a dog using a cystoscope and filtered air to create a pneumoperitoneum (Zucker, 2001).

Over the next 30 years there were a number of important developments. The first needle for the introduction of a pneumoperitoneum was designed by Korbsch in 1921. This was developed in conjunction with the first insufflator reported by Goetze (Lau et al, 1997). The first angled viewing scope (laparoscope) was used by Kalk in 1929. This was described as having a central viewing axis that was angled by 45 – 50 degrees from the longitudinal axis. It allowed better orientation of the laparoscope and therefore better inspection of the organs and greater diagnostic abilities. Kalk was also the first to introduce a second trocar incision (Gotz et al, 1993). This heralded the future of operative laparoscopic surgery.

Laparoscopy was used initially as a primarily diagnostic tool. Advances in light conduction, lens design and electricity made the possibility of operative procedures more realistic. Some of the first operative procedures included adhesiolysis and diagnostic biopsies of abdominal organs under direct vision. Ferrers in 1933 performed the first laparoscopic cauterisation of intra-abdominal adhesions (Gotz et al, 1993). He was also one of the first to recommend the use of carbon dioxide instead of the potentially hazardous use of oxygen. Carbon dioxide replaced oxygen as the gas of choice for insufflation in 1938. The first laparoscopic tubal sterilisation using monopolar electrocoagulation was performed by Boesch in Germany in 1936. Around this period the Veress needle was introduced to gain initial access to the abdominal cavity. It was designed originally to create a pneumothorax. The standard method today is the Hasson technique where entry to the abdomen is performed under direct vision (Hasson, 1978).

The demand for laparoscopy was proportional to advances in the viewing conditions. With the introduction of the fibre optic light source in the 1960's there was a dramatic improvement in the illumination potential. This meant that laparoscopy was now set to be transformed. The development of bipolar endoscopic electro-cauterisation provided further incentive for the development of operative laparoscopy since more complicated procedures required the ability to achieve haemostasis (Semm, 1989). Kurt Semm played a vital role in the development of laparoscopy. He was responsible for designing instruments such as the laparoscopic scissors, a pre-tied suture loop (Roeder loop or endoloop) and an irrigation/aspiration device. He also was the first to recognise the importance of training in laparoscopy and he created a pelvi-trainer that functioned to teach surgeons the necessary hand-eye coordination skills and suturing skills.

One of the first general laparoscopic surgeries was a laparoscopic appendicectomy. It was performed incidentally during a gynaecological procedure by Semm in 1982. Despite its successful application in gynaecology, operative laparoscopy was slow to gain acceptance among general surgeons. The hallmark procedure of general laparoscopic surgery was the laparoscopic cholecystectomy. In 1985 Muhe published the first report of a laparoscopic cholecystectomy performed on an animal (Muhe, 1992). His publication was met at first with much scorn and scepticism. It wasn't until the development of the video camera with a computer chip in 1986 allowing magnification and the projection of images onto a television screen that laparoscopy as a technique became properly integrated into the discipline of general surgery. Following this the first laparoscopic cholecystectomy on a patient was performed by Mouret in 1987. The laparoscopic cholecystectomy proved to be the single most important stimulus to the development of operative laparoscopy in general surgery and very quickly became a venture of interest and application. Laparoscopic cholecystectomy now represents the gold standard treatment for removal of the gallbladder (Wherry et al, 1996).

During the 1990's endoscopic surgery continued to evolve (Lau et al, 1997). Laparoscopic cholecystectomy was the cardinal endoscopic operation but enthusiasm for it led to the application of laparoscopy to other procedures. These included laparoscopic Nissan's fundoplication, appendicectomy, nephrectomy, splenectomy and inguinal hernia repair to name but a few. In 1991 the first laparoscopic colectomy was performed (Jacobs et al, 1991). Randomised controlled trials have lain to rest any oncological doubts that were initially associated with the minimally invasive approach (Jayne et al, 2010; Hazebroek et al, 2002; Fleshman et al, 2007). Studies have also demonstrated benefits in terms of post-operative pain, recovery and length of stay with major laparoscopic resections when compared to traditional open surgery (Braga et al, 2005; Zhou et al, 2004; Leung et al, 2004). The laparoscopic approach continues to be adopted into the daily operating schedule of the general surgeon and is fast becoming the gold standard of the future.

1.2.3 The History of Endovascular Surgery

Endovascular surgery is defined as the manipulative treatment of vascular lesions by an endoluminal or intravascular route. These treatments use a variety of catheters, guide wires, balloons, stents, endovascular stented grafts and some form of imaging guidance to correct stenoses, occlusions, aneurysms and injuries to arteries and veins. Treatment via the endovascular route uses vessels as natural channels to reach the area to be operated on. This route has the advantage of reducing incisions, eliminating the need for retraction, reducing the risk of infection and in the case of neurosurgery removes the need for craniotomy.

Minimally invasive intervention in the field of vascular surgery was first attempted in the late 1700's. During this time experiments were carried out whereby needles were inserted into aneurysms. The theory behind this was that the foreign body would induce a thrombosis. This was not a successful endeavour but it did stimulate a new interest in this sort of minimally invasive technique. In 1864, Moore suggested that to insert a wire into an aneurysm would provide an ideal environment for clot formation. He collaborated with Corradi in 1879 where they combined this idea with electrocautery. Again these experiments did not prove fruitful.

Endovascular techniques as we know them today were first introduced in the early 1900's. The first reports of attempted endovascular embolization date from 1904 when Dawbarn used a mixture of Vaseline and paraffin to embolize malignant tumors in the region of the external carotid (Richling, 2006). These reports remained relatively unknown. At this point in time endovascular procedures had a mainly diagnostic role. At this stage the endovascular approach was primarily used as a technique to inject particles to follow the flow into vascular lesions. It wasn't until the 1960's that therapeutic endovascular procedures became a possibility. A new therapeutic role was envisaged with the development of devices such as balloons, stents and coils.

The invention of the Fogarty catheter in 1961 was an important milestone (Fogarty & Cranley, 1965). The Fogarty catheter is still used today for embolectomy. In 1964 Luessenhop and Velasques described catheterisation of the internal carotid artery using silastic tubing. The first attempts to cure brain aneurysms from the "endovascular side" were reported in 1965, when Gallagher described the injection of a horse hair into a surgically exposed aneurysm (Richling, 2006).

In the late 1980s and 1990s endovascular surgery became more significant in the treatment of vascular lesions with the development of stents for occlusive lesions and endovascular stented grafts or endografts for the treatment of aneurysms and traumatic lesions.

The first ever endovascular aneurysm repair (EVAR) was performed in 1991 by Parodi. Good outcomes have been demonstrated with this technique (Greenhealgh et al, 2004). Studies have set out to evaluate the role of carotid artery stenting in high risk patients. The SAPPHIRE trial demonstrated that in certain high risk patients performing endovascular carotid artery stenting in contrast to an endartrectomy was a better approach (Yadav et al, 2004). Currently there are ongoing clinical trials (CORAL & ASTRAL) that are examining the role of endovascular techniques for renal artery stenosis.

The elegance of the endovascular approach was an important argument for this technology from its inception, but in early years, restricted endovascular efficacy limited the efficiency of embolizations. Increasing experience and exploding new technologies have made endovascular techniques not only safer, but also as effective as traditional surgery. The number of vascular pathologies where the minimally invasive approach is an option is ever increasing. It is now likely that endovascular procedures will replace, improve or simplify 60–90% of vascular operations (Veith, 2005).

1.3 The Advantages of Minimally Invasive Surgery

Minimally invasive surgery has been established today as one of the most exciting advances in contemporary medical practice. Since its initial introduction it has developed rapidly in both application and complexity. For medicine as a whole minimally invasive surgery was the transitional technology that marked the beginning of the informatic age of surgery (Satava, 1997).

The main advantage associated with minimally invasive procedures is the reduction in the traumatic insult inherent in surgical intervention. In particular this approach reduced the trauma of access. There are many other important advantages to the minimally invasive approach. The benefits that have been documented are a reduction in post-operative pain, a reduction in intra-operative bleeding, an improvement in cosmesis due to smaller scars, less fatigue post-operatively, a quicker recovery time post-operatively, reduced hospital stay and a better quality of life post-operatively (Braga et al, 2005; Zhou et al, 2004; Leung et al, 2004; Weeks et al, 2002). Benefits to the health care system when compared to the traditional open approach have also been demonstrated. These include low morbidity, reduced anaesthesia time, a shorter period of post-operative care, a greater turnover of bed occupancy and a greater number of day case procedures (Jain et al, 2000). All of these factors lead to subsequent financial savings.

Specific areas have also been examined. A study by Coskun and colleagues demonstrated that there was a significant reduction in the risk of pulmonary dysfunction as a result of reduced post-operative pain in patients that had laparoscopy in contrast to open surgery (Coskun et al, 2000). The MIS approach in patients with morbid obesity has been shown to be associated with a significantly better quality of life and a reduction in peri-operative morbidity (Karlsson et al, 1998). The MIS approach has allowed such high risk patients to undergo elective procedures in a safer manner.

The constant development of instrumentation and technology has allowed the extension of the MIS approach to all forms of surgical specialities and procedures. Cardiology, neurosurgery and interventional radiology are a few of the many specialities that have adopted MIS techniques into their daily practice.

The evolution of robotic surgery (Zeus and Da Vinci robots) has been another significant step. The advantages offered by these systems are better access to more difficult areas, increased stability, accuracy and mobility while reducing patient risk. Another benefit is a reduction in the ergonomic stress for the surgeon.

Finally minimally invasive surgery as a result of its inherent relationship with technology has the potential to develop on a continuum. This prospect holds much exciting promise for the years to come.

1.4 The Difficulties Associated with Minimally Invasive Surgery

1.4.1 The Learning Curve in Minimally Invasive Surgery

The concept of a learning curve for surgical procedures is not a novel one. A learning curve is a graphical representation of the changing rate of learning (figure 1.1). Typically the increase in retention of information is sharpest after the initial attempts. This increase gradually flattens out as less and less new information is retained after each repetition. There are two main issues that affect the learning curve in minimally invasive techniques. These are the attributes of the trainee and the teaching they receive.

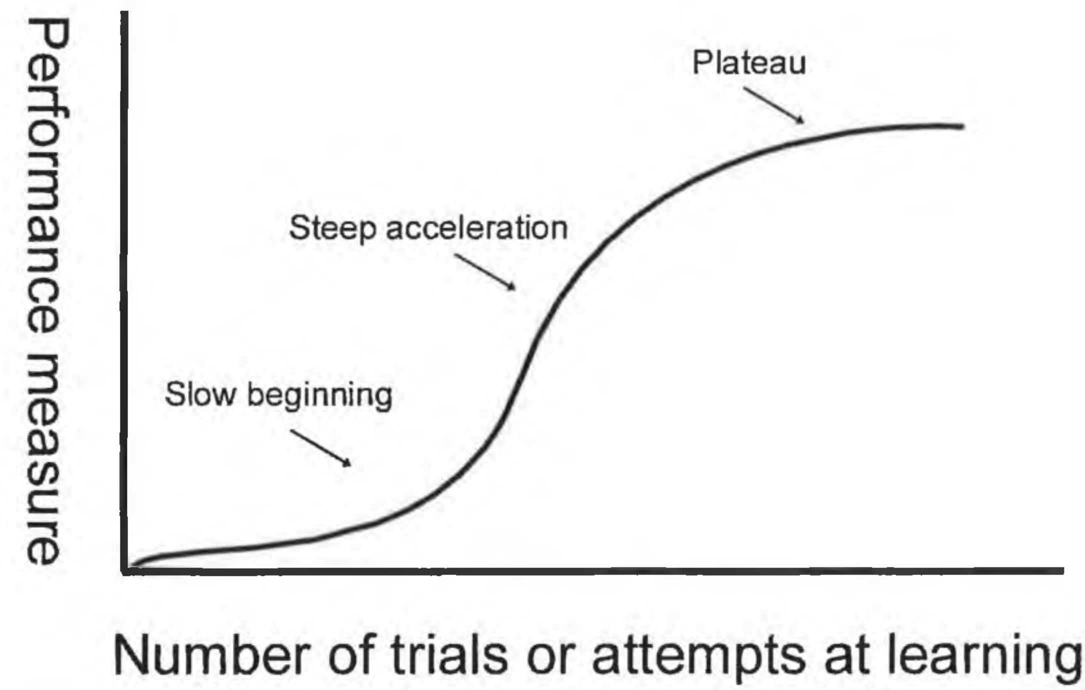


Figure 1.1 Graphical Representation of the Learning Curve

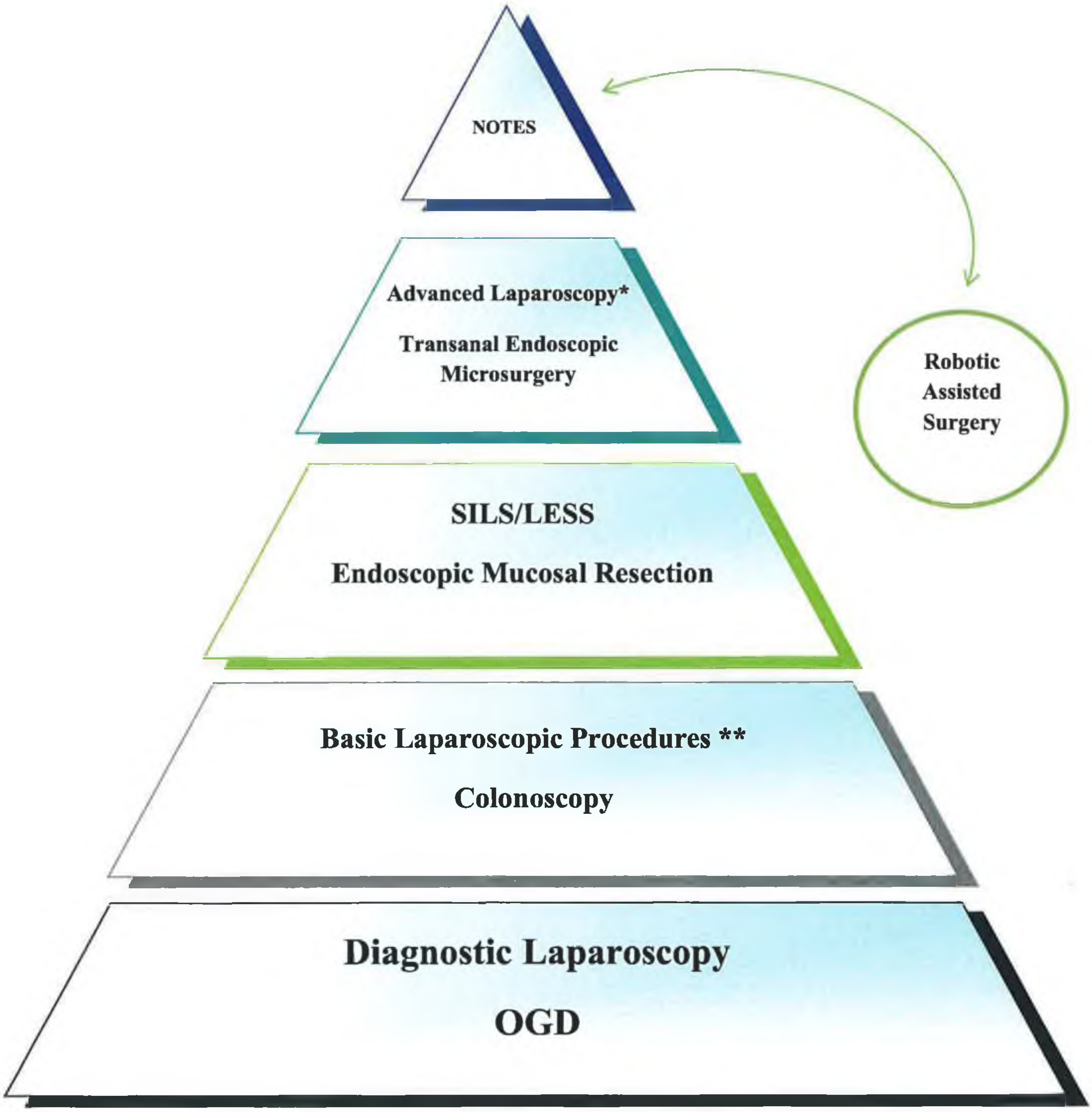
It is more difficult to teach trainees in the minimally invasive surgical environment. With the traditional open approach the supervising surgeon can directly guide the hands of the trainee and immediately intervene if a problem or difficulty arises. The situation in MIS is not as easy to control as the surgeon is operating with their tools at a distance. In open surgery the most important attributes that the surgeon requires are hand-eye coordination and finger dexterity. However with minimally invasive techniques there are further attributes the surgeon is expected to have. One example is whereby all MIS procedures require the ability to interact and interpret images from a 2D monitor. As a result, additional attributes such as visual-spatial aptitude and depth perception become relevant.

Laparoscopic cholecystectomy was the index procedure for laparoscopy. Although it was embraced with vigour it was also the procedure where problems and concerns with the minimally invasive approach were first highlighted. A higher than acceptable rate of bile duct injury in laparoscopic cholecystectomy when compared to open cholecystectomy became an important issue in the 1990's.

The Southern Surgeons Club study is an oft referenced paper. They found that 90% of common bile duct injuries occurred within the first 30 operations performed by the trainee surgeon (Southern Surgeons Club, 1995). They also predicted that the surgeon had a 1.7% probability of causing a bile duct injury in their first operation which reduced to 0.17% by the 50^{th} case. The probability of injury was found to have dropped to a significantly safe level by the 10^{th} case (Southern Surgeons Club, 1995; Wherry et al, 1994). This was one of the first articles to underline the significance of the learning curve in minimally invasive surgery.

As the complexity of the procedure increases so to does the learning curve. This has been demonstrated for laparoscopic fundoplication, where a significant reduction in complications has been reported to reduce only after the 50^{th} case with the highest complication rate found within the first 20 cases (Watson et al, 1996). The learning curve for laparoscopic colectomy has been estimated to be even higher, with the highest rate of complications occurring during the first forty procedures (Bennett & Styker, 1997a; Bennett et al, 1997b; Tekkis & Senagore, 2005). The initial learning curve has been shown to be associated with the period of the greatest risk to the patient.

One can only infer from this that the expected learning curve in an even more complex form of minimally invasive technique, such as NOTES or single incision laparoscopic surgery, should be even greater (Kavic et al, 2008). Although a NOTES procedure encompasses both endoscopy and laparoscopy prior studies have demonstrated that the ability to perform to a certain standard in both techniques is not transferable (Buzink et al, 2010). Therefore doctors who undertake NOTES surgery need the training and the attributes for both endoscopy and laparoscopy at a minimum. Training in MIS procedures should be in a stepwise fashion with the novice beginning and gaining experience in basic techniques before progressing on to more advanced surgery thereafter (figure 1.2).



*Advanced Laparoscopy – Laparoscopic Colectomy & Gastric Bypass Surgery

**Basic Laparoscopic Procedures – Laparoscopic Cholecystectomy, Nissen Fundoplication & Appendicectomy

Figure 1.2 The Stepwise Progression of Technical Skills in Learning MIS Procedures

It has been demonstrated that the greater the level of surgical experience in a certain minimally invasive technique the less the risk of intra-operative and post-operative morbidity (Deziel, 1994, Nugent & Neary, 2010). Nevertheless the question remains as to whether experience, defined by time and procedure number, is an optimal marker of quality.

There is also research demonstrating that there is a need for on-going practice and training. A study by Cooper and Fischer evaluated the complication rates of surgeons who had attended a training course after 3 months and 12 months (See et al, 1993). The study showed that at 3 months surgeons who had performed MIS procedures without any additional training were nearly 3 times more likely to have at least one complication compared to surgeons with further training. It also found that regardless of length of time passed since training the rates of complications correlated directly with the number of laparoscopic procedures performed.

The evidence indicates that the skills required for minimally invasive surgery are difficult to develop and require extensive practice and learning. Psychology the scientific study of behaviour and its related mental processes has a significant contribution to offer into the cause of the difficulties with learning minimally invasive techniques. A better understanding of the skills required for advanced MIS procedures may allow us to reduce this learning curve.

1.4.2 Visual Spatial, Psychomotor and Perceptual Aspects of MIS

When learning and developing the necessary skills for minimally invasive procedures most of the difficulties encountered can be explained by visual spatial, psychomotor and perceptual factors (Gallagher et al, 1998; Perkins et al, 2002). A greater understanding of these underlying psychological factors may therefore provide a better insight into the learning curve in minimally invasive techniques.

One of the main visual spatial and perceptual problems associated with minimally invasive techniques is the fact that the surgeon must be able to interpret a 3D image from a 2D monitor. The image is one which has been presented from only a single point perspective, for example the single camera source in laparoscopy and endoscopy or from fluoroscopy in endovascular procedures. This is further complicated by a reduction in binocular information whereby no clues as to the depth of the objects displayed on the 2D monitor are available. Normally binocular vision gives important information on depth perception which is lost in minimally invasive techniques due to the single point perspective except perhaps in TEMS.

Binocular clues are only one of a vast and complex stream of information used for depth perception.

Evidence also suggests that motion clues are likely to enhance the effectiveness of monocular information (Reinhardt-Rutland, 1996). The relationship between an individual's estimation of reach and grip required to obtain an object and the object's size and distance specified by pictorial cues require a period of learning and adaptation (Haffenden & Goodale, 2000). This applies to the monocular vision associated with minimally invasive techniques. It has been proposed that a fundamental aspect of motor adaptation involves establishing a relationship between the self-produced movements of the body and the resulting changes in the patterns of information encoded by the sense organs (Holzt, 1954).

Another problem is the scaling differences caused by magnification of the image and the degradation in the quality of the visual image in comparison to open surgery. Image degradation can be explained by the fact that the visual spatial information obtained from 2D video or fluoroscopy images whilst capable of displaying kinaesthetic information removes the viewer's spatial choices and ability to interact. This as a result dictates a degraded view of the spatial scene (Garling et al, 1997). This is however improving as technology advances.

The various visual spatial difficulties encountered during MIS are also related to cognitive mapping and hand-eye coordination problems. The appearance of anatomy is different due to the perspective and magnification of objects closest to the camera. Visual spatial discrepancies are also caused by a misinterpretation of the angular relationship, as the entry points of instruments do not correspond with the optical axis of the camera. These difficulties make accurate planning and executing movements within the abdomen a more complex and risky endeavour (Crosthwaite et al, 1995). Some of the psychomotor problems encountered include a reduction in tactile sensation of the hands. This can cause difficulties in delicate surgical procedures and also results in the loss of ability to diagnose tissue using sensory judgement. The reduction in tactile feedback can result in difficulty navigating through an internal landscape.

One of the main ergonomic issues associated with MIS is that instrumental manipulation is limited to only four degrees of freedom, unlike the six degrees of freedom available in open surgery. The fulcrum effect is considered one of the greater problems limiting the surgeon's ability to acquire psychomotor skill in laparoscopy (Crowthers et al, 1999). The fulcrum effect is defined as the perceived inversion of movements. Laparoscopic surgery creates a visual discordance between the eye and proprioceptive information. The resultant feedback becomes counterintuitive causing an incorrect sequencing of psychomotor output and a long period necessary for compensatory change (Gallagher et al, 1998). The result is first order paradoxical movement caused by the interface of unarticulated instrumentation when limited to a fixed axis (Patkin & Isabel, 1993). Consequentially an internal movement to the right is displayed as a movement to the left on the monitor. The perceived inversion affects horizontal and vertical movements. The effects of image inversion on various tasks have been well documented previously. Stratton (1897) noted the difficulty in even simple movements caused by prisms inverting the retinal image. Smith (1970) demonstrated the problems that humans had in adapting to writing in a mirrored reflection.

A further issue, that is unique to minimally invasive techniques, is the idea of surgical fatigue syndrome. This is characterised by the prolonged duration of an awkward stance, uncomfortable arm positioning and eye strain (Cushieri, 1995). This is often described at the early stages of the learning curve in minimally invasive techniques demonstrating the additional stresses that MIS place on the trainee when compared to open techniques.

MIS surgery makes specific and different demands on the surgeon when compared to open surgery. Fundamental to the efficient and safe execution of MIS is the surgeon's ability to adapt and interpret often conflicting sources of information. It is therefore likely that given the psychological difficulties involved that some individuals are better suited to minimally invasive surgery than others.

Demonstrating the competency of surgeons is crucial as is demonstrating their ability to maintain a consistent level of performance. As a result it has become necessary to objectively measure operative skill and set performance standards. Assessing the potential ability of a trainee has also become a topic of debate.

1.4.3 The Current Training Environment

When Johns Hopkins Hospital opened in 1889, William Halstead, a prominent surgeon at the time devised a training model. His training system based on progressive responsibility was the foundation for the residency programs that are still in place today. However in recent years there have been a number of changes in medicine that have resulted in problems with this current training system.

Firstly, there has been a change in the expectations of patients and the population as a whole. This has resulted from the publication of high profile medico-legal cases such as the 'Bristol Case' (Kennedy, 2001) and the 'To Err is Human' (Kohn et al, 1999) report in the British Isles and the US. These cases have brought medical errors and the quality of surgical training to the forefront.

Fatigue due to an excessive workload and hours worked first became recognised as a significant problem following the landmark Libby Zion case (Asch & Parker, 1988). It has been demonstrated that fatigue is directly linked to medical error and a reduction in clinical performance (Van Dorsen & Dinges, 2000; Dinges et al, 1997). Fatigue has also been shown to effect mood and psychomotor performance.

The European Working Time Directive (EWTD) was a piece of legislation that demanded that doctors work less hours per week (www.doh.ie). The aim of reducing hours worked was to ensure that patients receive high quality and safe care. The EWTD should have been fully implemented in the Irish healthcare system from 2004. It has been rolled out to a certain extent but as yet has not reached the ascribed targets.

However with the introduction of the Calman reforms in the UK and the implementation of the European Working Time Directive the surgical community have been forced to debate how best to train junior surgeons in a shortened period of time (The Calman Report, 1993). Although the proposed reforms have received a cautious welcome from the medical community, there are significant worries about the impact of shortening the training time on trainees' experience (Crofts et al, 1997; Skidmore, 1997). In the UK, studies have shown that this has resulted in a reduction in the number of cases that a trainee is exposed to by a factor of nearly half (Ross, 2002).

Other issues include continuing professional development (CPD), peer review of practice, recertification and credentialing as well as remedial re-training of surgeons who are failing to provide accepted standards of care. The Irish Medical Council in 2003 introduced a system of Competence Assurance Structures (CAS) to ensure that medical practitioners maintain the necessary knowledge and skill throughout their careers. One of the current issues in surgical training is the lack of pre-set standards as a benchmark for competency. Surrogate markers of quality, such as time spent in training and the number of procedures performed, should no longer be acceptable. The National Bowel Cancer Screening Program in the UK is a good example of what surgical training should aspire to in terms of both site and physician accreditation (NHS BCSP, 2010).

The last decade has seen considerable changes in the structure of healthcare delivery. There has been a steady shift towards a consultant-based service with reduced service activity by trainees. This shift is set to continue into the future. One factor propelling a consultant-led service is the fact that the complexity of surgery is increasing. This is due to advancements in the minimally invasive approach but it is also due to improvements in critical care services allowing more elderly and sicker patients to be operated on. With the proposed creation of a limited number of Centre's of Excellence in Ireland there will be further dramatic changes in the way surgical training is delivered.

Economic factors also affect training structures. The length of elective waiting lists and time pressures in the operating theatre play an important role in the amount of operative experience a trainee now receives. Coupled with the increasing cost of new operative technologies and instrumentation and the global economic recession the financial restraints on supervising surgeons is greater than before.

There has been an overall shift in recent years in the attitude of the newer generations of physicians. The desire for a better quality of life, including a greater involvement in family life has affected the number of trainees attracted into surgical training (Viola et al, 2010; Yeo et al, 2010). An increase in the numbers of female graduates has also negatively impacted on the number of potential surgical trainees.

The age old Halstedian method of teaching in surgery should be no longer acceptable. The idea of "see one, do one, teach one" is now an outdated method. However, most teaching in Ireland continues along this traditional apprenticeship route, where trainees are exposed to surgical procedures with the guidance of an experienced teacher. As a result teaching is quite unstructured and is very much dictated by the location of the hospital the trainee works in (tertiary referral centre versus regional hospital), the case load and case variation and the enthusiasm of the supervising surgeon for teaching. Furthermore, the current training paradigm lacks objective feedback on trainee performance. The current structure is unlikely to change and therefore the approach to training must. Training needs to be done in a more efficient manner to optimise the learning experience and surgical exposure of the trainee.

Proficiency based progression training has recently been embraced as an important and new concept in surgery. This is due to the difficult and emerging challenges that the practice of surgery faces today. A proficiency based curriculum requires achievement of expert-derived, performance based criteria, regardless of the amount of practice needed. Using such training goals enhances motivation, and learning, thus maximizing skill acquisition and retention. It also tailors training to meet individual needs while simultaneously ensuring that uniform performance is achieved by all trainees (Brunner et al, 2004; Korndorffer et al, 2005; Stefandis et al, 2005). It allows for trainees to acquire skills at different rates. There has been strong evidence that PBP training for general surgical trainees does indeed improve intra-operative performance (Seymour et al, 2002; Grantcharov et al, 2004). A PBP training programme will allow us to send a pre-trained junior surgeon into the operating theatre and instead of starting from first principles; he/she can polish or perfect the newly learned skills. This optimises the surgeons learning experience but more importantly, it exposes patients to less risk during the trainees' learning curve. Another advantage of the proficiency level approach is that it focuses training effort on those surgeons who require the most training, as those trainees who already perform well will take less effort to reach the proficiency level.

Surgical training and skill acquisition are particularly important in minimally invasive surgery as exact and precise techniques are essential to minimise patient morbidity. Training a junior surgeon in minimally invasive techniques is more difficult than training in an open procedure. This is because, for example, with laparoscopy the expert surgeon has less control over what the trainee is doing. If a complication were to arise during the course of the surgery it would be more difficult for the expert surgeon to intervene and rectify the situation. The same can be said for endovascular procedures and endoscopy. The learning curve is also steeper in minimally invasive procedures than for open surgery as trainees have to learn to manage not only new technology and overcome obstacles like the fulcrum effect but they also have to have a good fundamental ability for these procedures as well.

Traditionally the skills required for MIS have been attained in the operating theatre. It has been here that the steepest part of the learning curve has been battled out. It is obvious that this situation is not the ideal for either the patient or the trainee. However, the introduction of simulation to minimally invasive surgery has helped to address these issues. Simulation provides a safe environment for trainees to overcome the initial learning curve including the visual spatial, perceptual and psychomotor difficulties associated with minimally invasive techniques.

1.5 The Role of Simulation in MIS Training

The introduction and development of virtual reality (VR) simulators has been one of the main innovations that have resulted in a change in training curricula in surgery. Satava was the first to recommend VR simulation as a complement to current training models (Satava, 1993). The term "virtual reality" was coined by Jaron Lanier a philosopher and scientist in the 1980's. It is a phrase used to describe the concept of a virtual world which supports interaction instead of something that is passively visualised.

Simulation has its roots in the commercial and military aviation industry. It was first considered in 1910 when student pilots trained in land-borne aircraft with reduced wingspans (Winslow, 1910). The first rudimentary simulator was available in 1929 and was known as the Links Trainer (Kelly, 1970). It consisted of a wooden fuselage mounted on an air bellows which was able to represent the movements involved in flight. This allowed the pilot to train for hours. In 1934 the US purchased six Links simulators following a series of aviation accidents. At this stage it was recognised that the current training programmes were inadequate and simulation was a step towards improving the training system. World War II also had a dramatic impact on the uptake of simulation for training purposes. The war demanded that a greater number of pilots be trained and that skills such as the need to become proficient in instrument or blind flying were paramount. These factors led to simulator development and usage. Nowadays pilots need to complete a set number of simulator hours before they are allowed to fly a plane. They are required to train and be certified in a simulator which is specific to the type of plane they will fly. Astronauts are also required to follow the same procedures (Ball et al, 2008).

The first surgical simulator to use virtual reality technology was created at NASA by Rosen and Delp (Delp et al, 1990). It was an orthopaedic lower limb model that simulated tendon transfer. It was unique in that it allowed planning and therefore optimisation of operations. Virtual reality technology has evolved to the point today where actual patient data and radiological images can be in-putted into the simulator allowing for a simulated run-through before operating on the patient, a process known as mission rehearsal (Levy, 1996). Modern simulators are often augmented or hybrid reality instruments where they combine VR with real physical materials, instruments and feedback. The advantage of augmented reality is that haptic feedback is possible which aids the learning process.

The benefits of simulation for surgical training were championed by Satava in the early 1990's (Satava, 1993). It has however, taken greater than ten years for it to be properly recognized as a valid training tool. It now is acknowledged as an important tool for training in the minimally invasive setting (Okrainec et al, 2010). Simulators like the GI MENTOR II, the VIST and the ProMIS have all been extensively validated for surgical training (Ritter et al, 2003; Ferlitsch et al, 2002). The first study to demonstrate a transfer of simulator learned skills to the operating room was in Yale, 2001 (Seymour et al, 2002). They demonstrated that those trainees randomised to VR simulation training performed 29% faster and made six times fewer errors in laparoscopic cholecystectomy. Use of VR simulation for training has been approved by the FDA in the US for carotid artery stenting (Gallagher & Cates, 2004) and simulator training is also mandatory in laparoscopic procedures for surgical residents as per the Accreditation Council for Graduate Medical Education (ACGME).

The advantage of simulation is that it allows the trainee to learn basic tasks in a safe and controlled environment. All movements the trainee makes can be recorded and therefore there is the facility for immediate and objective feedback. It is also possible to set a proficiency level on a simulator and therefore design a training program giving set goals that a trainee needs to accomplish before being allowed perform in the operating theatre. All of these factors contribute to skill learning, assessment, selection and credentialing. Simulators will also be invaluable in the teaching of the newer forms of surgery, single incision laparoscopy and natural orifice transluminal endoscopic surgery. The use of simulation should provide the setting in which challenges such as the use of new instruments and technology can be overcome. An example of this is in single incision laparoscopic surgery where it is difficult to have instruments working parallel to each other in a very narrow operative field.

1.6 Addressing the Difficulties Associated with Minimally Invasive Surgery

1.6.1 Aptitude Assessment for Minimally Invasive Techniques

Aptitude assessment relies on the ability to demonstrate differences in desirable innate qualities that are essential to a specific task (Annett, 1974). Skills displayed in the operating theatre or in simulators represent an individual's ability to adapt to MIS but provide little insight into the innate factors that mediate the level of performance. The quantification of individual differences in measures of perceptual, visual spatial and psychomotor ability may therefore expose the underlying mechanisms that determine performance in MIS.

The development of sound and accurate measures of differences in individuals is known as psychometrics or mental measures (Cooper, 1998). These are tests or instruments designed to gain understanding of an individual in order to predict behaviour and provide a basis for future action (Edenborough, 1994). Psychometric tests originated in work related to education in the 1800's (Cattell, 1890). They were initially employed in the First World War (Yoakum & Yerkes, 1920). Following the war tests were developed to assess suitability for certain employments. Some examples include aptitude tests for clerical work (Burt, 1922) and for dress-making (Spielman, 1923). The first battery of aptitude tests was published in 1947 in the US and was called the Differential Aptitude Test (DAT). This was a multi-occupational guidance package comprising of a range of tests covering abstract reasoning, spatial relationships and spelling.

The accurate identification of those individuals' best suited to an advanced career course or which job applicants would best suit a position can bring significant financial and personal benefits to an individual and company whilst reducing potential problems (Cooper, 1998). Aptitude is synonymous with ability and both refer to stable and innate characteristics such as intelligence, manual dexterity etc that represent the individuals level of cognitive processing and skill when dealing with a particular task.

In minimally invasive surgery the aptitudes that have been identified as important are visual spatial, psychomotor and depth perception aptitude.

1.6.2 Visual Spatial Ability

Psychometric research has successfully established a visual spatial factor by documenting significant individual differences with success in solving spatial problems of intermediate difficulty and distinguishing this factor from verbal and numerical factors (Smith, 1964). There is much evidence to suggest that our visual spatial ability is innate (Wertheimer, 1961) and shaped through life experiences to be very individualistic (Foreman & Gillett, 1997).

Over the years of research individual differences in visual spatial abilities have been well established between gender (Moffat et al, 1998; Dabbs et al, 1998; Lawton, 1994), age (Hassler, 1991; Cornell et al, 1992), culture (Gay & Cole, 1967; Brislin, 1983) and handedness (Sanders et al, 1982). Visual spatial tests have also been proven to be an integral part of mechanical ability assessment (Humphries et al, 1993), general intelligence (Thurstone, 1938) and pilot screening (Calvert, 1997).

The effects of visual spatial misjudgement have been well documented in military aviation and are believed to account for a considerable proportion of aviation accidents (Regan et al, 1995; Collins & Harrison, 1995). Of note it has been found that accidents resulting from visual spatial disorientation do not decrease with increasing pilot experience, which indicates that learning alone cannot compensate for the occurrence of visual spatial disorientation (Cheung et al, 1995; Navathe & Singh, 1994).

The previous literature and research has identified the impact of various visual spatial problems involved in MIS and how these are likely to affect the ability of surgeons to plan, interpret and perform procedures (Hedman et al, 2006; Hassan et al, 2007). The possible involvement of visual spatial disorientation, misinterpretation and poor representation has been implicated as potential causes of errors in MIS. Research has also demonstrated that ability to adapt to these spatial difficulties is mediated by individual differences in experience, understanding and cognitive functioning. Therefore it should be considered worthwhile to further investigate the role of visual spatial aptitude and its effect on performance outcomes in MIS.

1.6.3 Psychomotor ability

Psychomotor skill refers to the ability to accurately perform, learn or adapt to situations requiring fine and complex sequences of motor activity (Adams, 1990). The process is dependent on the body's sensory information regarding the position and movement of the limbs. Kinaesthetic information is primarily gained from body movements whether self-generated or externally imposed (Clark & Horsch, 1986). Proprioception also plays a role.

Psychomotor ability provides the necessary information to move, interact and manipulate ourselves and objects within the environment. The accurate integration of visual spatial, perceptual and psychomotor information is of fundamental importance in nearly every aspect of everyday life.

With motor skills the hands are the effector system for manipulative skills and the trunk and limbs are the principle effectors for whole body skills (Adams, 1987). Another important effector is the ocular motor system which is involved in spatially orientated behaviour and specifically tracking and localisation (Courjan et al, 1981). The combination of the properties of the object, the type of movement required and the effector systems involved are all significant in determining the kind of control that is needed for the task (Lee & Swinnen, 1995).

Research over the years has demonstrated a strong individual difference in psychomotor ability between age (Heikkila, 2000), gender (Joseph & Willingham, 2000), handedness (Balis et al, 1998) and response accuracy (Kohl et al, 1998). Psychomotor assessment has also been repeatedly demonstrated to be a significant factor in the assessment of pilot ability (Griffin, 1998; Burke et al, 1997; Wolfe & Larson, 1997; Calvert, 1997).

The psychomotor difficulties associated with MIS were probably the first and most obvious problem encountered by the trainee and as a result were documented quite quickly in the surgical literature (Noar & Soehendra, 1992). The main psychomotor issues with minimally invasive techniques relate to hand-eye coordination ability and dexterity, primarily of the hands and fingers. Psychomotor aptitude and its relevance to all fields of surgery is without question. The use of a simple test to assess psychomotor aptitude therefore could have a significant predictive value for performance in MIS and requires research.

1.6.4 Perceptual Ability

The perceptual problems experienced in minimally invasive surgery are a result of the difficulties in establishing 3D structures from 2D monitors. This is not an easy process as it involves resolving issues related to size, depth, orientation, movement, shading, texture, colour, experience and learning. Each of these considerations represents an important aspect of perception in MIS. All these factors are equally important but the one we consider in further detail is the idea of depth perception.

Pictorial cues are interpreted as depth as a result of our visual interaction with geometric objects and the reflection of light encoded by the eyes in the external world. In aviation the difficulties processing multiple aspects of visual depth information (colour, light, size, motion etc) in the absence of effective physiological cues has been identified as a serious cause of aircraft manoeuvring errors and a source of considerable inter subject variability (Regan et al, 1995).

The theory behind pictorial perception is that the structured arrangement of light (optic array) reaches the eye and projects a 2D representation of the environment that bears a geometrical relationship to the scene in 3D space (Wade, 1992). As light travels in straight lines at any given moment the environmental projection on the eye can be described geometrically as a pictorial representation of the scene. The independent varying points of light on the 2D optical image are then translated into a 3D understanding of the environment (ie spatial layout, objects, height, length, direction, depth) referred to as a visual image (Crothers, 2001).

There have been a number of experimental studies investigating how innate perceptual ability is. Gibson and Walk in the 1960's demonstrated that crawling infants could perceive depth with the visual cliff experiment (Gibson & Walk, 1960). Spatial localisation and special segregation ability have also been demonstrated in newborn infants (Wertheimer, 1961; Fantz, 1963). Therefore the evidence suggests that our ability to construct and interpret depth is indeed innate but further shaped and influenced by our life experiences (Gibson & Walk, 1960; Hochberg & Brooks, 1962; Ross, 1974; Bertenthal & Campos 1989)

Various studies have demonstrated individual differences in depth perception for culture (Hudson, 1960; Ardila et al, 1989) age (Hochberg & Brooks, 1962; Bertenthal & Campos, 1989) colour segregation (Baylis & Driver, 1992) & reconstruction of 3D images from projective displays. The reconstruction of 3D shapes from a 2D image have been shown to be of importance in engineering, physical science and art (Humphries et al, 1993), dress making & architecture (Yaslow, 1976) and computer aided design (Duesbury & O'Neil, 1996). It has also been demonstrated to be vital in flying (Gibson, 1950). Previous studies have also demonstrated a strong individual difference in the ability to reconstruct depth from pictorial displays (Cowie, 1998; Duesbury & O'Neil, 1996).

There has been limited research into the role of depth perception aptitude in minimally invasive techniques to date. One of the main aims of this thesis is to evidence the importance of spatial, psychomotor and perceptual abilities in MIS and to empirically demonstrate how individual differences in psychological ability are related to performance. This in turn should delineate what role aptitude assessment may have in helping to overcome the difficulties with training in MIS.

1.6.5 Human Factors Influencing Surgical Performance

It is clearly important for all surgeons to have a sound knowledge and understanding of the theory of surgical practice. It is likewise important for surgeons to be technically adept at the craft of surgery. On their own, however, knowledge and skills do not necessarily make a good surgeon. Sometimes, surgeons with extensive theoretical knowledge can be less than adequate in the operating room. Likewise, some surgeons who are technically very expert in the operating theatre consistently fail to get the results that would be expected from such expertise. Often, surgeons with less knowledge and less technical expertise get better outcomes for their patients because they operate on the right patients at the right time, they continue to perform well under stress or in times of crisis, and they manage to successfully harness the support of a multidisciplinary team to get the best results for their patients. This is the "human factor" in surgery.

It has been estimated that only 25% of the important events which occur during a surgical procedure are related to manual or technical skills and that 75% relate to human factors such as decision making (especially during crises or emergencies), communication, team work and leadership. Other human factors which are important in surgical practice include self-awareness (i.e. insight), distractibility and performance under pressure. It has always been considered that these personal skills are innate aspects of human personality and that they can neither be taught nor acquired however whilst some individuals seem to be born with these skills, many others can have these skills improved by formal education and training. Although it is unlikely that innate personality can be changed, it is undoubtedly possible to alter aspects of behaviour which impact negatively on colleagues and ability to perform in the work place.

Human factors have long been recognised as important in surgery (Chodhary, 2004; Anjum et al, 2005; www.parliament.uk/healthcom). Assessment and training in human factors has recently been highlighted as increasingly relevant in the field of surgery. This has occurred secondary to reports demonstrating that medical errors cause up to 98,000 deaths per year in the US (Kohn et al, 1999). Human factors have been established as one of the main causes of medical error. The top three areas in the hospital setting associated with the greatest risk of medical error are the operating theatre, intensive care and the emergency department. These three areas are the primary settings in which surgeons work on a daily basis. Therefore it is clear that in order to reduce the morbidity and mortality rates associated with medical error focus on how to improve safety and efficiency in these environments are critical.

The operating theatre is a highly pressurised environment. It is an environment whereby the surgeon must accomplish cognitively and technically challenging tasks in a limited period of time. This is accompanied with the knowledge that the impact of any error may have serious consequences. Some of the potential intra-operative stressors include unexpected bleeding, complicated procedures, time pressure and noise. Coupled with this is the acknowledged fact that MIS is inherently more pressurised and stressful than open surgery (Bergeur et al, 2001).

Minimally invasive techniques are more stressful due to the additional visual spatial, perceptual and psychomotor challenges faced by the surgeon (Gallagher et al, 2003). The technical complexity of a procedure and the associated learning curve also add to the pressure to perform. A study carried out by Hassan demonstrated that poor stress coping ability correlated with poor laparoscopic performance (Hassan et al, 2006).

Stress is defined as the interaction between three elements: perceived demand, perceived ability to cope and the perception of the importance of being able to cope with the demand (McGrath, 1976). Arousal theory suggests that some stress can add to and enhance performance. However as the level of stress increases, performance is actually hampered (Yerkes & Dodson, 1904). This effect has been well documented in the aviation industry (Mueller, 2004). Some of the negative effects of stress include impairment of attention, vigilance, memory, judgement and decision-making (Steal, 2004). It is also recognised that certain personality traits amongst doctors are also related to outcomes such as stress and burnout (McManus et al, 2004).

Personality testing is used widely for employee selection (Rothstein & Goffin, 2006). Interest has been expressed in the literature in using this for surgical selection (Bann & Darzi, 2005; Gilligan et al, 1999). To date however no institute has formally evaluated how human characteristics could impact on surgical performance. In particular no psychometric test that specifically evaluates an individual's ability to perform under pressure has been examined in relation to surgery.

The TAIS or The Attentional and Interpersonal Style Inventory is a psychometric test that was developed specifically to measure the building blocks of performance (Nideffer, 2007). It was designed as an instrument to provide highly specific performance relevant feedback to individuals who must be able to perform at high levels of pressure, the prime example being the operating theatre environment.

The theory of attentional and personal style and the construct of behavioural styles is important as it lends itself to the behavioural definition of the various types of concentration required by vastly different performance arenas. The attentional constructs measured by the TAIS lead to the identification of an individual's concentration strengths and weaknesses within that person's particular performance environment. It is those attentional constructs in combination with other personal and interpersonal attributes that determine why when two people have the skill sets and knowledge necessary to be successful what it is that allows one of them to succeed while the other fails. The TAIS inventory was designed to answer these questions.

Individuals achieve higher levels of success when their dominant behaviours match the performance requirements of their performance arena. It is easier for people to practise and develop behaviours that come naturally to them, to which they are predisposed, than it is for them to practise and develop behaviours that do not come naturally. For example an introvert can behave in an extroverted manner for a while but it is far less comfortable and enjoyable for them. As a result individuals tend to gravitate towards situations that play to their particular behavioural predispositions and away from those that do not. This tendency is especially true at an elite level such as in minimally invasive surgery. Performance at an elite level places a heavy burden on a particular set of skills and abilities. If performance skills do not come easily and naturally it is extremely difficult to maintain the motivation and to make sacrifices necessary to develop those skills and abilities to a higher level.

Clark Hull's drive theory suggests that those behaviours which are most practised and have the strongest "habit strength" are the ones that are most resistant to disruption from increasing arousal (Hull, 1943). Therefore in high pressure situations those behaviours that are the most dominant are the ones that are relied on in these situations. Under pressure an individual's dominant behaviour becomes more trait-like and less adaptable to new situations or changing conditions. Under pressure an individual will perform once the situation plays to their strengths. Performance will deteriorate though when the situation requires skills that are inconsistent with the dominant styles or behaviours. An individual's greatest strengths become greater liabilities in high pressure situations that require the inhibition of those dominant styles.

The core competencies identified by the TAIS are; concentration skills, intrapersonal behaviours and interpersonal behaviours. It determines the types of situations in which an individual will perform well and not so well in but it also determines the types of mistakes that they are most likely to make under highly stressful conditions.

Objectively measuring human factor elements that are relevant to surgery and in particular to minimally invasive surgery is a novel endeavour. One of the aims of this thesis was to further evaluate the TAIS and the role it may have in both selection and training for MIS.

1.6.6 Non-surgical Skills in MIS

When learning minimally invasive techniques certain attributes may confer an advantage. Some of the attributes that have been associated with ease of learning in minimally invasive surgery are fundamental aptitudes and personality factors both of which we have described at an earlier stage. Another set of attributes that require consideration are certain non-surgical skills. These non-surgical skills include extra-curricular activities such as musical ability, participation in competitive sport and playing video games.

Any attribute a trainee may have at the start of their career that allows them to progress to proficiency at a faster pace is worthwhile evaluating. The ability that each surgical trainee has at baseline varies (Gallagher et al, 2009; Matthews et al, 2000). Being able to predict the baseline skill or starting point of a trainee in minimally invasive techniques may prove useful when it comes to designing and implementing a training curriculum. In particular it could allow the development of individualised training programmes with individualised goals. Therefore the assessment of non-surgical skills like musical ability, video game playing and participation in competitive sport is an area that needs consideration.

There has been little in the way of research into the role of musical ability on surgical skills (Enochssson et al, 2004; Schlickum et al, 2009). Musical performance demands complex cognitive and motor operations. Musicians must translate music notation (visual spatial information) into precisely timed sequential finger movements involving coordination of both hands. Studies have demonstrated that in musicians certain regions of the brain have structural differences when compared to non-musicians (Münte et al, 2002). It has been hypothesised that these changes are due to learning as functional and structural brain changes are associated with acquiring and practising new skills (Karni et al, 1995). The type of instrument played has also been shown to influence the type of brain changes. Violin training is associated with adaptations in the brain region controlling fine motor movements of the left hand and piano training has been shown to be associated with adaptations in the brain region controlling finger movements of both hands (Amunts et al, 1997). Prior research has reported that music training enhances visual spatial ability in young children (Costa-Giomi, 1999). Understandably studies have also demonstrated that motor training has positive effects on motor skills (Forgeard et al, 2008). The tapping rate of both the right and left index fingers were shown to be faster in musicians in contrast to non-musicians and the tapping rate in the non-dominant hand was shown to increase with musical training (Jancke et al, 1977).

It is clear therefore that musical ability is an area that is relevant to surgical training. In particular it is applicable to minimally invasive surgical techniques where dexterity in both hands and a greater degree of visual spatial and perceptual ability is required when compared to open surgery. Taking into account the type of instrument, the number of years' experience in playing music and other factors such as distinctions achieved in examinations could play an important role in determining what trainees expected ability should be and how quickly they should progress.

The previously published benefits of video game playing are well known. These include increased hand-eye coordination, spatial visualisation and mental rotation (Griffith et al, 1983; De Lisi & Wolford, 2002; Dorval & Pepin, 1986; Green & Bavelier, 2003). Video game playing is a very popular extra-curricular activity with many adults dedicating a number of hours per week to it (Gentile et al, 2004). Playing video games can be the first exposure to a graphical user interface that an individual encounters (Rosser et al, 2007). It has been demonstrated that video game players are able to react more quickly to visual stimuli than people who do not play video games (Castel et al, 2005).

Previous studies have shown that laparoscopic technical ability can be predicted by video game usage (Grantcharov et al, 2005; Schlickum et al, 2008). Similar to playing video games, in minimally invasive surgery the operator is looking at the screen and not their hands, with the result that they have to translate 2D object movements into 3D. Playing video games allows a novice to become familiar with a 2D monitor and allows them to acquire the basic hand-eye coordination skills required for minimally invasive techniques.

The military in the US have recently adapted video game playing into the training schedule of their special operations forces (Johnson, 2000). The exact role of video game playing in minimally invasive surgical techniques has yet to be elicited. Examining whether trainees play video games, the type of game they play, the number of hours per week they spend playing and whether they have completed a game or achieved the maximum score and comparing these elements to their MIS skills may allow us to determine a trainees skill ability.

Video games are becoming more accessible than ever and increasing in complexity. It is logical to assume that future generations of surgical trainees will have prior or extensive experience with playing video games. Therefore consideration should be given to whether it is of value to incorporate video game playing into current surgical training schedules.

Sport is the one extra-curricular activity of the three we plan to examine that has the least available information in terms of published studies on the relationship between sport and surgical skill performance. It is easy to accept that there is a significant relationship between sporting performance and psychomotor and spatial ability. The literature suggests that sport may be considered a spatial activity and therefore engaging in sport increases the capacity of the individual to implement and relate to mental imagery (Ozel et al, 2004). It has also been shown to affect the speed at which an individual can process information from a constantly changing environment. Studies have demonstrated that athletes are better at performing spatial and psychomotor tasks than non-athletes (Ozel et al, 2004; Kioumourtzoglou et al, 1998). The nature of the sport played has also been demonstrated to influence the way perceptual and spatial abilities differentiate elite athletes from novices (Kioumourtzoglou et al, 1998a).

As spatial and motor activities are closely linked to sporting ability it is reasonable to expect that surgical trainees participating in sport may have a learning advantage when it comes to certain minimally invasive procedures. In surgery one study showed that when learning and performing an advanced task such as laparoscopic suturing those trainees with sporting ability performed better than those without (Harper et al, 2007).

No study has examined the impact of three different non-surgical skills – video game playing, musical ability and playing competitive sport on an array of minimally invasive tasks. One of the aims of this study was to explore the relationship between these various non-surgical skills with ability to perform minimally invasive surgical tasks.

1.7 Objectives

1.7.1 Hypothesis Underlying the Objectives

The overall objective of this thesis is to investigate and evaluate those factors that influence the capacity of a trainee to become a proficient minimally invasive surgeon. This has become relevant due to the fact that there has been a recent change in the training structure in surgery and also due to an increasing demand for the minimally invasive approach. As a result there has been a need identified to investigate those factors that may allow an individual's learning curve in minimally invasive techniques to be mapped out before they start their training pathway. The idea is that training programs could be potentially individualised to match the strengths and weaknesses of the trainee in learning minimally invasive techniques. As we continue to move closer to the era of simulation training and proficiency based progression, appraising the role of these factors becomes more pertinent.

1.7.2 Detailed Objectives

Objective 1:- To evaluate the impact of psychometric aptitude on performance in basic minimally invasive surgical skills.

Psychometric factors that have been identified as important in minimally invasive surgery are visual spatial, depth perception and psychomotor aptitude. Everybody's pattern of aptitude is different and this we believe has an impact on an individual's ability to perform minimally invasive skills. We aim to evaluate the impact of visual spatial, psychomotor and depth perception aptitude on performance in three different areas of minimally invasive surgical skill (laparoscopy, endoscopy, endovascular) at novice, junior surgical trainee and senior surgical trainee level.

Objective 2:- To determine if certain personality characteristics influence performance in minimally invasive techniques.

Learning is also affected by cognitive and personality characteristics. The ability to perform under pressure and to have a good level of attentional ability is vital in surgery in general. We aim to determine if certain personality characteristics, in particular ability to deal with stress and attentional level, influence performance in MIS. We also wish to determine if there is an overall difference in distribution of certain personality characteristics between a group of students, junior trainees and senior surgical trainees.

Objective 3:- To investigate the influence of non-technical skills on performance in basic minimally invasive techniques.

Other personal attributes that a trainee has, such as playing a musical instrument, sport or video games, should be considered as they affect an individual's spatial and psychomotor ability. This in turn should influence ability to perform various minimally invasive skills. Using the same cohort of subjects we aim to investigate if part-taking in extra-curricular activities has any effect on ability to perform basic minimally invasive skills in an effort to evaluate the impact they may have on the early part of the learning curve.

Objective 4:- To determine if psychometric factors also impact on performance in an advanced minimally invasive procedure.

As a follow on from examining the influence of aptitude on performance in basic MIS skills we aim to evaluate the impact of these same psychometric factors on performance in an advanced procedure. Prior studies in this field have focused on basic skills or a single skill. No study has determined the effect of aptitude on a complete and advanced procedure such as a sigmoid colectomy. We aim to determine the pattern of aptitude that affects laparoscopic sigmoid colectomy performance.

Chapter 2

Materials and Methods

2.1 Ethical considerations

Ethical approval for the study was awarded by the Research Ethical Committee of RCSI. Each volunteer was given a subject information sheet explaining the study in detail and outlining what their expected involvement was. Volunteers were required to give written informed consent according to the protocol agreed by the ethics committee. All data collected was coded and stored in an anonymous format. It was made clear to all volunteers that all data collected was not going to be shared with any third party, in particular their hospital, tutor or supervisor(s).

2.2 Recruitment of Participants

A general e-mail was circulated to all the medical students attending RCSI in the pre-clinical years 1-3, all the basic surgical trainees and higher surgical trainees throughout Ireland and the general practice trainees' year 3 & 4 attached to RCSI and Trinity College Dublin (TCD). Posters were also displayed in the National Surgical Training Centre (NSTC). Participation was voluntary. Participants were randomly selected from the responses received.

All assessments were performed at the National Surgical Training Centre, The Royal College of Surgeons in Ireland, 121 St. Stephen's Green, Dublin 2.

2.3 Participant Demographics

In total 66 medical students, 205 surgical trainees, 5 experts in MIS and 25 general practice registrars took part in the study. Further demographic details are outlined in each chapter.

The inclusion criterion for the group of medical students was that the subjects could only be in preclinical years 1-3. This meant that they did not have any previous clinical exposure, in particular to surgery, and therefore were complete surgical novices. Students were excluded if they were in clinical year four onwards or if they had undertaken a summer elective in a surgical rotation.

Inclusion criteria for the basic surgical trainees (BSTs) were that they had to be in either year one or two of their postgraduate training. Currently postgraduate surgical training in Ireland is unstandardised which is reflected in the variable clinical settings a trainee is exposed to. As a result it was difficult to control for the differing baseline abilities of the surgical trainees.

However we attempted to standardise the group using the following exclusion criteria. A trainee was excluded if they had performed any colonoscopies unsupervised or greater than ten colonoscopies under supervision, if they had performed greater than ten basic laparoscopic procedures under supervision or any laparoscopic procedures without supervision and if they had performed any endovascular procedures.

The inclusion criterion for the higher surgical trainees was that they had to be in at least year five of their postgraduate surgical training. They were excluded from the study if they were deemed to be an expert in any of the minimally invasive techniques being assessed.

Inclusion criteria for the general practice registrars were that they had to be in either year three or four of their postgraduate training program. This was considered to be equivalent to the mean stage of postgraduate training of the higher surgical trainees. They were excluded if they had previously participated in any form of postgraduate surgical training.

2.4 Aptitude Assessment

Aptitude is defined as a set of attributes that determine potential for a given activity. This potential may be developed into skilled behaviour with training and practice.

There are three main areas of aptitude that are considered relevant in minimally invasive procedures. These are visual spatial aptitude, psychomotor aptitude and depth perception.

2.4.1 Visual-spatial Aptitude

Visual-spatial aptitude is defined as the ability to generate, retain, retrieve, and transform well-structured visual images. The visual-spatial domain represents a collection of different abilities that each emphasise a different process involved in the generation, storage, retrieval and transformation of visual images.

The visual-spatial domains that are of importance in minimally invasive procedures are spatial visualisation, spatial orientation and spatial scanning. The paper tests chosen for the studies have been demonstrated to be good markers for the abilities they represent (Carroll, 1993). These tests have all demonstrated excellent test-retest reliability measures (table 2.1) (Ekstrom et al, 1976).

Aptitude Test	Test-retest Reliability
Card rotation	0.80 (Ekstrom et al, 1976)
Cube comparison	0.84 (Ekstrom et al, 1976)
Map planning	0.80 (Ekstrom et al, 1976)
Surface development	0.90 (Ekstrom et al, 1976)
Grooved Pegboard	0.82 (Dikmen et al, 1999)
PicSOr	0.94 (Crothers, 2001)

Table 2.1 Test-retest Reliability for the Aptitude Tests Used

Spatial visualisation is the ability to apprehend a spatial form, object, or scene and match it with another spatial object, form, or scene with the requirement to rotate it (one or more times) in two or three dimensions.

Spatial orientation is a measure of the ability to maintain orientation with respect to objects in space. It examines the ability to mentally rotate a configuration. The main difference between spatial visualisation and spatial orientation is that with visualisation only parts of the figure are manipulated, whereas with orientation the entire figure is manipulated. Spatial visualisation requires the use of short term memory. Spatial visualisation is considered to be a more complex and less speed reliant form of spatial orientation.

Spatial scanning is the ability to quickly and accurately survey and visually explore a wide or complicated spatial field or pattern and identify a particular configuration or path through the visual field.

2.4.2 Visual-spatial Aptitude Assessment

The tests were taken from the Kit of Factor Referenced Cognitive Tests (Ekstrom et al, 1976). The kit consists of 72 tests that examine 23 cognitive factors. They are paper-based timed tests. Each test has the same format. There is an introductory page outlining the instructions to do the test and giving sample questions with explanations of the answers. This is followed by two further test pages.

The tests were administered in a standardised fashion. Two minutes were given to read the introductory page; thereafter candidates were offered the opportunity to ask questions. Each test consisted of two parts. Three minutes was allowed for the completion of each part. The only exception was the surface development test where the candidates were given six minutes to complete each part. The tests are scored by awarding a mark for each correct answer and taking away a mark for each incorrect attempt, except for the map planning test where no marks were subtracted for incorrect answers.

2.4.3 Spatial Orientation Assessment

Spatial orientation was assessed using the card rotations test and the cube comparison test.

In the card rotation test each item is a drawing of a card cut into an irregular shape (appendix I.1). To its right are eight other drawings of the same card sometimes merely rotated and sometimes turned over to its other side. The task is to indicate whether or not the card has been turned over.

In the cube comparison test each item presents two drawings of a cube (appendix I.2). Assuming no cube can have two faces alike the task of the subject is to indicate which items present drawings that can be of the same cube and which present drawings that cannot be of the same cube.

2.4.4 Spatial Visualisation Assessment

Spatial visualisation was assessed using the surface development test (appendix I.3). In the surface development test drawings of solid forms are presented that could be made out of paper. With each drawing there is a diagram to show how a piece of paper may be folded so as to make the solid form, dotted lines show where the paper may be folded. One part of the diagram is marked to correspond to a marked surface in the drawing. The task of the subject is to indicate which lettered edges in the drawing correspond to numbered edges or dotted lines in the diagram.

2.4.5 Spatial Scanning Assessment

Spatial scanning was assessed using the map planning test (appendix I.4). In the map planning test there is a diagram that represents a city map. The streets are blocked at various points by barriers represented by circles. The subject must plan routes between given points in such a way that no roadblock is crossed. The task is to find the shortest available route as quickly as possible. The subject must be able to scan the field quickly, follow paths with the eye and reject false leads. Due to the name this test has sometimes been interpreted as a planning function test but the level of planning required by this test is the simple willingness to find the quickest route through visually before wasting time in marking the paper. This is analogous to that required in rapidly scanning a printed page for comprehension.

2.4.6 Psychomotor Aptitude

Psychomotor aptitude is defined as the ability to perform body motor movements with precision, coordination or strength.

There are many subcategories of psychomotor aptitude (table 2.2). For the purpose of this study we were specifically interested in manual & finger dexterity and hand-eye coordination. Manual dexterity is the ability to make precisely coordinated movements of a hand, or a hand and the attached arm. Finger dexterity is the ability to make precisely coordinated movements of the fingers, with or without manipulation of objects. Hand-eye coordination is the ability to coordinate control of eye movement with hand movement. It also involves the processing of visual input to guide reaching and grasping along with the use of proprioception of the hands to guide the eyes.

Psychomotor Aptitude Categories
Control precision
Multi-limb coordination
Hand-eye coordination
Manual dexterity
Finger dexterity
Arm-hand steadiness
Static strength
Aiming
Gross body equilibrium

Table 2.2 Subcategories of Psychomotor Aptitude

Psychomotor aptitude was assessed using the Grooved Pegboard. The Grooved Pegboard is a commonly used and validated test of motor performance. It is a component of several neuropsychological assessment batteries. These include - the Wisconsin Neuropsychological Test Battery (Harley et al, 1980; Matthews & Clove, 1964), the Repeatable Cognitive-Perceptual-Motor Battery (Kelland et al, 1992; Lewis & Kupke, 1992), and the expanded

Halstead-Reitan Battery (Heaton et al, 1992). Test-retest reliability for the Grooved Pegboard has been reported as r > 0.82 (Dikmen et al, 1999).

2.4.7 The Grooved Pegboard

The Grooved Pegboard (Lafayette instruments model 32025) consists of a board with a metal surface which is 10.1cm by 10.1cm in size (figure 2.1). There is a matrix of twenty five keyhole-shaped holes that are orientated in a random variety of ways. Each peg is three millimetres in diameter and has a small ridge that runs along its length. A round receptacle for holding the pegs is located at the top of the pegboard.

Figure 2.1 The Grooved Pegboard

The Grooved Pegboard is a measure of manual dexterity and hand-eye coordination. In particular it measures finger dexterity and fine motor control. It involves the integration of visual information, kinaesthetic information, fine motor dexterity and accuracy. The visual input comes from viewing the keyhole shaped slots on the board. The kinaesthetic feedback is gained from the use of the fingertips to orientate the pegs correctly. Fine motor dexterity involves shifting the peg to match the orientation of it to the slot on the board. Accuracy is required to place the peg firmly in the keyhole. As the pegs must be rotated into position to be successfully placed, the Grooved Pegboard Test adds a dimension of complexity not found in other motor tasks, such as the Purdue Pegboard Test (Tiffen, 1968).

2.4.8 Assessment using the Grooved Pegboard

To administer the test the pegboard is placed in mid-line with the candidate so that the board is at the edge of the table and the peg tray is immediately above the board. The examiner explains the test by pointing out to the candidate the pegboard and the pegs. The examiner then demonstrates that each peg is the same, with a groove, like a key and that each hole on the pegboard is the same. The examiner explains that the task is to match the groove of the peg with the groove of the board to put the peg in accurately. The examiner demonstrates how to do this by completing the first row. The pegs are then removed and placed back into the receptacle. The candidate is told that they must try and put all the pegs into the pegboard as quickly as they possibly can with the use of only one hand.

The first trial is with the dominant hand. The dominant hand of the candidate is taken as the hand they write with. When the first trial is finished all the pegs are removed and placed into the receptacle. The second trial is with the non-dominant hand. If necessary the examiner should give encouragement to the candidate to speed up. Only one hand should be used at a time.

For the right hand the pegs are placed from left to right across the board. For the left hand the pegs are placed from right to left across the board. Each peg has to be placed in sequence and in the correct direction. Only one peg should be picked up at a time. If a peg is dropped throughout the trial it should be left where it falls and the candidate should be instructed to pick up a different peg from the receptacle.

Each candidate was questioned about any upper limb or hand injuries that could affect their performance. If there was an injury or a problem present they were excluded from the test.

2.4.9 The Grooved Pegboard Scoring

Each candidate was timed from the moment they picked up the first peg to the moment they inserted the last peg correctly. The time was recorded in seconds for each hand. The number of pegs dropped was recorded also.

2.4.10 Depth Perception Aptitude

Perceptual ability is the ease at which one can reconstruct a 3D structure from a 2D image.

Pictorial surface orientation, otherwise known as PicSOr, was initially developed to examine the issue of depth perception in laparoscopic surgery (Cowie, 1998). PicSOr is where the surface slant of an object is used to describe the orientation of the object. The surface slant describes the angle between one of the axes of a surface of an object at an arbitrarily selected point, and its projection in a picture. This orientation can be recovered accurately from the "flanking angles" which are at the foremost corner of the object where the three surfaces of the object are visible or approximately from the intra-surface angle at the foremost corner. PicSOr relies on the ability of the candidate to recognise the equality of the slant for each object. It is the first objective psychometric test of perception to be used in minimally invasive surgery (Gallagher et al, 2003).

2.4.11 Pictorial Surface Orientation (PicSOr)

The test is run as a computer software package (figure 2.2). It consists of a picture of a geometric object, either a cube or a sphere with a spinning arrowhead on the surface of the object. The geometric object is minimally shaded to reduce any clues to depth. The point of the spinning arrowhead touches the surface of the geometric object. The task of the candidate is to move the arrowhead using the cursor keys until the shaft of the arrow is perpendicular to the object surface at the point at which they touch. The task is a relatively pure test of the candidate's ability to recover the pictorial cues that specify how structures are orientated in virtual pictorial space and to compare the implied orientations. The programme measures the correlation between the theoretically correct arrowhead orientation and the settings chosen by the subject. For the purpose of our experiments we have used the cube format rather than the sphere. The cube represents the perceptual problem in its simplest form. The test-retest reliability of PicSOr has been demonstrated to be $r = 0.94$ (Crothers, 2001).

2.4.12 Assessment using PicSOr

Each candidate was given the same clear instructions as to the purpose of the test and what they had to do to complete the task. Each candidate was given the opportunity to practice before the test commenced. Each candidate was allowed eight practice runs. This was carried out using the practice mode of the software programme. With this mode the candidate receives feedback after they decide on the correct position for each arrowhead. This enabled the candidates to better understand the task being asked of them and it also allowed any issues regarding the use of the cursor keys to be addressed. Once the eight practice runs were complete the candidate was then formally examined. This was done using the experiment mode of the software package. With the experiment mode the candidate does not receive any feedback as they go along. There are 35 objects in total. No time limit was imposed on the candidates however they were encouraged to complete the task as quickly and as accurately as possible.

2.4.13 Scoring PicSOr

The programme gives the actual angle of the object in space and the candidates estimate of that angle in an excel spreadsheet. Pearson's correlation coefficient was used to determine the strength of the relationship between the actual angle and the estimated answer. This was recorded for each candidate. Time in minutes and seconds to complete the task was also recorded.

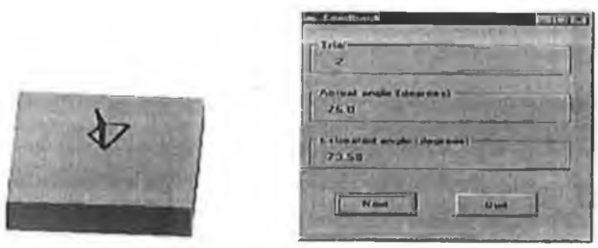


Figure 2.2 Pictorial Surface Orientation Test (PicSOr)

2.5 The Attentional & Interpersonal Style Inventory (TAIS)

The TAIS or the attentional and interpersonal style inventory was designed as a psychometric instrument to provide highly specific performance relevant feedback to individuals who must be able to perform under high levels of pressure.

2.5.1 TAIS: What it Measures

Successful performance in any area depends on one's ability to shift a focus of concentration along a dimension of width (broad to narrow) and a dimension of direction (external to internal) in response to the changing demands of the performance situation (Nideffer et al, 2002; Nideffer, 1976). The ability to make these shifts is affected by the individual's preferred or dominant style of attention and by their level of emotional arousal.

The TAIS was developed in response to a recognised need for a psychological tool that assesses behaviour competencies that are important in clusters of life outcomes (McClelland, 1973). When designing the TAIS the emphasis was on identifying behaviours that have relevance to performance across different situations. These are commonly referred to as the building blocks of performance (Nideffer, 2003).

The competencies identified by the TAIS are (a) concentration skills, (b) intra-personal behaviours and (c) inter-personal behaviours.

(a) Concentration skills (cognitive abilities)

To be successful a person needs to pay attention to and remain focused on task relevant cues. According to the TAIS theory in order to do this, respondents must be able to shift their focus of concentration along two intersecting dimensions of attention. An individual uses a broad external focus of attention to rapidly assess the world around them, to read and react to situations. A broad internal focus of concentration is used to analyse problem solve and strategize. A narrow internal focus of concentration is used to mentally rehearse a particular move, for example when memorising maths times-tables. A narrow external focus is used when you execute or perform a skill like hitting a serve in tennis or directing a sales pitch to a customer.

Another factor that influences attention is the speed and amount of information an individual processes within a given time period. Some people seem to be able to learn quicker than others. The speed at which a person learns seems to be related to the efficiency with which they are able to separate task relevant cues (signals) from task irrelevant cues (noise).

(b) Intrapersonal behaviours

Intrapersonal behaviours are carried from situation to situation regardless of whether someone else is present. Self-confidence is an example of intrapersonal behaviour that for many people describes their attitude and approach to any situation whether other people are present or not. Some people approach every situation expecting to be successful others to fail.

(c) Interpersonal behaviours

Interpersonal behaviours are those that come into play only when the performance situation requires interaction with other people. Intellectual expressiveness is an example of interpersonal behaviour.

Certain characteristics have both an intra and interpersonal aspect. An example would be competitiveness.

These factors; concentration skills, intra and interpersonal behaviours, interact with each other and the level of cognitive arousal an individual has to play an important role in impacting on performance outcomes.

2.5.2 Assessment using the TAIS

The TAIS is an easily administered self-report instrument designed to measure those concentration skills and interpersonal characteristics that are the building blocks of performance. It is used to identify the types of situations and conditions under which an individual is more or less likely to perform at their potential.

The TAIS can be used for both selection and development purposes within the sporting world and within the work environment. It has been used to assess performance in elite athletes in swimming, gymnastics and figure skating (Bond & Nideffer, 1992), in military units and in business settings. The test-retest reliability of the TAIS has been reported as $r = 0.83$ (Nideffer, 1976). The content, construct and predictive validity have also been described (Nideffer, 2006).

The TAIS consists of 144 items distributed across twenty scales (appendix II). It measures six different concentration skills and fourteen different personal and interpersonal behavioural attributes. It is referenced to the normal populations in terms of age and gender. The four broad areas it examines are: concentration and information processing, prognostic indicators, interpersonal characteristics and scales in development.

It uses a five point Likert style response format in which respondents are asked to indicate the frequency with which a particular item describes their behaviour. The response options are: never, rarely, sometimes, frequently or always. The TAIS, similar to most psychological assessments, has measures in place to control for any individual who either over or under estimates their own ability.

The test can be administered in two formats – either as a paper based test or as an online assessment. In order to use the TAIS a license is required from the company holding the copyright for the assessment (MHS assessments). There are no time constraints placed on the individual taking the test. The individual is encouraged to answer the questions as truthfully as possible.

2.5.3 Scoring the TAIS

The TAIS is scored by MHS assessments. This generates a highly specific personal profile of the individual.

2.6 Surgical Skills Assessment

Minimally invasive surgical skills were assessed using simulators. The areas examined were laparoscopy, endoscopy and endovascular skill.

2.6.1 Laparoscopic Skill

The ProMIS (Haptica, Ireland) was the laparoscopic simulator used (figure 2.3). This simulator is a hybrid of virtual reality modules and modules with haptic feedback and thereby is an augmented reality simulator. It consists of a box trainer that is connected to a laptop where the graphics are displayed.

The modules assessed were locating and coordination, object positioning and sharp dissection. The simulator generates objective measurements of time (seconds), path length (millimetres) and path smoothness. The path length is the distance travelled between two points and the path smoothness is measured as the number of times the instrument changes velocity.

Figure 2.3 The ProMIS Laparoscopic Simulator

The locating and coordination module requires the operator to interact with objects in a virtual reality environment. The simulator gives verbal instructions to touch the object that appears on the screen using a specific hand and to hold the instrument in place for five seconds. There are three levels in this module.

Figure 2.4 The Object Positioning Module

The object positioning module requires the operator to move small beads from one pot to another inside the simulated abdominal cavity (figure 2.4). There is also a non-fixed bag. Again the simulator gives verbal instructions to pick up and transfer the beads from one pot to another or to place the beads in the bag. There are three levels in this module.

The sharp dissection module involves following the verbal instructions given by the simulator to cut out first a triangle and then a circle shape on a fixed glove. There are two layers on the glove and the operator is told to only pick up and cut the top layer. The number of perforations made in the second layer of the glove is noted.

With the ProMIS simulator there is also the option to perform procedure specific modules. The module that we used for one of the studies was the laparoscopic colectomy task. This requires the addition of a synthetic anatomy tray (Limbs and Things, Bristol, UK). The module consists of nine steps (table 2.3). There are two modes that can be used for the laparoscopic colectomy module – "teach me" or "test me". The "teach me" mode gives both verbal instructions for each step and also onscreen graphical demonstrations. This mode also contains short video clips of the particular step being performed in the real life setting, thus promoting clinical correction. In the "test me" mode the onscreen graphical cues are removed. With this module the candidate gets the opportunity to use real life instruments such as the Harmonic scalpel and staplers. At the end of the procedure the anatomy tray is scored for errors using a previously validated set of thirteen errors (appendix III) (Neary et al, 2008). The error scoring is carried out by two blinded assessors.

Step	Description
1.	Tilting of the patient to move small bowel
2.	Identification of the Inferior Mesenteric Artery
3.	Identification of the Left Ureter
4.	Ligation of the Inferior Mesenteric Artery & Vein
5.	Mobilisation of the sigmoid colon
6.	Mobilisation of the descending colon
7.	Taking down of the splenic flexure
8.	Rectal transection
9.	Anastomosis formation

Table 2.3 The Steps of the Laparoscopic Colectomy Module

2.6.2 Endoscopic Skill

The endoscopy simulator used was the GI Mentor II (figure 2.5). This simulator consists of a plastic body-form with a trunk and an alternating head and tailpiece. The endoscope is a customised Pentax ECS-3849F. It has two steering wheels, buttons for air, water and suction, the capacity to capture photographic images and an instrument channel. Once the endoscope is inserted into the simulator its movements are traced using sensors. The simulator also is connected to a keyboard and monitor on which the images are displayed.

The GI Mentor II has a variety of procedures and cases that can be performed. These include OGD, colonoscopy and ERCP. There are also two modules designed for skill learning – the endobubble task and the endobasket task.

Figure 2.5 The GI Mentor II Endoscopic Simulator

For the purpose of our experiments the candidates were assessed on the endobubble task and a colonoscopy. Each candidate was shown how to operate the endoscope prior to beginning the task.

The endobubble task requires the operator to manoeuvre the endoscope around a tunnel that simulates the colon. There are yellow balloons present and the task of the operator is to burst as many of them as possible without hitting the side wall while passing through the tunnel. There are two levels. The first level has twenty balloons and the second level has forty balloons. The second level is more difficult due to the greater number of balloons to pop and because the balloons are smaller in size, move more and disappear after a few seconds. The measurements of the simulator are listed in table 2.4.

The candidates were also asked to perform a colonoscopy (module 1, case 1). The instructions were to reach the ceacum with the endoscope while viewing as much mucosal surface as possible on the way in. There was no pathology to identify. The objective measurements are outlined in table 2.4. The parameters measured are all relevant to the real life clinical environment.

	Metrics
Endobubble Task	Time taken
	Number of balloons popped
	Number of times the wall of the tunnel was hit
Colonoscopy	Time to reach caecum
	% mucosal surface viewed
	% time spent with a clear view
	% screening efficiency
	% time patient was in pain
	Looping of the colon

Table 2.4 Metrics Measured by the GI Mentor II Endoscopic Simulator

2.6.3 Endovascular Skill

The VIST was used to assess endovascular skill (figure 2.6). This is a high fidelity advanced simulator. It consists of a supine patient with a plastic body-form that is connected to a desktop computer and two monitors. There are various procedures and cases that can be performed on this simulator. There are also a number of simulated points of arterial access.

Real guidewires and catheters are used in this simulator with their tips removed. When for example a standard catheter has been inserted the operator can choose from a range including Cobra, Judkins and Pigtail catheters. The operator can also choose from a range of balloons and stents. There are separate controls for stent deployment, contrast administration, fluoroscopy, x-ray, and c-arm and table movement. The display monitor shows the fluoroscopic images generated by the x-ray. The second monitor allows the operator to choose the case type and instruments required.

The module chosen for experimentation was a case of left renal artery stenosis. The candidates firstly had the workings of the simulator demonstrated to them. They were shown how to insert a guidewire and catheter into the right femoral artery of the simulator.

The candidates were instructed to perform a series of tasks. They were asked to insert the guidewire to the level of the renal arteries. Then they were instructed to insert a Judkins catheter over the guidewire to the level of the renal arteries. Following this they were instructed to manipulate the guidewire and catheter into the left renal artery. Once in the left renal artery they were told to leave the guidewire in place, to avoid pushing it further into the renal vasculature or to pull it out into the aorta, and to remove the catheter out over the guidewire. The time taken to complete the task was measured. The other objective measurement recorded by the simulator was an error score.

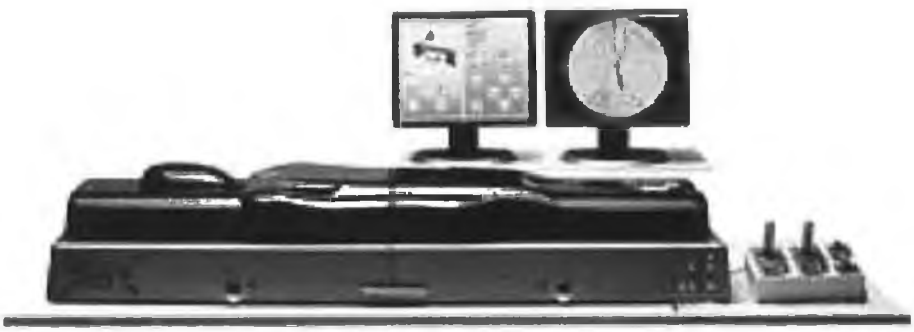


Figure 2.6 The VIST Endovascular Simulator

The candidates were also recorded as they performed the task. A video camera was used to record their hand movements only and a second camera recorded the screen.

The recordings were assessed separately by two endovascular experts. The experts scored the performance of the candidates using a modified version of objective structured assessment of technical skill (OSATS) (Appendix IV).

2.7 Statistical Analysis

The statistical package software, SPSS 18.0 was used for all analysis. Normality of the data was assessed using the one sample Kolmogorov Smirnov test. Where it was deemed acceptable to retain the null hypothesis then parametric methods of analysis were used, where it was deemed unacceptable to retain the null hypothesis non-parametric methods of analysis were used. Relationships between different categorical variables were explored using Chi-square for independence. Correlation coefficients were calculated to determine the strength of relationship between two continuous variables. The independent t test was used for the comparison of two means. Where numbers were small the non-parametric Wilcoxon rank sum test was used to compare means in independent groups. Analysis of variance was used to compare means in more than two groups. Multiple regression was used to adjust for confounders where the outcome variables were continuous.

Chapter 3

Aptitude Assessment: Comparing Surgical Trainees to Controls

3.1 Introduction

Until relatively recent times, the practice of surgery was associated with quite a low level of technology. Surgical procedures within the abdomen, for instance, were performed with instruments which were technologically unsophisticated (forceps, scissors, haemostats) which had not changed much in more than a century (Kirkup, 2002). These instruments were held in the surgeon's hands and the surgeon operated inside the abdomen under direct vision. The development of laparoscopic/minimally invasive surgery in the early 1990's brought about rapid advances in the technological complexity of surgical instruments (Muhe, 1992; Jacobs et al, 1991). Furthermore, for the first time, surgeons operated whilst looking at a 2D image of the abdomen on a screen rather than a 3D image on direct vision. This, along with the "fulcrum effect" of manipulating instruments through a port in the abdominal wall, posed significant challenges for surgeons (Gallagher et al, 2005; Crothers et al, 1999). Some surgeons made the transition to image guided surgery easily; many others struggled considerably before feeling at ease; some surgeons could never adapt. Today, we are on the cusp of even greater challenges to the traditional skill sets of surgeons. Single Incision Laparoscopic Surgery (SILS), Natural Orifice Transluminal Endoscopic Surgery (NOTES) and robotic surgery are just some examples of evolving techniques in surgery which will pose major challenges to existing and trainee surgeons (Nugent et al, 2011; Stroup et al, 2010; Lee et al, 2011).

The role of fundamental or innate ability (aptitude) has not been a major consideration in traditional open surgery. Repeated practice for long hours during many years of training usually resulted in technical proficiency in most surgeons. This is unlikely to be the case for the evolving areas of surgery which clearly require psychomotor, visual spatial and depth perception skills which may not be quite so important for traditional surgery (Gallagher et al, 2009). Prolonged training may not necessarily confer these skills. This poses the question: are surgeons, as a group, fundamentally different to other health care professionals in terms of fundamental abilities? And, if so, does this matter?

This study was undertaken to assess the aptitudes of surgical trainees to determine if these are different to a control group. The study also aimed to compare the aptitudes of surgical trainees across different specialties. Finally, we aimed to examine the relationship between surgical aptitude and technical skill performance.

3.2 Objectives

3.2.1 Hypothesis Underlying the Objectives

The restructured selection process for Higher Surgical Training (HST) was introduced in 2007 in RCSI. Since then all data collected from the aptitude and technical skills assessments have been entered prospectively into a database.

The purpose of restructuring the selection process was to try and incorporate more objective parameters of measuring potential ability. Two new tools were identified as holding promise; aptitude assessment and technical skill assessment. We set out to analysis all the data collected over the four year period in an effort to determine the value, if any, that these two new objective tools could have.

The overall interest of this thesis is in identifying and examining potential factors or attributes that could be used to help improve the training of future surgical trainees. One of the attributes that we have an interest in exploring is fundamental aptitudes and their impact on surgical performance. In particular we are interested in their role in minimally invasive surgery. Before exploring the role of aptitude and its impact in MIS we decided that a good starting point would be to analysis data already available to us. The data is novel in that no other surgical training body has collected such a sample of aptitude scores and technical skill assessments in a group of surgical trainees. Therefore this chapter in examining technical skills and by comparing aptitude between surgical trainees and a control group could help to better define the role of these objective tools and how best to use them.

3.2.2 Detailed Objectives

Objective 1:- To determine if there is a difference in aptitude between surgical trainees and a control group

We aimed to compare the aptitude scores of the surgical trainees to a group of controls. The control group consisted of medical students and general practice trainees. The general practice trainees were recruited as they were considered to be at a similar stage in their training as the surgical trainees, were of a similar age distribution and are a speciality where surgical aptitudes and skills for the most part are not essential. The medical students were recruited to represent a more heterogonous sample of the normal population. We wished to investigate whether the sample of surgical trainees shortlisted for aptitude assessment had a higher level of aptitude from the outset when compared to a control group that was considered to represent a normal population distribution of aptitude.

Objective 2:- To determine if there is a similar distribution in aptitude across all the surgical specialities

We aimed to determine whether there was a similar distribution in aptitude scores between the various surgical specialities. One would expect that there should be a similar level of aptitude across the surgical specialities. However in some specialities specific skills are of greater value than in others, for example in ophthalmology and plastic surgery where fine motor skills are required a higher than average level of psychomotor dexterity may be expected and considered desirable. We aimed to determine if trainees with these attributes self-selected into their speciality.

Objective 3:- To investigate whether there is a correlation between aptitude and technical skill performance

Two of the surgical specialities; general and plastic surgery, also assessed the technical ability of their shortlisted surgical candidates. We aimed to investigate whether there was a relationship between aptitude score and technical skill performance to determine if aptitude could be used to predict potential surgical skills ability.

3.3 Materials and Methods

3.3.1 Recruitment of Participants

In Ireland, surgical training consists of two phases. Basic Surgical Training (BST) introduces trainees to the principles of surgery in general. This is followed by Higher Surgical Training (HST) which is specialty specific. Selection for HST is highly competitive and only the top performing graduates (approximately 30%) from our BST programmes progress to HST.

Candidates eligible for Higher Surgical Training in Ireland have the opportunity to apply to the Royal College of Surgeons on a standardised and structured application form (Carroll et al, 2009; Gallagher et al, 2008). Candidates with the highest scores are then shortlisted for interview and further assessment. The short-listing of suitable candidates is an entirely objective process.

It was those candidates that were shortlisted that were included in this data set. Ethical approval was granted by the Research Ethics Committee of RCSI. All shortlisted candidates gave informed and written consent to have any data collected as part of the assessment process analysed and used for research purposes. A prospective database was set up to gather all data collected from the short-listed assessments between the years 2007 – 2010.

We also had two control groups for the purpose of this study. The first control group was a group of pre-clinical medical students that volunteered to take part in the study. They were recruited through class/group emails that were circulated. Medical students were enrolled into the study on a first come first served basis.

The second control group was a group of general practice trainees. They were recruited through a group email that was circulated to all the general practice trainees in year three and four of postgraduate training.

The group of preclinical medical students and general practice trainees gave written informed consent to take part in the study. It was made clear to them that all data collected was to be anonymous and was to be stored in a secure and anonymous fashion.

3.3.2 Participant Demographics

Over the four year period of 2007 to 2010, 155 applicants to higher surgical training were shortlisted for interview and further assessment (table 3.1). In total 110 men and 45 women were shortlisted. The shortlisted candidates were from a range of surgical specialties that included general surgery, orthopaedics, plastic surgery, cardiothoracic surgery, ophthalmology, paediatrics, urology and neurosurgery. Each speciality has a separate higher surgical training scheme with a varying number of vacant positions each year. The number of applicants shortlisted depends on the number of vacant training posts available. The breakdown of the number of trainees shortlisted per speciality is displayed in figure 3.1.

A group of thirty six medical students from the preclinical years one to three were tested also (table 3.1). Each medical student had their visual spatial and depth perception and psychomotor aptitude assessed.

There were twenty five general practice trainees from postgraduate training year three and four that volunteered to take part in the study (table 3.1). Each trainee had their visual spatial, depth perception and psychomotor aptitude assessed.

The medical student and general practice trainee groups were used as a control group to compare aptitude data with the shortlisted higher surgical trainees.

Subject	Age: range (mean, SD)	Gender: F : M	Dominant Hand: L : R	Corrected Vision: Y : N	Year of Training
HST	29-34 (32.5, 3.7)	45 : 110	-	-	-
Medical Student	18-24 (20.64, 1.8)	19 : 17	5 : 31	22 : 14	Year 1: 11 Year 2: 19 Year 3: 6
GP Trainee	27-37 (29.8, 1.02)	16 : 9	5 : 20	13 : 12	Year 3: 11 Year 4: 14

Table 3.1 Participant Demographics

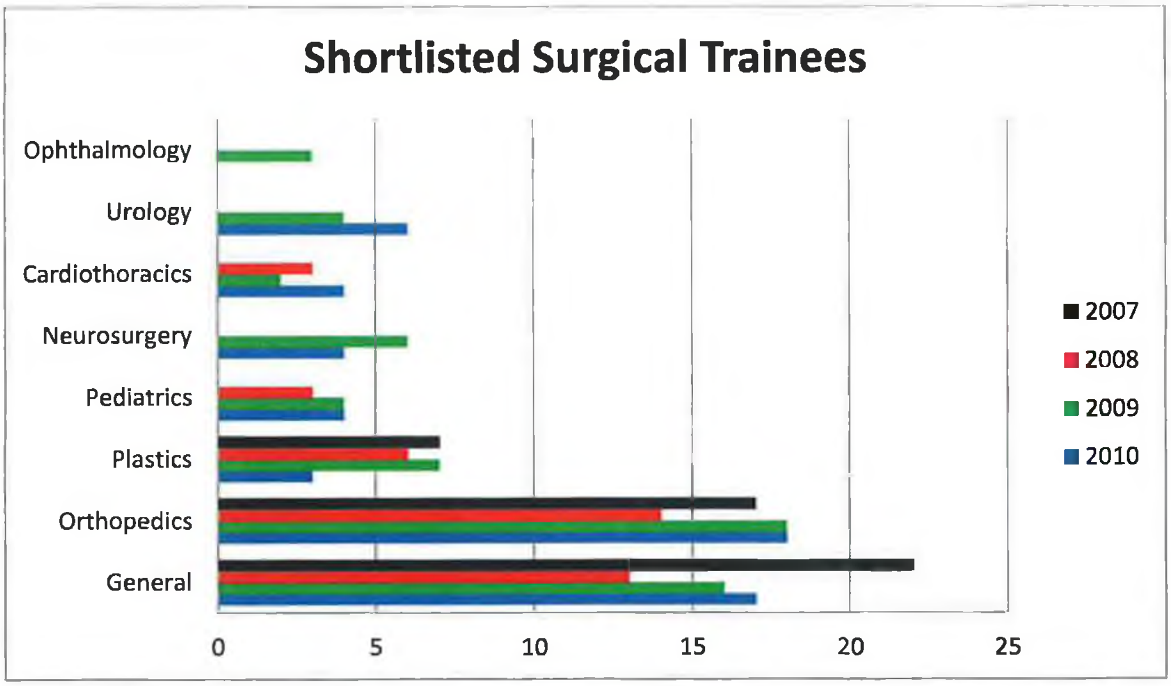


Figure 3.1 Number of Surgical Trainees Shortlisted per Specialty per Year; This figure gives the breakdown of trainees shortlisted each year for further assessment for a higher surgical training position.

3.3.3 Assessment Procedure

Following short-listing, all the candidates for higher surgical training were invited to the National Surgical Training Centre (NSTC) at the Royal College of Surgeons (RCSI) for a day of further assessment. Further assessment involved examining a range of surgical technical skills, emotional intelligence, personality factors and fundamental aptitude. All the specialities assessed aptitudes whereas only general and plastic surgery assessed technical skills.

The control group of medical students were assessed on just their fundamental aptitudes at the NSTC. Assessment of the general practice trainees took place at both RCSI and in the Adelaide and Meath Hospital, Tallaght, Dublin 24.

3.3.4 Aptitude Assessment

All of the surgical specialities assessed aptitude. These were visual spatial, depth perception and psychomotor aptitude. The tests used have been described in detail in chapter 2. We have outlined them again briefly below.

Visual spatial aptitude was tested using paper based tests, the card rotations test, cube comparison test and map planning test. These tests were taken from the Kit of Factor-Referenced Cognitive Tests and have been previously extensively validated (Ekstrom et al, 1976). Depth perception was assessed using a computer based programme, Pictorial Surface Orientation (PicSOr), a method that was developed and validated by Cowie (Gallagher et al, 2003; Cowie, 1998). Psychomotor aptitude was assessed using the ProMIS simulator for the years 2007 – 2009 (Gallagher et al, 2002). Psychomotor aptitude was assessed using the Grooved Pegboard in 2010 (Dikmen et al, 1999).

The group of medical students and general practice trainees had their visual spatial aptitude and depth perception assessed using the same tests as for the higher surgical shortlisted applicants. Psychomotor aptitude was assessed using the Grooved Pegboard.

3.3.5 Surgical Skills Assessment

The general surgery and plastic surgery trainees were the only specialities to assess technical skill. Technical skills were assessed using a mixture of bench models (Limbs and Things, Bristol, UK) and simulators. The candidates were assessed by means of an eight station OSCE. Candidates rotated through the stations every 30 minutes. All stations were given equal marks. The stations are listed in Appendix V and they differed between the two specialities. The skills stations were chosen to reflect those procedures that a trainee would be expected to be able to perform at the end of their BST program. Procedure specific checklists combined with a global rating scale were used to examine the candidates for the years 2007-2009. In 2010 the global rating scale was replaced by OSATS.

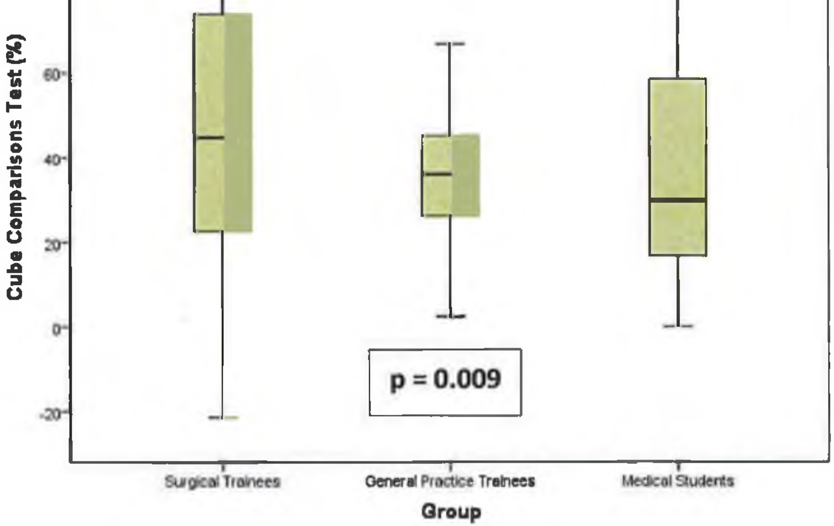
3.3.6 Statistical Methods

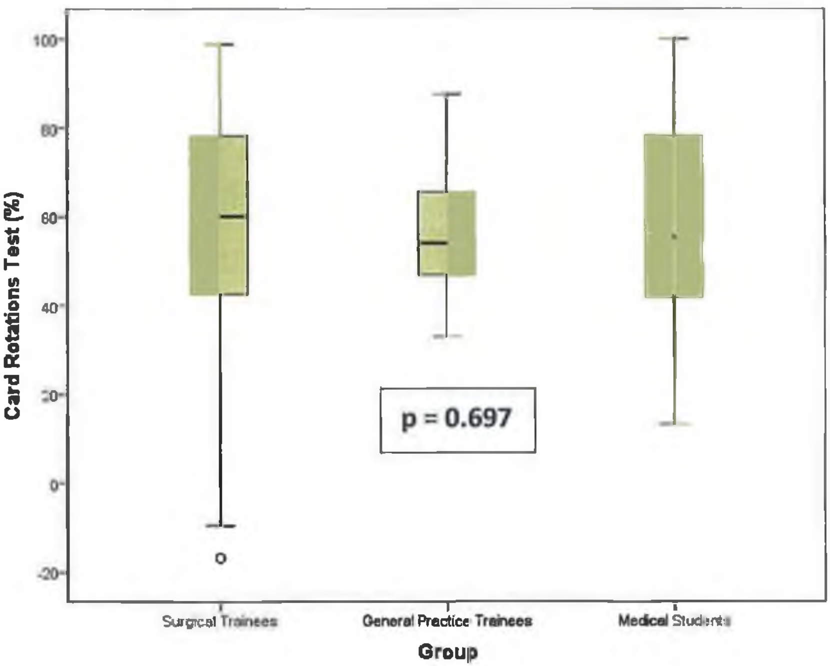
Data was analysed using the SPSS 18.0 software (SPSS Inc, Chicago, Ill). The relationships between different categorical variables were explored using the chi-square test for independence. The mean scores of the different groups were compared using One-way ANOVA. The median scores of different groups of non-parametric data were compared using the Mann-Whitney U test. One way and two way analysis of variance was used to compare the variability in scores between different groups. The Kruskal-Wallis test was used where the data was non-parametric. Pearson's correlation coefficient was used to determine if there was a relationship between aptitude and surgical performance. A p value of <0.05 was considered significant.

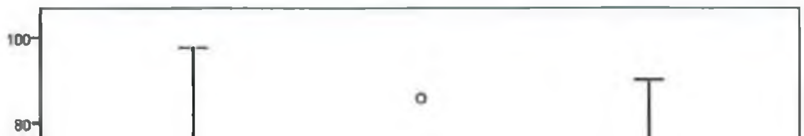
3.4 Results

3.4.1 Participant Demographics

Over a four year period, from 2007 to 2010, 155 surgical trainees were shortlisted and underwent assessment of their innate aptitudes and 67 of these trainees also had their surgical skills assessed. The distribution of scores for the various aptitude tests performed by the surgical trainees, the medical students and general practice trainees can be seen in figures 3.2, 3.3 & 3.4. The distributions of scores are also broken down per surgical speciality in figures 3.5, 3.6 & 3.7.


Cube Comparisons Test (%)
60
40
20
0
-20
p = 0.009
Surgical Trainees
General Practice Trainees
Medical Students
Group


Card Rotations Test (%)
100
80
60
40
20
0
-20
p = 0.697
Surgical Trainees
General Practice Trainees
Medical Students
Group


100
80

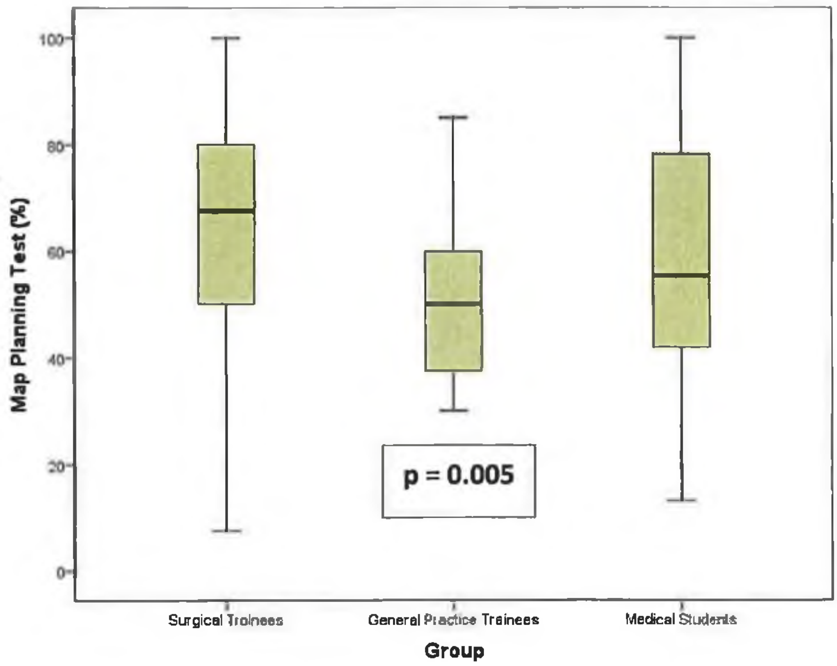


Figure 3.2 Distribution of Visual-spatial Aptitude Score; The above figure (boxplot & whiskers graph) demonstrates a significant difference in aptitude scores on two of the visual-spatial tests (cube comparison & map planning) with the surgical trainees scoring higher than the general practice trainees and medical students.

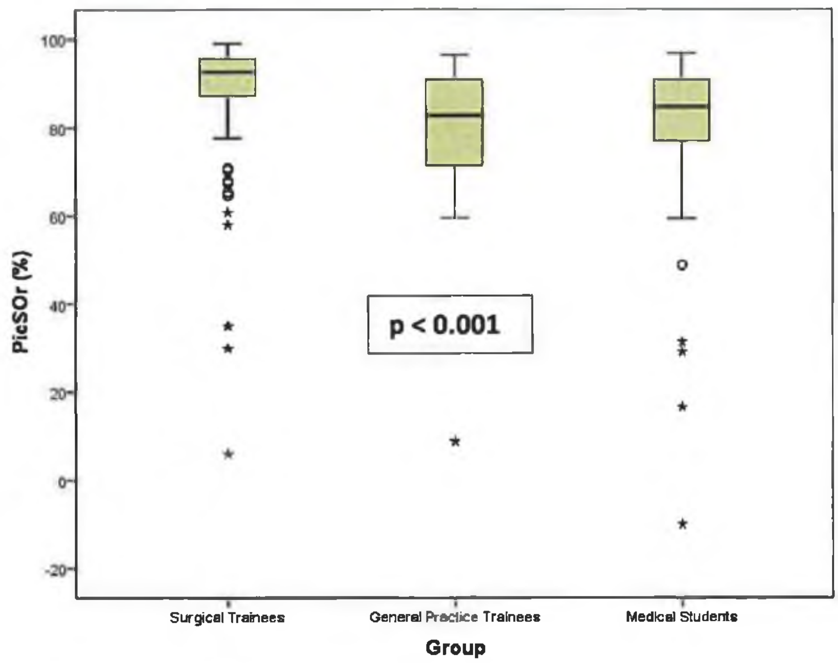


Figure 3.3 Distribution of Depth Perception Aptitude Scores; The above figure (boxplot & whiskers graph) demonstrates a significant difference in depth perception aptitude score

where the surgical trainees achieved higher scores in comparison to the general practice trainees and medical students. (The stars indicate outliers that were omitted from analysis)

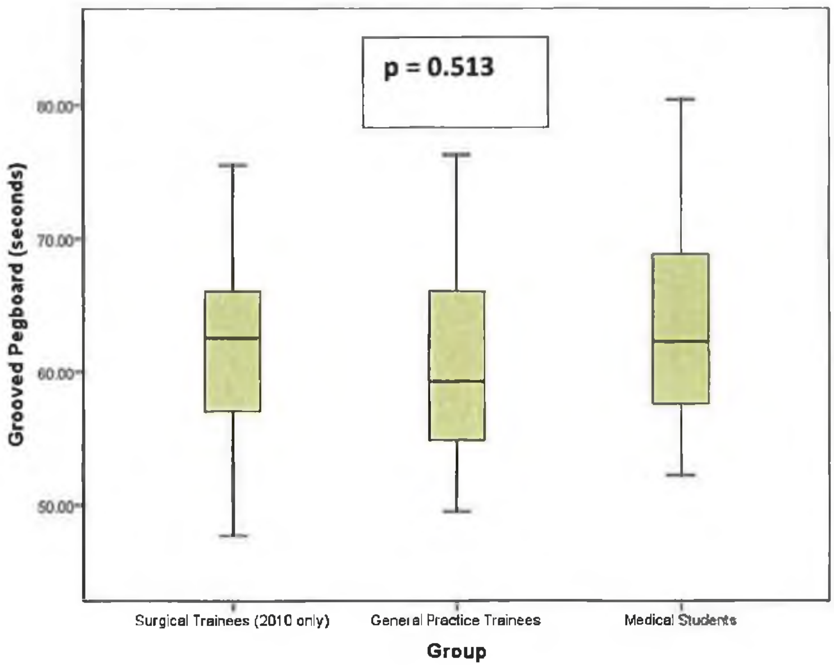


Figure 3.4 Distribution of Psychomotor Aptitude Score; The above figure (boxplot & whiskers graph) demonstrates no significant difference in psychomotor aptitude scores between the three groups.

3.4.2 Aptitude Results: Surgical Trainees versus Controls

Our first aim was to compare the distribution of aptitude scores between the surgical trainees that were shortlisted for higher training and the control group (consisting of thirty six medical students and twenty five general practice trainees). Using One-way ANOVA to compare the mean scores we found a significant difference in visual spatial aptitude and depth perception scores. The surgical trainees scored higher than the control group in these aptitude tests.

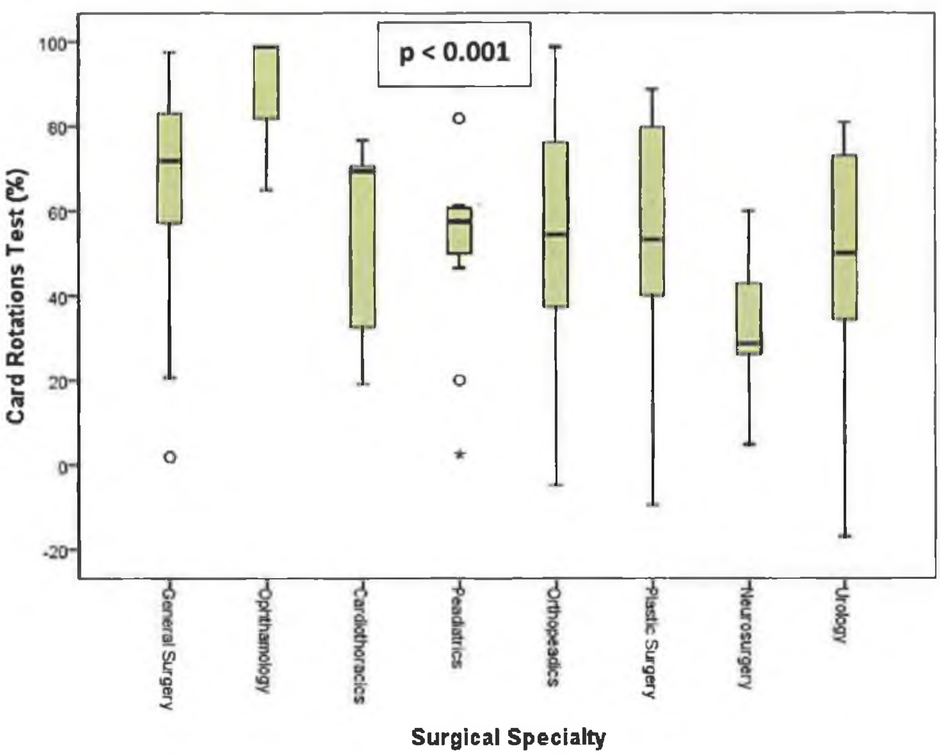
There was a significant difference in visual spatial scores on the cube comparison test ($p = 0.009$) and the map planning test ($p = 0.005$) with the surgical trainees achieving higher scores (figure 3.2). There was no significant difference for the card rotations test ($p = 0.697$) but there was a significant difference found for the overall visual spatial score ($p = 0.006$).

There was also a significant difference found for the scores achieved on PicSOr ($p < 0.001$) (figure 3.3). Again the surgical trainees scored higher in this test. Our results did not demonstrate a significant difference on scores for the psychomotor test of aptitude; the Grooved pegboard ($p = 0.513$) (figure 3.4). We were unable to compare the results of the ProMIS psychomotor test as the control group were not assessed on this.

3.4.3 Aptitude Distribution across the Surgical Specialities

We hypothesised that the aptitude scores across the different surgical specialities should be similar. The surgical specialities assessed were general surgery, orthopaedics, plastic surgery, urology, neurosurgery, paediatrics, cardiothoracics and ophthalmology.

We found no significant difference in the mean scores for depth perception, the cube comparison and the map planning visual spatial tests and the tests of psychomotor aptitude between the various specialities using one-way ANOVA (figure 3.5, 3.6 & 3.7). There was a significant difference found between three specialities for the card rotations test ($p < 0.001$) (figure 3.5). Post hoc comparison using the Tukey HSD test indicated that the mean score for the general surgical trainees (68.03, SD 19.80) significantly differed from the mean score of the neurosurgery trainees (30.60, SD 18.25) and the mean score of the ophthalmology trainees (87.5, SD 19.48) differed significantly from the neurosurgical trainees.



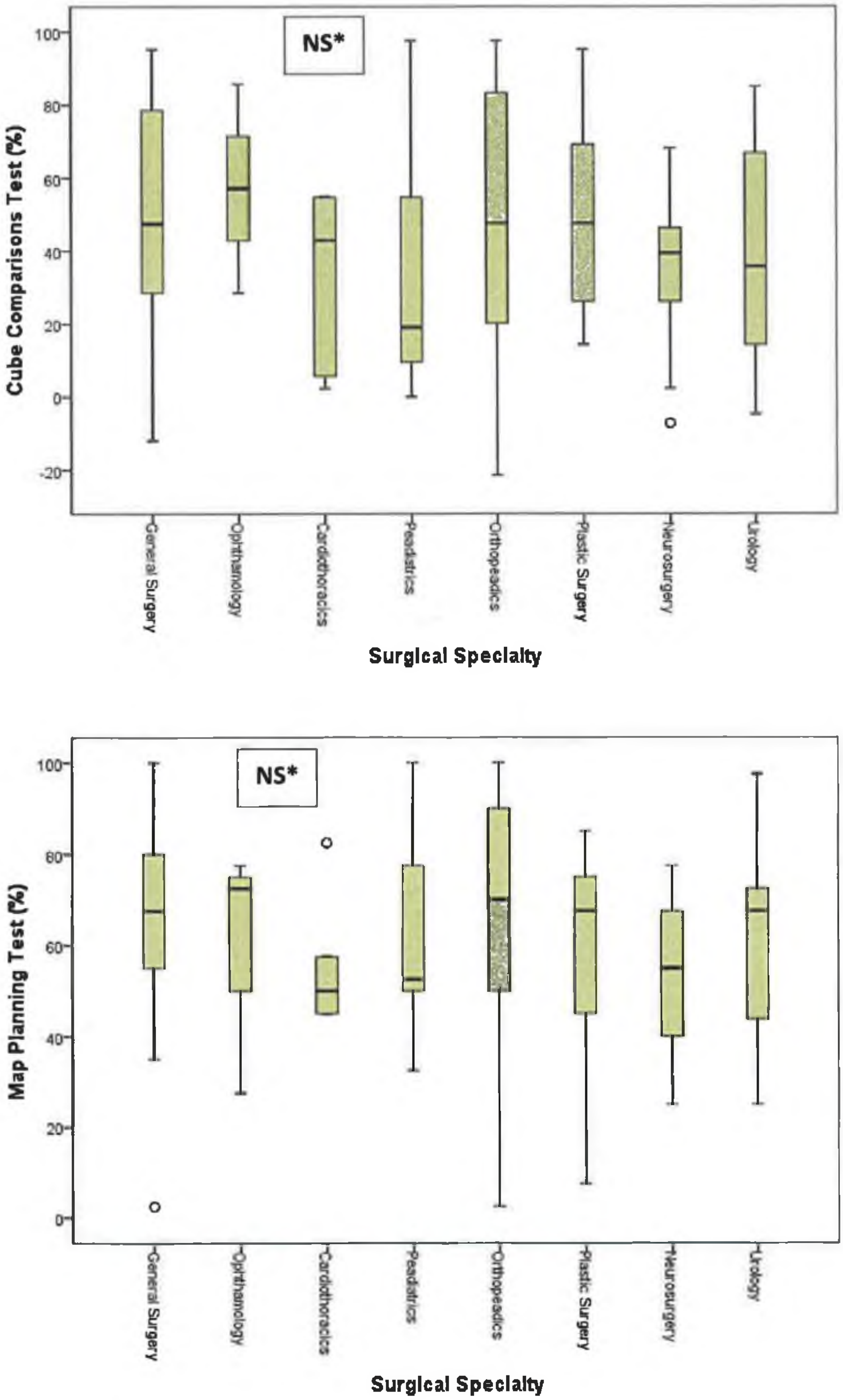


Figure 3.5 Visual-spatial Aptitude Scores per Surgical Specialty; [NS* = non-significant] The above figure (boxplot & whiskers graph) shows the difference in visual-spatial aptitude scores between the eight surgical specialties. There was no significant difference found for two of the tests (cube comparison & map planning). There was a

significant difference found for the card rotations test with general & ophthalmology trainees scoring higher than the neurosurgery trainees.

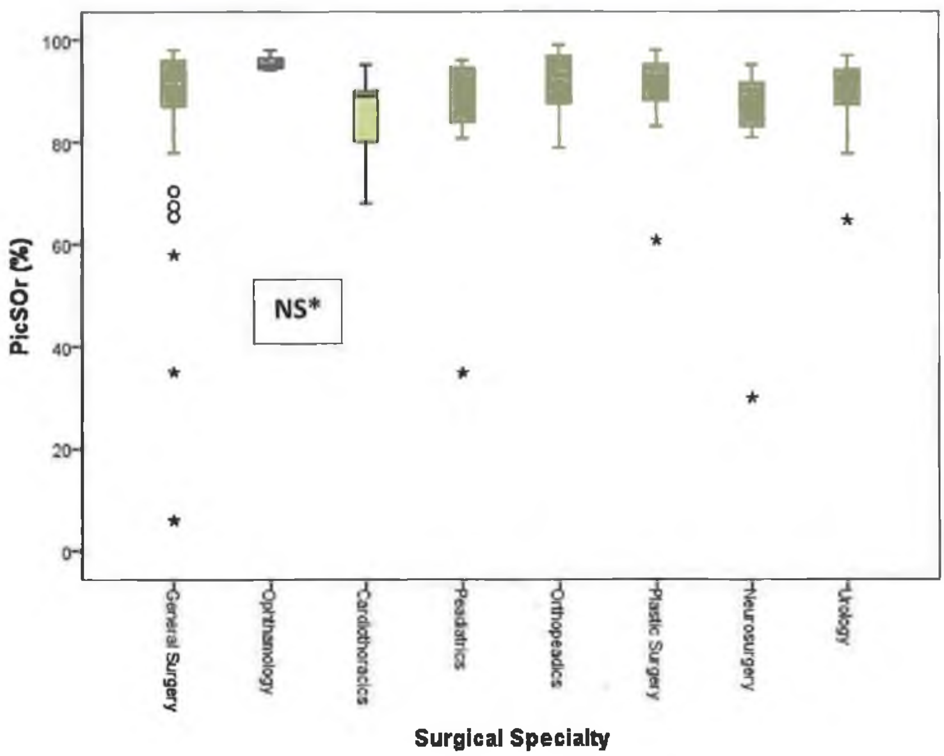
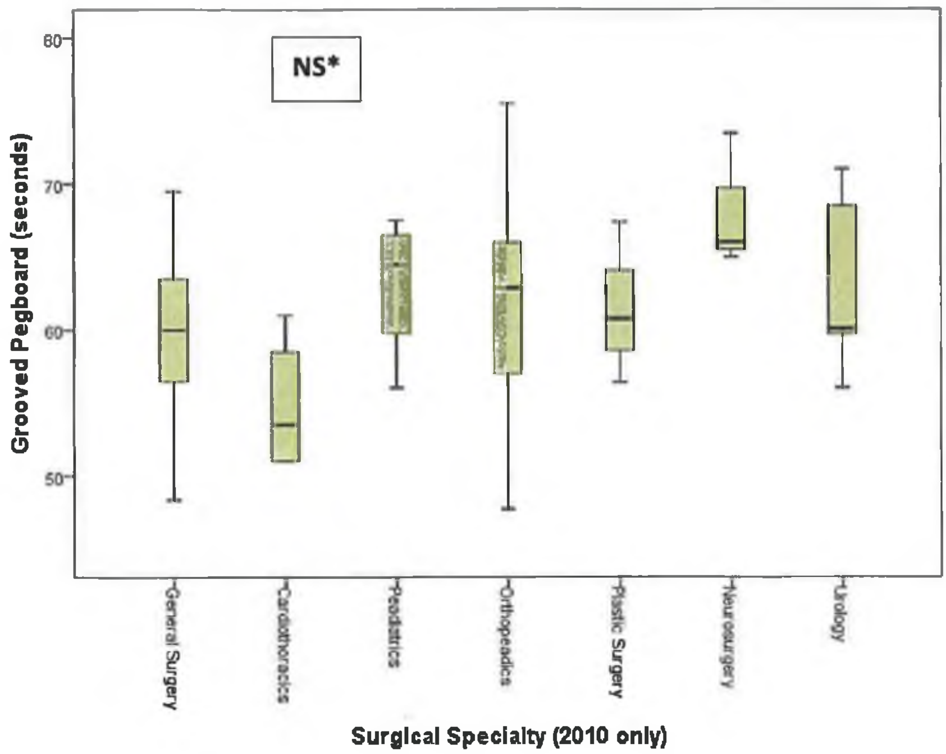
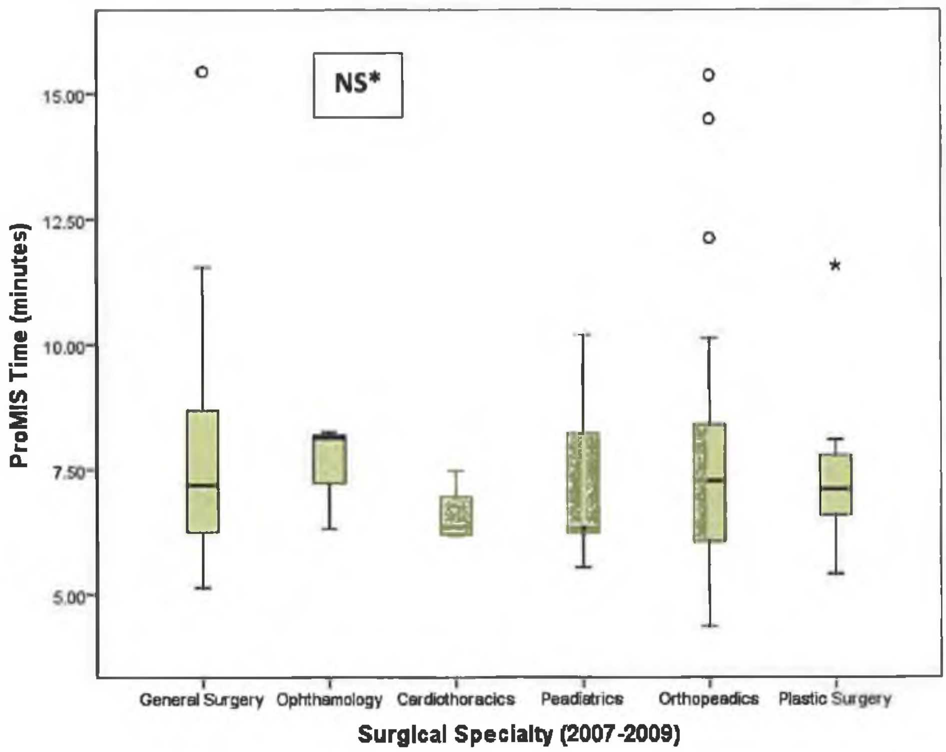


Figure 3.6 Depth Perception Aptitude per Surgical Specialty; [NS* = non-significant] The above figure (boxplot & whiskers graph) shows no significant difference in depth perception aptitude scores across the eight surgical specialties.


NS*
Grooved Pegboard (seconds)
80
70
60
50
General Surgery
Cardiothoracics
Peadiatrics
Orthopeadics
Plastic Surgery
Neurosurgery
Urology
Surgical Specialty (2010 only)


NS*
ProMIS Time (minutes)
15.00
12.50
10.00
7.50
5.00
General Surgery
Ophthamology
Cardiothoracics
Peadiatrics
Orthopeadics
Plastic Surgery
Surgical Specialty (2007-2009)

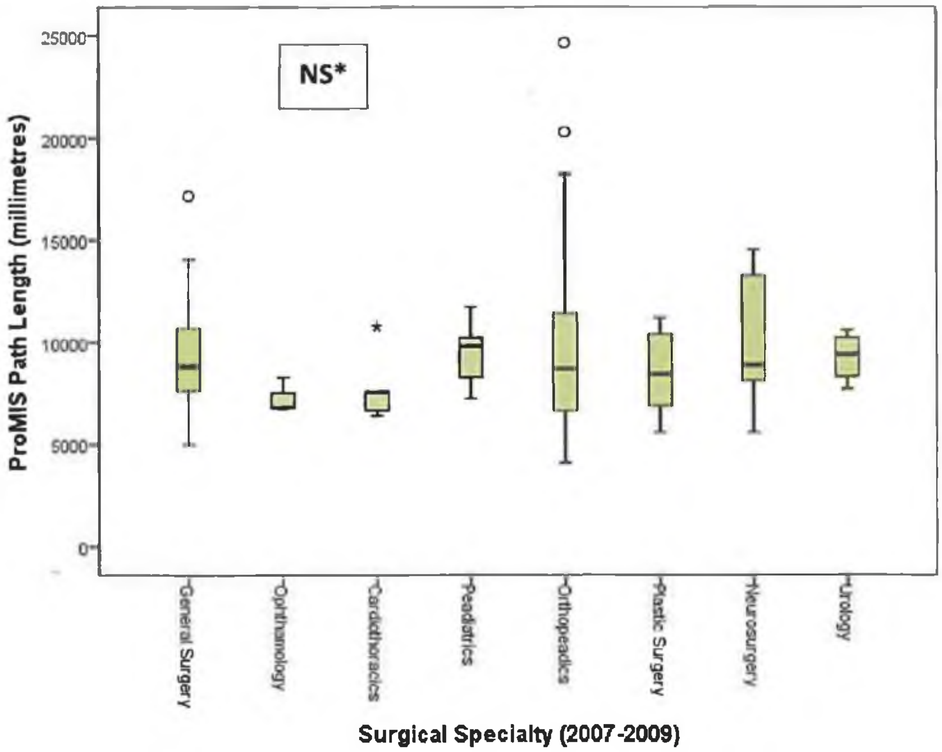
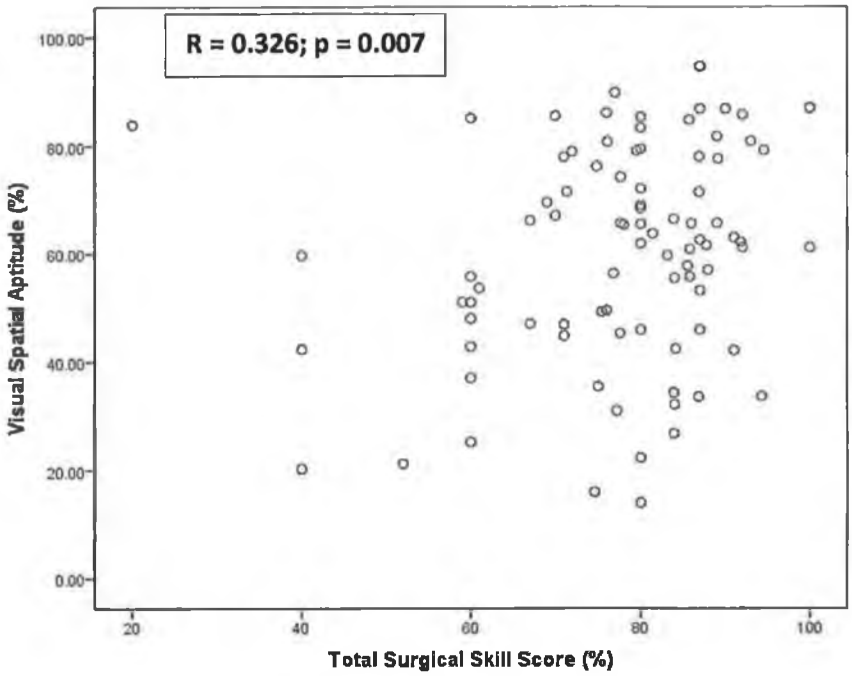


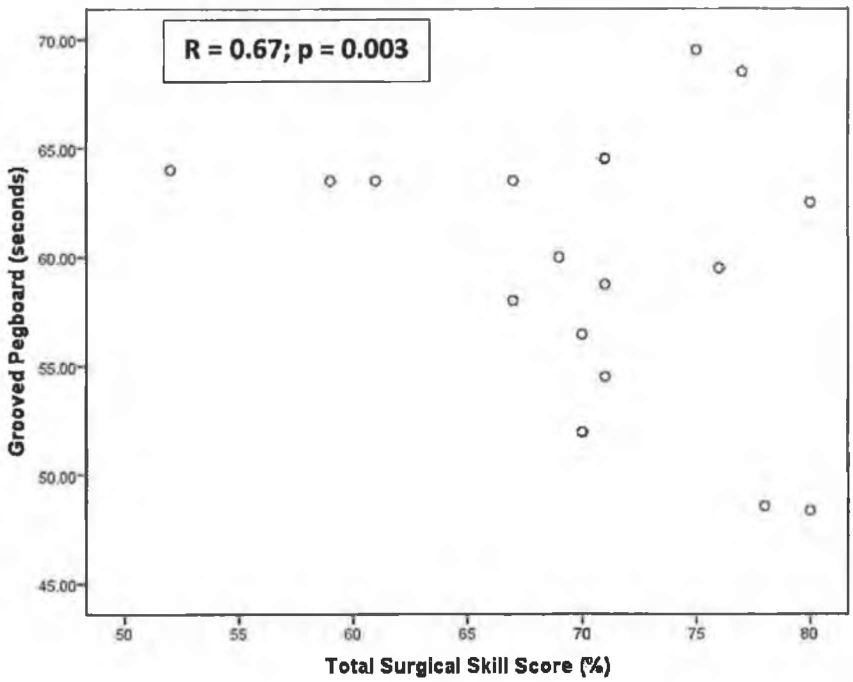
Figure 3.7 Psychomotor Aptitude per Surgical Specialty; [NS* = non-significant] The above figure (boxplot & whiskers graph) demonstrates no significant difference in psychomotor aptitude scores (as measured by the Grooved Pegboard & the ProMIS simulator) between the surgical specialties.

3.4.4 Correlation between Aptitude and Surgical Skill Performance

Two of the surgical specialities formally assessed surgical skills as part of the selection process; general and plastic surgery. Over the period from 2007 – 2010, 67 shortlisted general and plastic surgery trainees had their surgical skills assessed.

We set out to determine whether there is a relationship between aptitude score and performance in the various surgical skills. Using Pearson's correlation coefficient we correlated the aptitude test scores with the various skill stations and the overall surgical skill score. We found a number of significant relationships between the various aptitude tests and performance in technical skills for the plastic and general surgery trainees (table 3.2). The results demonstrated that visual spatial aptitude correlated significantly with the overall score for surgical skill performance ($r = 0.326$, $p = 0.007$), the psychomotor test also correlated significantly the overall surgical skill score (Grooved pegboard: $r = 0.67$, $p = 0.003$). Depth perception aptitude was found to only correlate with performance on the laparoscopic cholecystectomy ($r = 0.314$, $p = 0.025$) (figure 3.8).





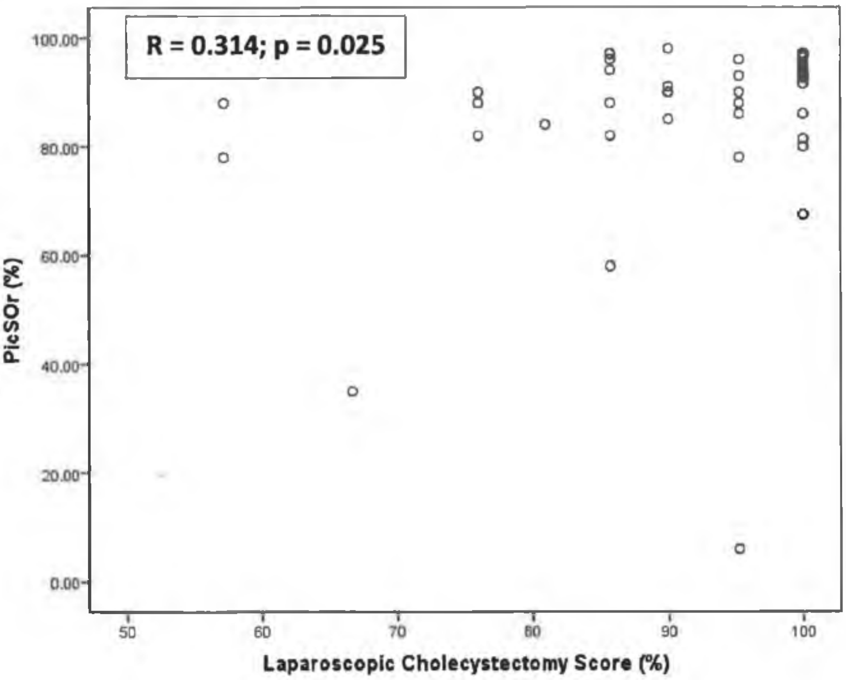


Figure 3.8 Scatterplot of Correlation between Aptitude and Technical Skill Score; The above scatterplots demonstrate the significant correlations found between the overall score for the technical skills assessment and both visual-spatial & psychomotor aptitude. There was also a significant correlation found between depth perception aptitude and performance on the laparoscopic cholecystectomy station.

Skill Station	**Aptitude: values displayed are correlation coefficients, r (values in red have a p < 0.05)**		
	Visual-spatial	**Depth Perception**	**Psychomotor**
Suturing of wound	0.016	0.031	-
Sapheno-femoral jxn ligation	0.054	0.084	-
Basic laparoscopic skills	0.023	0.176	-
Lap cholecystectomy	0.086	**0.314**	-
Bowel anastomosis	0.010	0.183	-
Inguinal hernia repair	0.003	0.173	-
OGD	0.112	0.094	-
Colonoscopy	0.209	0.072	-
Arterial anastomosis	0.101	0.208	-
Tendon repair	0.026	0.010	-
Lipoma excision	0.195	0.285	-
Flap formation	0.434	0.143	-
Cyst excision	0.101	0.402	-
Z-plasty	0.002	0.077	-
Overall Total Score	**0.326**	0.053	**0.67**

Table 3.2 Correlation between Aptitude and Technical Skill Performance

3.5 Discussion

The results demonstrate that the study group of surgical trainees performed better in the various tests of aptitude when compared to controls. There was no difference in aptitude distribution across the surgical specialties assessed. We also found that there was an association between aptitude and technical skill ability.

From the results we report it is clear that there is a huge level of competition in the challenge of getting accepted onto a higher surgical training scheme in Ireland. The number of 155 candidates' only represents those individual's that were shortlisted for further consideration. As a result the pool of candidates that underwent aptitude and technical skills testing was the 'cream of the surgical trainee crop'.

When we compared the aptitude scores between the surgical trainees and the control group we found that the surgical trainees did significantly better on all the tests except for psychomotor aptitude. There are two ways of interpreting these results. We could be reassured that doctors of a high aptitude calibre seem to be attracted into surgery. Also basic surgical trainees that struggled technically in the early stages of training may have chosen a different career pathway as a result. This could suggest that self-selection into a surgical career might play a role. On the other hand we may have seen these results because as surgical trainees' progress and gain experience in image based procedures their fundamental visual-spatial, depth perceptual and psychomotor abilities improve. If this is true it would question how innate these skills are and if so whether they have any importance in the learning curve in minimally invasive surgery.

Our results also raise the question of when the most suitable time to test aptitude in surgical trainees is. It may seem that aptitude assessment of trainees at the point of shortlisting for HST is too late. Perhaps instead trainees should be assessed at entry into basic surgical training or as an undergraduate, where assessment is incorporated into a career guidance structure. Assessment of aptitude at the start of training would also eliminate the bias that surgical experience creates. Evaluation of aptitude at an earlier stage in a surgical trainee's career may help us determine whether self-selection in surgery truly occurs.

As expected on comparing aptitude between the different specialties there was no significant difference in scores. Quite a diverse number of surgical specialties had their aptitude assessed. One might assume if self-selection played a part, that the different surgical specialities would display differing distributions in aptitude scores. For example one might expect that the plastic surgery and cardiothoracic trainees would have greater psychomotor ability as the skills they practice involve delicate fine motor control, or orthopaedic trainees to have higher visual-spatial aptitude as they rely on interpreting 2D x-ray images in the placement of screws and wires. This was not the case in our sample however.

There was one exception and this was the card rotation test. Here the general surgical trainees and the ophthalmology trainees did significantly better than the neurosurgical trainees. This test however is only one test of spatial orientation, the other being the cube comparison test. We found that with the cube comparison test there was no difference. It is fair to say that overall there was no difference in aptitude between the different surgical specialities.

The term "image guided surgery" encompasses a broad range of surgical techniques and includes endoscopy, laparoscopy, endovascular surgery, microsurgery, NOTES, and robotic surgery. All of these have a common factor: the surgeon performs a surgical procedure whilst viewing an image on a screen rather than by direct visualisation of the operative field. When learning and developing the necessary skills for image guided surgery, most of the difficulties encountered can be explained by visual spatial, psychomotor and perceptual factors (Gallagher et al, 1998; Noar & Soehendra, 1992; Perkins et al, 2002). A greater understanding of these underlying psychological factors may therefore provide a better insight into the learning curve in this area of surgery. The previous literature has identified the impact of various visual spatial and psychomotor problems involved in surgery and how these are likely to affect the ability of surgeons to plan, interpret and perform procedures (Hedman et al, 2006; Hassan et al, 2007). The possible involvement of visual spatial disorientation, misinterpretation and poor representation has been implicated as a potential cause of error in minimally invasive surgery.

We found that aptitude was associated with technical skill ability in both general and plastic surgery. There have been a number of studies published that have demonstrated that aptitude correlates with surgical performance in a variety of surgical specialties and in a variety of surgical tasks (Aora et al, 2005; Ritter et al, 2006; Gallagher et al, 2005). We found that what could be considered the more visually demanding surgical tasks such as colonoscopy were not significantly associated with aptitude. However the overall technical skill score was associated with visual spatial and psychomotor aptitude. These results suggest that aptitude does influence technical performance and that it would be worthwhile to further evaluate its role.

In conclusion, surgical trainees have a higher visual spatial and perceptual aptitude when compared to controls. There remains further work to be carried out in this area. One proposal for a future study is the re-evaluating of aptitude in those surgical trainees that have completed their training in order to determine if their visual spatial, perceptual and psychomotor ability have improved with training. Another proposal, which we plan to address in this thesis, is to investigate the impact of aptitude at the novice stage of training on the learning curve in minimally invasive procedures.

Minimally invasive procedures are fast becoming the mainstay of modern day surgery, therefore, if there is a significant relationship between natural ability and technical performance this will become increasingly relevant.

Chapter 4

Aptitude Assessment and Performance Outcomes in Basic Minimally Invasive Surgical Tasks

4.1 Introduction

Minimally invasive surgery is an exciting new advance in modern medicine that is becoming progressively more main-stream. There are many documented advantages to the minimally invasive approach (Braga et al, 2005; Zhou et al, 2004; Leung et al, 2004; Weeks et al, 2002). However there are also a number of difficulties associated with MIS. These difficulties relate to the different skill set required by surgeons for MIS surgery. These difficulties have been highlighted in Chapter 1. nevertheless we recapitulate some of the most important points in the coming paragraphs.

Minimally invasive surgery is more technically demanding than open surgery and has a longer learning curve (Southern Surgeons Club, 1995). This is because it requires the surgeon to overcome problems such as reconstructing 3D images from a 2D screen, the fulcrum effect, the manipulation of instruments that are operating at a distance, a reduction in the amount and quality of tactile feedback and the loss of major visual and depth cues to name but a few (Gallagher et al, 1998; Perkins et al, 2002). All of these factors contribute to the complexity of minimally invasive procedures that require a higher level of skill and dexterity.

Coupled with the increased difficulty of learning minimally invasive surgery is the fact that surgical training is undergoing restructuring. No longer is the Halstead model of progressive responsibility considered sufficient. Changes in the surgical working environment such as the reduction in working hours, economic pressures to get through operating lists more efficiently and changes in public perception and demands have led to a situation where the surgical trainee is not being exposed to or getting the same opportunities to learn the art of surgery as in previous years (Crofts et al, 1997; Skidmore et al, 1997). Therefore teaching the skills required for minimally invasive surgery to a surgical trainee becomes even more difficult in this environment. As a result there has been a shift towards the use of other, different methods of training such as simulation (Satava et al, 2003). Also there has been a re-evaluation of how best to optimise the training pathway.

The evidence indicates that the skills required for minimally invasive surgery are difficult to develop and require extensive practice and learning. As a result there is a need to identify processes or methods that can be used to aid and clarify the learning pathway in MIS. Aptitude testing is one avenue that is currently under exploration in an attempt to examine the role it may play in optimising the training pathway. Evaluating a trainee's aptitude for learning minimally invasive procedures may allow the prediction of expected learning curves for an individual and, as a result, it may allow the development of an optimal, individualised training curriculum.

In this chapter we evaluate how aptitude impacts on performance outcomes in basic minimally invasive tasks. These are surgical tasks that although they are not procedure specific relate to essential techniques such as instrument handling and interpretation of images from 2D monitors. Without proficiency in these basic tasks a trainee cannot be expected to progress to learning more complex procedure specific steps.

The overall aim of this chapter is to demonstrate the relationship between aptitude and performance outcomes in basic MIS tasks across a spectrum of experience levels and to explore the role that aptitude may play in ability to reach a predefined goal. From these results we aim to design expected and unique learning pathways that can be adjusted to the pattern of aptitude of an individual.

4.2 Objectives

4.2.1 Hypothesis Underlying the Objectives

We set out to test the hypothesis that certain aptitudes play an important role in the ability of the surgeon to perform various minimally invasive techniques. Aptitude has been shown to predict skill ability in surgical novices, however, as a trainee gains experience its role becomes less clear (Wanzel et al, 2003). In particular no study has evaluated a range of experience levels to investigate whether the effect of aptitude tapers off, or has any impact as a trainee gains experience and therefore competency in basic MIS tasks.

The primary aim of our study was to determine the relationship between aptitude and performance in a range of basic minimally invasive surgical tasks and subsequently, to determine whether aptitude testing may be used to predict baseline surgical skill for minimally invasive procedures. The secondary end point of our study was to evaluate the learning pathway required to reach predefined goals and to investigate whether aptitude level influences this. The learning pathways could be used to demonstrate where an individual trainee should expect to be in terms of performance outcomes depending on their aptitude level and stage of training and they could also be used to determine their potential ability. They could be of benefit in helping to identify those trainees that may require extra training and therefore a greater amount of time in the simulation laboratory in certain aspects of basic MIS tasks.

4.2.2 Detailed Objectives

Objective 1:- To Assess the Distribution of Aptitude across a Range of Experience Levels

We aimed to assess aptitude in three different groups of trainees; surgical novices, trainees with basic experience and trainees with more extensive experience in minimally invasive procedures. We aimed to compare the distribution of aptitude across the different groups so that we could determine how aptitude affects surgical performance.

Objective 2:- To Assess Performance across a Range of Experience Levels on MIS Tasks

In the same group of participants we aimed to assess their performance in three different areas of minimally invasive surgery; laparoscopy, endoscopy and endovascular tasks using surgical simulators. We again aimed to examine the distribution of performance scores across the three levels of surgical experience.

Objective 3:- To Investigate the Relationship between Aptitude and Performance in MIS Techniques

We aimed to correlate the aptitude scores with the surgical skill performance scores in order to determine if there is a relationship between aptitude and MIS performance across the three different experience groups. We aimed to determine from these results whether aptitude can be used to predict performance outcomes in MIS.

Objective 4:- To Set Proficiency for Basic Surgical Tasks on the Laparoscopic and Endoscopic Simulators

As a follow on and to further evaluate the relationship between aptitude and performance we aimed to determine whether aptitude also played a role in the ability of the trainee to reach predefined proficiency goals. In order to do this we needed to establish proficiency levels for the basic surgical tasks on both the laparoscopic and endoscopic simulators. We aimed to recruit a group of expert consultant surgeons to set proficiency.

Objective 5:- To Determine if Aptitude Impacts on Ability to Reach Proficiency

Our next aim was to determine whether aptitude level has an influence on the ability to reach predefined proficiency goals. We aimed to evaluate this in a separate group of surgical novices on their performance in basic laparoscopic and endoscopic tasks.

4.3 Materials and Methods

4.3.1 Recruitment of Participants

As outlined in chapter 2, a general e-mail was circulated to all the medical students attending RCSI in the pre-clinical years one to three, all the basic surgical trainees and higher surgical trainees in general surgery throughout Ireland. Posters were also displayed in the National Surgical Training Centre. Participation was voluntary. Participants were randomly selected from the responses received.

In addition, five experts (consultant surgeons) in minimally invasive surgery were recruited to set the proficiency levels on the laparoscopic and endoscopic simulators.

The candidates gave written informed consent allowing all data collected to be used for research purposes. It was made clear that all information gathered would be stored and presented in an anonymous format.

The assessments were performed at the National Surgical Training Centre, The Royal College of Surgeons in Ireland, 121 St. Stephen's Green, Dublin 2.

4.3.2 Participant Demographics

Forty medical students, 20 basic surgical trainees and 20 higher surgical trainees volunteered to take part in the study. For the second part of the study, where we looked at ability to reach predefined proficiency levels, an additional 26 medical students were recruited. Further demographic details are outlined in table 4.1.

The inclusion and exclusion criteria for the study participants have been previously outlined in chapter 2, Materials and Methods.

4.3.3 Aptitude Assessment

Aptitude is defined as a set of attributes that determine potential for a given activity. This potential may be developed into skilled behaviour with training and practice.

There are three main areas of aptitude that are considered relevant in minimally invasive procedures. These are visual spatial aptitude, psychomotor aptitude and depth perception.

Visual spatial aptitude was assessed using tests sourced from the Kit of Factor Referenced Cognitive Tests (Ekstrom et al, 1976). These are all paper based timed tests that examine specific areas of visual spatial aptitude. Spatial orientation was examined using the card rotation and cube comparison tests, spatial scanning by the map planning test and spatial visualisation by the surface development test.

Depth perception was assessed using a computer based software program known as Pictorial Surface Orientation (PicSOr). This was developed in the late 1990's specifically to test ability to convert a 2D image on a screen into a 3D image (Cowie, 1998). Psychomotor aptitude was tested using the Grooved Pegboard. This assesses manual dexterity and hand-eye coordination (Dikmen et al, 1999).

A more detailed explanation of these aptitude assessments, their background in the psychological literature and their relevance to MIS are outlined in chapter 2, Materials and Methods.

	Medical Students (N = 66)	**BST (N = 20)**	**HST (N = 20)**	**P value**
Age:				
Range	18-26	25-31	29-40	0.001
Mean	20.75	26.85	34.15	
SD	1.76	1.69	3.62	
Gender:				
Male (%)	48	75	85	0.002
Female	52	25	15	
PC/PGT* Year:				
1:2:3 (%)	29:58:13	60:40	-	
Dominant Hand:				
Right (%)	90	95	100	NS**
Left	10	5	0	
Ethnicity:				
Caucasian (%)	27	85	65	0.001
Asian	42	0	10	
Arabic	29	10	15	
African	2	5	10	
Corrected Vision:				
Yes (%)	58	55	60	NS
No	42	45	40	

Table 4.1 Participant Demographics [PC/PGT* = preclinical/postgraduate training; NS = non-significant]**

4.3.4 Surgical Skills Assessment

Minimally invasive surgical skills were assessed using simulators. The areas examined were laparoscopy, endoscopy and endovascular skill.

Laparoscopic skill was tested on the ProMIS (Haptica, Ireland). Each candidate was asked to perform a series of tasks – locating and coordinating, object positioning and a sharp dissection task. Objective metrics such as time, instrument motion and errors were recorded. Additional metrics such as the number of times the candidate dropped a bead in the object positioning task and the number of perforations to the glove in the sharp dissection task were also noted.

Endoscopic skill was tested using the GI Mentor II (Simbionix, USA). On this simulator each candidate performed the endobubble task and a colonoscopy case (Module 1, Case 1). The number of balloons burst, time to complete the task and the number of times the candidate hit the side wall were noted in the endobubble task. The time to reach the ceacum, percentage mucosa viewed, looping of the colon, patient pain and overall screening efficiency were recorded in the colonoscopy task.

Endovascular skill was assessed on the VIST (Mentice, Gothenburg, Sweden). The candidates were instructed to insert a standard guidewire and catheter into the left renal artery and then to remove the catheter out over the guidewire while keeping the guidewire steadily in place. The time to complete this was recorded. The candidates were also video recorded while performing this task. A camcorder recorded their hand movements while manipulating the instruments and another camcorder recorded the movements of the instruments on the screen. The video recordings were anonymous. They were scored by two blinded experts using a modified version of OSATS (appendix IV).

Further detail is available on the various minimally invasive tasks and the simulators used for the study in chapter 2, Materials and Methods.

4.3.5 Setting Proficiency Levels

The five experts in minimally invasive surgery were asked to complete three modules on the laparoscopic simulator (locating & coordinating, object positioning, sharp dissection) and the endobubble task and colonoscopy module. Each expert performed the tasks three times. The average scores, based on the objective parameters generated by the simulators and the error scores, were calculated and this was determined to be the proficiency level for each task (table 4.2).

4.3.6 Assessing Proficiency

Proficiency was assessed in a group of surgical novices (preclinical medical students, n = 26). Each subject repeatedly performed the series of laparoscopic and endoscopic tasks on the simulators until the predefined proficiency goals were attained.

Laparoscopy	**Proficiency Level**
Locating & Coordinating:	
Time (s)	46
Path Length (mm)	1300
Smoothness (v)	220
Object Positioning:	
Time	50
Path Length	2300
Smoothness	270
Error Score	0
Sharp Dissection:	
Time	110
Path Length	3800
Smoothness	750
Error Score	0
Endoscopy	
Endobubble:	
Ratio Popped (%)	65
Time (s)	95
Wall Hits	0.5
Colonoscopy:	
Mucosal Surface (%)	78
Time (s)	180
Screening Efficiency (%)	85
Clear View (%)	98.5
Local Pressure (%)	0
Pain (%)	<1
Looping (s)	0

Table 4.2 Proficiency Levels for Laparoscopic and Endoscopic Tasks

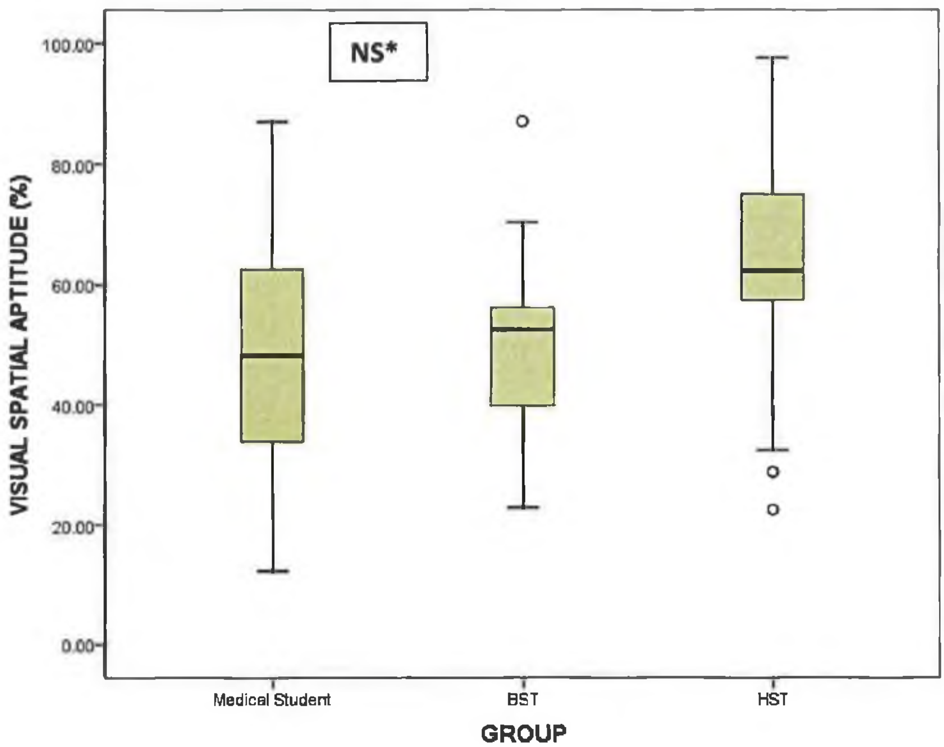
4.3.7 Statistical Analysis

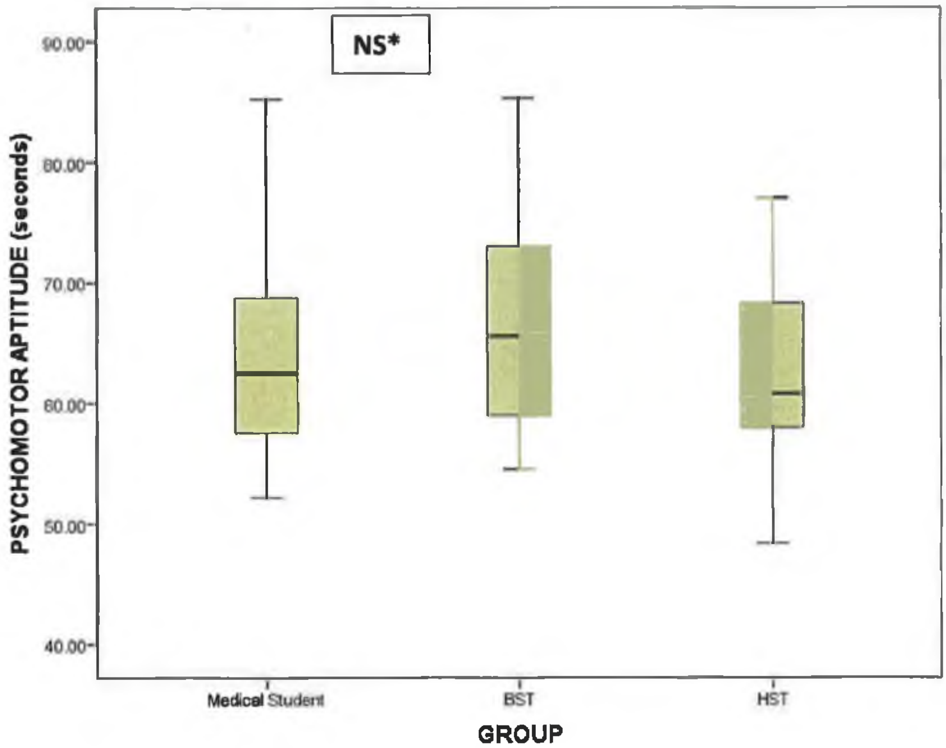
A database was constructed using SPSS (version 18.0 software, Chicago, Ill). Data was analysed by descriptive statistics, non-parametric tests and parametric correlation with calculation of the Pearson's coefficient of correlation (r). The Pearson's r was used to examine correlations between objective measures generated by the simulators and the score results from the aptitude assessments. The p-value of less than 0.05 was considered statistically significant. Post-hoc, exact bivariate power analysis was also performed, as appropriate. Chi square test was used to look at data where there were two categorical variables. Repeated measures ANOVA was used to evaluate the effect of practice on performance.

4.4 Results

4.4.1 Participant Demographics

In total hundred and eleven subjects took part. Sixty-six of these were medical students, 20 were basic surgical trainees (BST), 20 were higher surgical trainees (HST) and five were expert surgeons. Demographics for the groups in terms of age range and gender can be seen in table 4.1 and figure 4.1 gives the distribution of scores on the various aptitude tests.





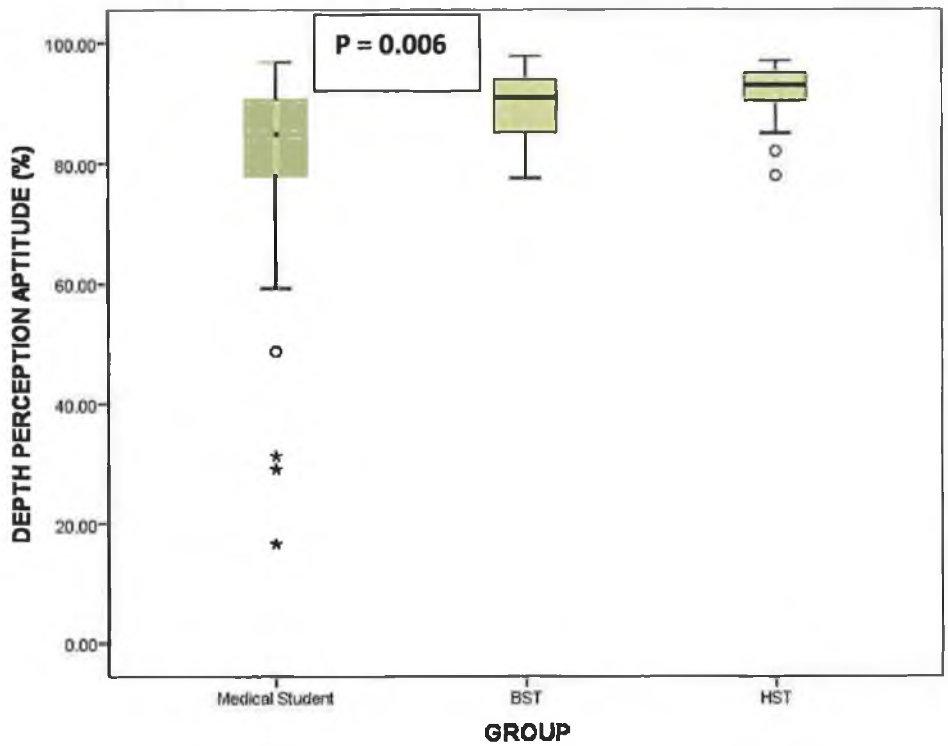


Figure 4.1 Aptitude Distribution per Experience Level; [NS* = non-significant] The above figures (boxplot & whiskers graph) shows the distribution of aptitude per group. The only significant difference in scores were found for the test of depth perception where the

HST's achieved greater scores than the BST's, who in-turn achieved greater scores than the medical students.

4.4.2 Aptitude Distribution across Experience Levels

The range of aptitude scores in the three different groups are displayed in figure 4.1. We found that there was no significant difference between the medical students, basic surgical trainees and higher surgical trainees in terms of visual spatial and psychomotor aptitude. On the test of depth perception we did find a significant difference (p = 0.006), where the HST's scored significantly better than the BST's, who in turn scored significantly higher than the medical students.

We also found that there was no difference in aptitude scores across the different ethnic breakdowns and between right and left hand dominant subjects. We did however find a gender difference for two of the aptitude tests (table 4.3). The results show that females scored significantly higher than the males in the psychomotor test (p = 0.023) and conversely males scored higher than the females on the test of depth perception (p = 0.013). When we looked at those that had corrected vision (wore glasses or contact lenses) we found that this group did better on the test of psychomotor aptitude (p = 0.038).

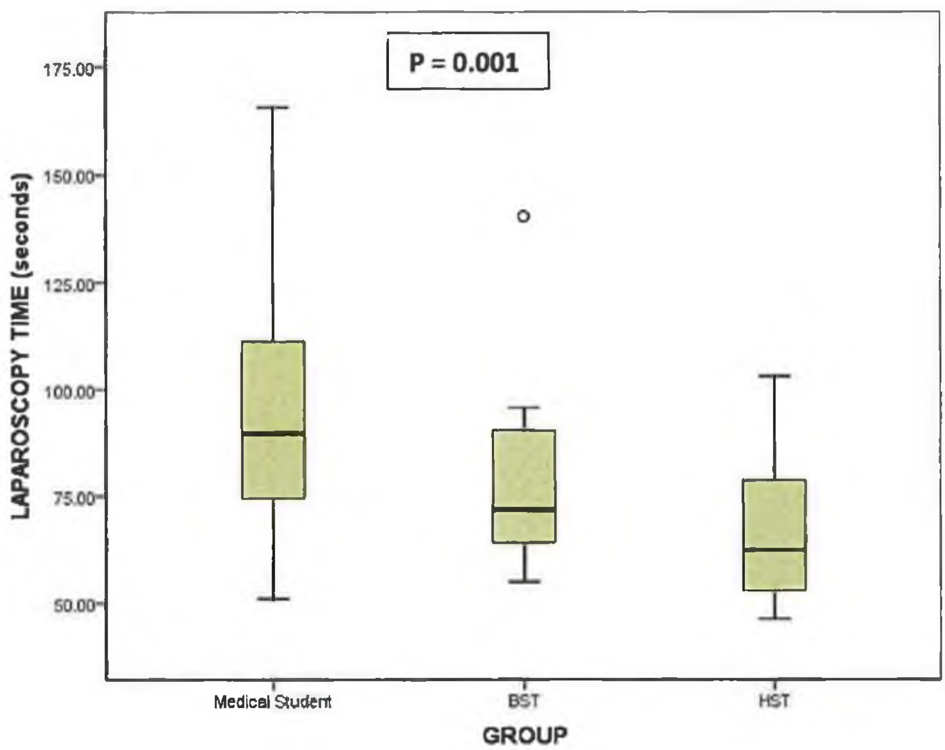
Variable	**Aptitude Test [mean scores]**					**P Value**
Gender		*Male*		*Female*		
	Visual spatial	61.5		62.59		NS*
	Psychomotor	66.0		61.61		0.023
	Depth perception	87.22		76.48		0.013
Dominant hand		*Right*		*Left*		
	Visual spatial	62.27		57.29		NS
	Psychomotor	64.17		67.01		NS
	Depth perception	83.33		88.05		NS
Corrected vision		*Yes*		*No*		
	Visual spatial	63.83		59.56		NS
	Psychomotor	62.66		66.66		0.038
	Depth perception	83.15		84.10		NS
Ethnicity		*Caucasian*	*Asian*	*Arabic*	*African*	
	Visual spatial	64.49	67.24	52.0	51.88	NS
	Psychomotor	64.59	62.3	67.72	72.3	NS
	Depth perception	83.49	83.11	83.13	91.35	NS

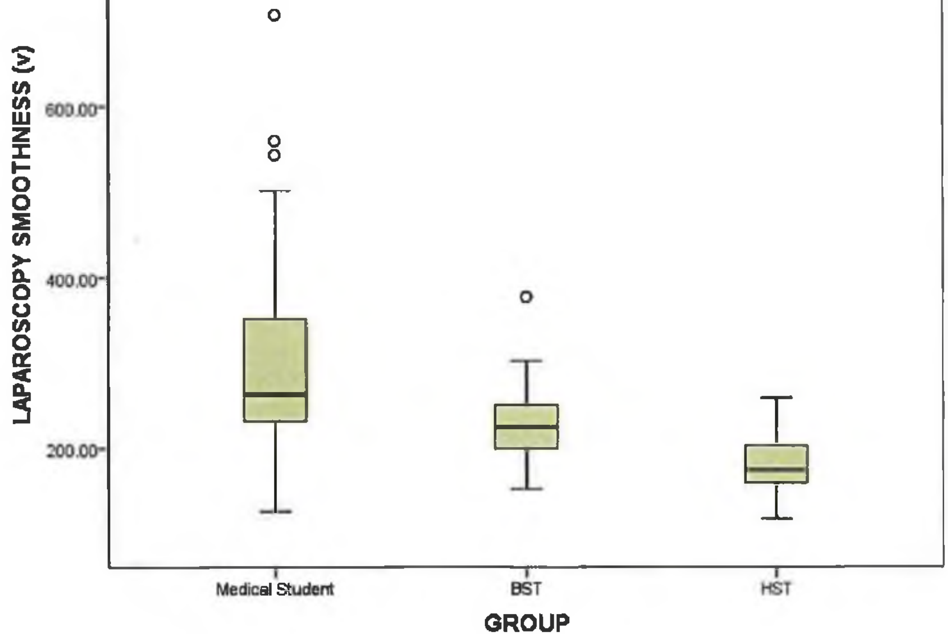
Table 4.3 Difference in Aptitude Distribution per Gender, Hand Dominance, Corrected Vision & Ethnicity [NS* = non-significant]

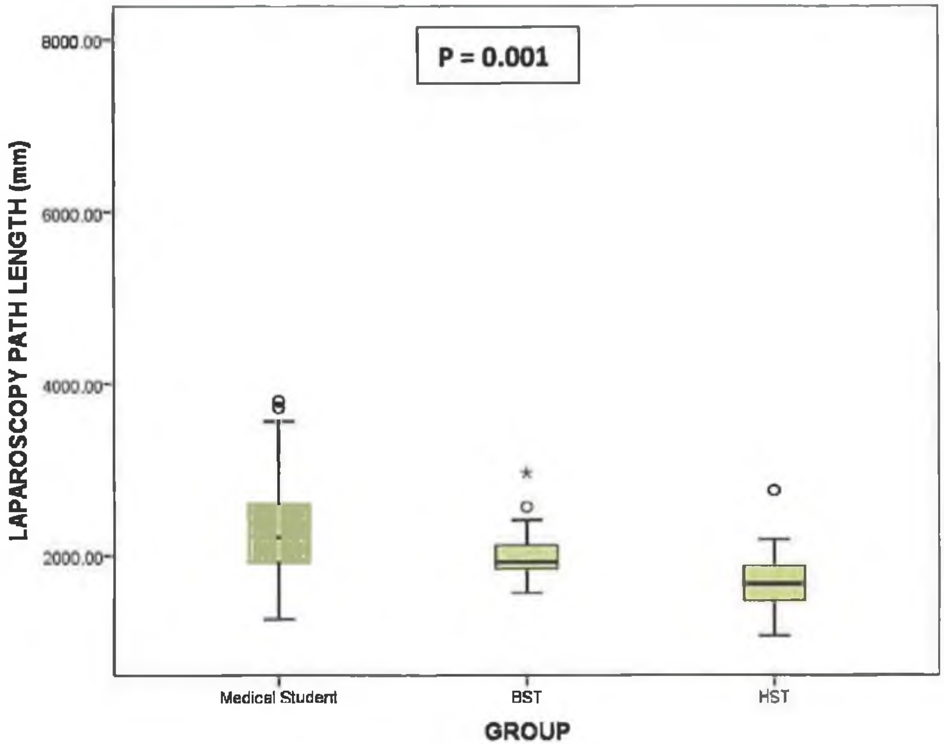
4.4.3 Performance Distribution across Experience Levels in the MIS Tasks

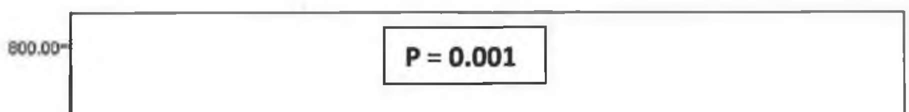
The range of scores on the surgical tasks can be seen in figure 4.2. We found that there was a significant difference in scores between the different groups. This was true for all the laparoscopic tasks, the endobubble endoscopy task and time taken in the endovascular task. There was also a significant difference in scores for time taken (p = 0.001), time spent with a clear view (p = 0.009) and percentage of time the patient was in pain (p = 0.002) in the colonoscopy case. The results demonstrated that HST trainees achieved better scores than the BST trainees, who in turn achieved better scores than the medical students.

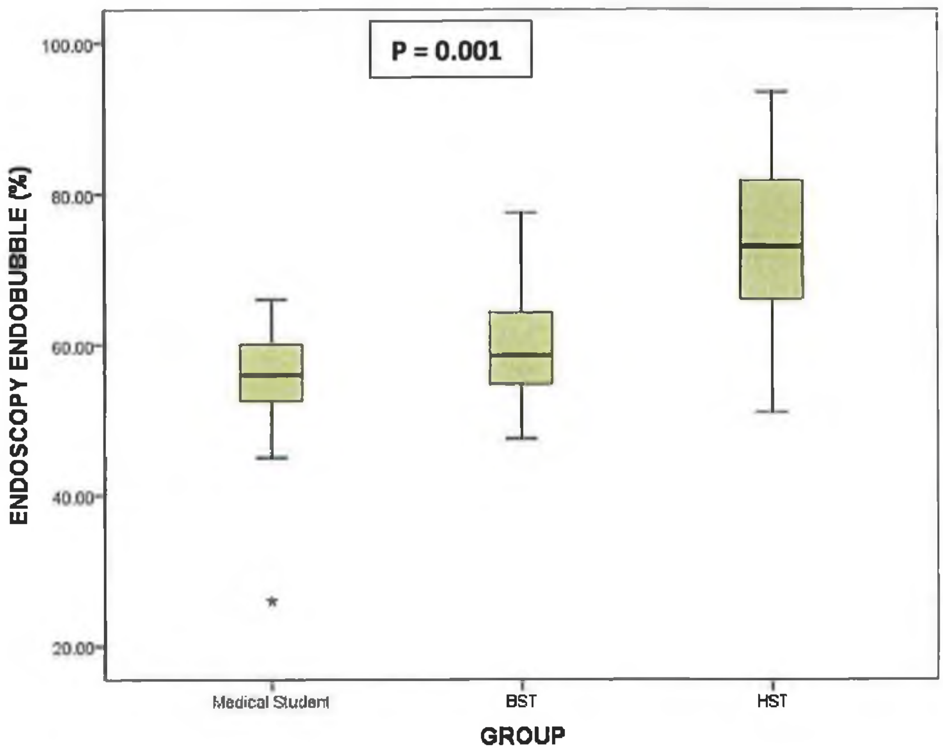
We also found that there was no difference in scores for hand dominance, corrected vision and ethnicity. There was a significant difference in scores between males and females, with males scoring higher on the laparoscopic (p = 0.007) and endoscopic tasks (p = 0.001).




LAPAROSCOPY SMOOTHNESS (v)
600.00
400.00
200.00
Medical Student
BST
HST
GROUP


P = 0.001
8000.00
6000.00
4000.00
2000.00
LAPAROSCOPY PATH LENGTH (mm)
Medical Student
BST
HST
GROUP


P = 0.001
800.00



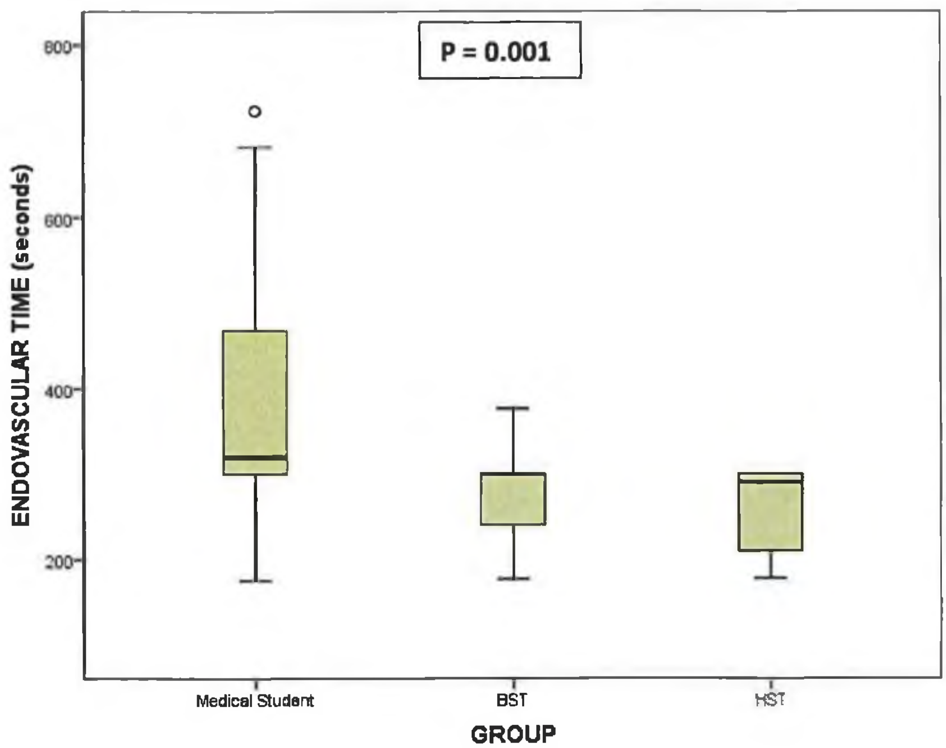


Figure 4.2 Performance in MIS Tasks; The above figure demonstrates the distribution of scores for performance in the laparoscopic, endoscopic & endovascular tasks. We found a significant difference in scores between the three groups, where the HST's performed better than the BST's, who in turn performed better than the medical students.

4.4.4 Medical Students Visual Spatial Aptitude and Surgical Skills

All the visual spatial aptitude tests (card rotation, cube comparison, map planning and surface development test) correlated significantly with the various laparoscopic tasks (table 4.4). All the visual spatial aptitude tests also correlated significantly with the endoscopic tasks and with performance on the endovascular task.

Visual-spatial Aptitude	Laparoscopic Surgical Skill	Correlation (R)	P Value
Card Rotation	Locating & Coordinating	0.48	0.002
	Object Positioning	0.45	0.003
	Sharp Dissection	-	NS*
Cube Comparison	Locating & Coordinating	0.39	0.01
	Object Positioning	0.35	0.02
	Sharp Dissection	0.34	0.03
Map Planning	Locate & Coordinating	-	NS
	Object Positioning	0.35	0.02
	Sharp Dissection	0.37	0.01
Surface Development	Locating & Coordinating	0.38	0.03
	Object Positioning	-	NS
	Sharp Dissection	0.38	0.01
	Endoscopic Surgical Skill		
Card Rotation	Endobubble	0.36	0.02
	Colonoscopy	0.35	0.02
Cube Comparison	Endobubble	0.37	0.01
	Colonoscopy	0.4	0.01
Map Planning	Endobubble	0.39	0.01
	Colonoscopy	-	NS
Surface Development	Endobubble	0.42	0.007
	Colonoscopy	0.39	0.01
	Endovascular Surgical Skill		
Card Rotation	Time Taken	0.51	0.002
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS
Cube Comparison	Time Taken	0.48	0.004
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS
Map Planning	Time Taken	-	NS
	Renal Artery Guidewire/Catheter	0.36	0.03
	Errors	-	NS
Surface Development	Time Taken	0.44	0.01
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS

Table 4.4 Correlation between Visual-spatial Aptitude & Surgical Skill in Medical Students [NS* = non-significant]

4.4.5 Medical Students Psychomotor Aptitude and Surgical Skill Performance

Psychomotor aptitude correlated significantly with performance on the laparoscopic and the endoscopic tasks (table 4.5). There was no significant correlation found in the case of time taken in endovascular performance.

Psychomotor Aptitude	Laparoscopic Surgical Skill	Correlation (R)	P Value
Grooved Pegboard	Locating & Coordinating	0.45	0.005
	Object Positioning	0.38	0.03
	Sharp Dissection	-	NS*
	Endoscopic Surgical Skill		
Grooved Pegboard	Endobubble	0.34	0.03
	Colonoscopy	0.45	0.008
	Endovascular Surgical Skill		
Grooved Pegboard	Time Taken	-	NS
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS

Table 4.5 Correlation between Psychomotor Aptitude & Surgical Skill in Medical Students [NS* = non-significant]

4.4.6 Medical Students Depth Perception Aptitude and Surgical Skill Performance

Depth perception aptitude correlated significantly with all the minimally invasive surgical tasks performed (table 4.6).

Depth Perception Aptitude	Laparoscopic Surgical Skill	Correlation (R)	P Value
PicSOr	Locate & Coordinating	-	NS*
	Object Positioning	-	NS
	Sharp Dissection	0.49	0.002
	Endoscopic Surgical Skill		
PicSOr	Endobubble	0.57	0.001
	Colonoscopy	0.47	0.004
	Endovascular Surgical Skill		
PicSOr	Time Taken	0.4	0.03
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS

Table 4.6 Correlation between Depth Perception Aptitude & Surgical Skill in Medical Students [NS* = non-significant]

4.4.7 BST Visual Spatial Aptitude and Surgical Skill Performance

The card rotations test and the surface development test correlated significantly with both laparoscopic and endoscopic performance (table 4.7). There was no significant correlation found between time taken to perform the endovascular task and the various visual spatial aptitude assessments.

Visual Spatial Aptitude	Laparoscopic Surgical Skill	Correlation (R)	P Value
Card Rotation	Locating & Coordinating	0.48	0.03
	Object Positioning	0.46	0.04
	Sharp Dissection	-	NS*
Cube Comparison	Locating & Coordinating	-	NS
	Object Positioning	-	NS
	Sharp Dissection	-	NS
Map Planning	Locating & Coordinating	-	NS
	Object Positioning	-	NS
	Sharp Dissection	-	NS
Surface Development	Locating & Coordinating	0.59	0.01
	Object Positioning	-	NS
	Sharp Dissection	-	NS
	Endoscopic Surgical Skill		
Card Rotation	Endobubble	-	NS
	Colonoscopy	0.54	0.01
Cube Comparison	Endobubble	-	NS
	Colonoscopy	-	NS
Map Planning	Endobubble	-	NS
	Colonoscopy	-	NS
Surface Development	Endobubble	-	NS
	Colonoscopy	0.61	0.01
	Endovascular Surgical Skill		
Card Rotation	Time Taken	-	NS
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS
Cube Comparison	Time Taken	-	NS
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS
Map Planning	Time Taken	-	NS
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS
Surface Development	Time Taken	-	NS
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS

Table 4.7 Correlation between Visual-spatial Aptitude & Surgical Skill in BST's [NS* = non-significant]

4.4.8 BST Psychomotor Aptitude and Surgical Skill Performance

Psychomotor aptitude (the Grooved Pegboard) correlated significantly with performance on the laparoscopic and endovascular tasks (table 4.8). There was no significant correlation found between performance on the Grooved Pegboard and performance on the various endoscopic tasks.

Psychomotor Aptitude	Laparoscopic Surgical Skill	Correlation (R)	P Value
Grooved Pegboard	Locating & Coordinating	-	NS*
	Object Positioning	0.48	0.03
	Sharp Dissection	0.69	0.001
	Endoscopic Surgical Skill		
Grooved Pegboard	Endobubble	-	NS
	Colonoscopy	-	NS
	Endovascular Surgical Skill		
Grooved Pegboard	Time Taken	0.46	0.04
	Renal Artery Guidewire/Catheter	0.47	0.03
	Errors	-	NS

Table 4.8 Correlation between Psychomotor Aptitude & Surgical Skill in BST's [NS* = non-significant]

4.4.9 BST Depth Perception Aptitude and Surgical Skill Performance

The Pictorial Surface Orientation Test (PicSOr) correlated significantly with performance on the laparoscopic and endoscopic tasks (table 4.9). There was no significant correlation found between PicSOr and performance on the endovascular task.

Depth Perception Aptitude	Laparoscopic Surgical Skill	Correlation (R)	P Value
PicSOr	Locating & Coordinating	-	NS*
	Object Positioning	0.52	0.04
	Sharp Dissection	-	NS
	Endoscopic Surgical Skill		
PicSOr	Endobubble Time	0.55	0.03
	Colonoscopy	-	NS
	Endovascular Surgical Skill		
PicSOr	Time Taken	-	NS
	Renal Artery Guidewire/Catheter	-	NS
	Errors	-	NS

Table 4.9 Correlation between Depth Perception Aptitude & Surgical Skill in BST's [NS* = non-significant]

4.4.10 HST Visual Spatial Aptitude and Surgical Skill Performance

We divided the higher surgical trainees into two separate groups for analysis based on experience level. Group A (n = 8) consisted of trainees that were year one to three of the higher training scheme and group B (n = 12) consisted of trainees that were year four to six of the higher training scheme.

We found significant correlations between the visual spatial tests and performance in group A (table 4.10). This was true for laparoscopy and the colonoscopy case in endoscopy and the error score in endovascular. The only significant correlation found for group B was between the cube comparison test of visual spatial aptitude and the endobubble endoscopy task (r = 0.65, p = 0.04).

Visual Spatial Aptitude	Laparoscopic Surgical Skill	Correlation (R) [p value] Group A	Group B
Card Rotations	Locating & Coordinating	- [NS*]	- [NS]
	Object Positioning	- [NS]	- [NS]
	Sharp Dissection	- [NS]	- [NS]
Cube Comparison	Locating & Coordinating	- [NS]	- [NS]
	Object Positioning	- [NS]	- [NS]
	Sharp Dissection	0.769 [0.026]	- [NS]
Map Planning	Locating & Coordinating	- [NS]	- [NS]
	Object Positioning	0.752 [0.032]	- [NS]
	Sharp Dissection	0.799 [0.017]	- [NS]
	Endoscopic Surgical Skill		
Card Rotation	Endobubble	- [NS]	- [NS]
	Colonoscopy	0.722 [0.043]	- [NS]
Cube Comparison	Endobubble	- [NS]	0.65 [0.04]
	Colonoscopy	0.770 [0.026]	- [NS]
Map Planning	Endobubble	- [NS]	- [NS]
	Colonoscopy	0.851 [0.007]	- [NS]
	Endovascular Surgical Skill		
Card Rotation	Time Taken	- [NS]	- [NS]
	Renal Artery Guidewire/Catheter	- [NS]	- [NS]
	Errors	0.927 [0.003]	- [NS]
Cube Comparison	Time Taken	- [NS]	- [NS]
	Renal Artery Guidewire/Catheter	- [NS]	- [NS]
	Errors	- [NS]	- [NS]
Map Planning	Time Taken	- [NS]	- [NS]
	Renal Artery Guidewire/Catheter	- [NS]	- [NS]
	Errors	- [NS]	- [NS]

Table 4.10 Correlation between Visual-spatial Aptitude & Surgical Skill in HST's [NS* = non-significant]

4.4.11 HST Psychomotor Aptitude and Surgical Skill Performance

We found a number of significant correlations for both group A and group B (table 4.11). This was true of all the laparoscopic tasks for group A and for the object positioning task for group B. In the endoscopy tasks both groups demonstrated a significant relationship with psychomotor aptitude. There were no significant correlations found for the endovascular task.

Psychomotor Aptitude	Laparoscopic Surgical Skill	Correlation (R) [p value] Group A	Group B
Grooved Pegboard	Locating & Coordinating	0.75 [0.032]	- [NS*]
	Object Positioning	0.78 [0.023]	0.70 [0.037]
	Sharp Dissection	0.77 [0.025]	- [NS]
	Endoscopic Surgical Skill		
Grooved Pegboard	Endobubble	- [NS]	0.736 [0.024]
	Colonoscopy	0.89 [0.003]	0.76 [0.027]
	Endovascular Surgical Skill		
Grooved Pegboard	Time Taken	- [NS]	- [NS]
	Renal Artery Guidewire/Catheter	- [NS]	- [NS]
	Errors	- [NS]	- [NS]

Table 4.11 Correlation between Psychomotor Aptitude & Surgical Skill in HST's [NS* = non-significant]

4.4.12 HST Depth Perception Aptitude and Surgical Skill Performance

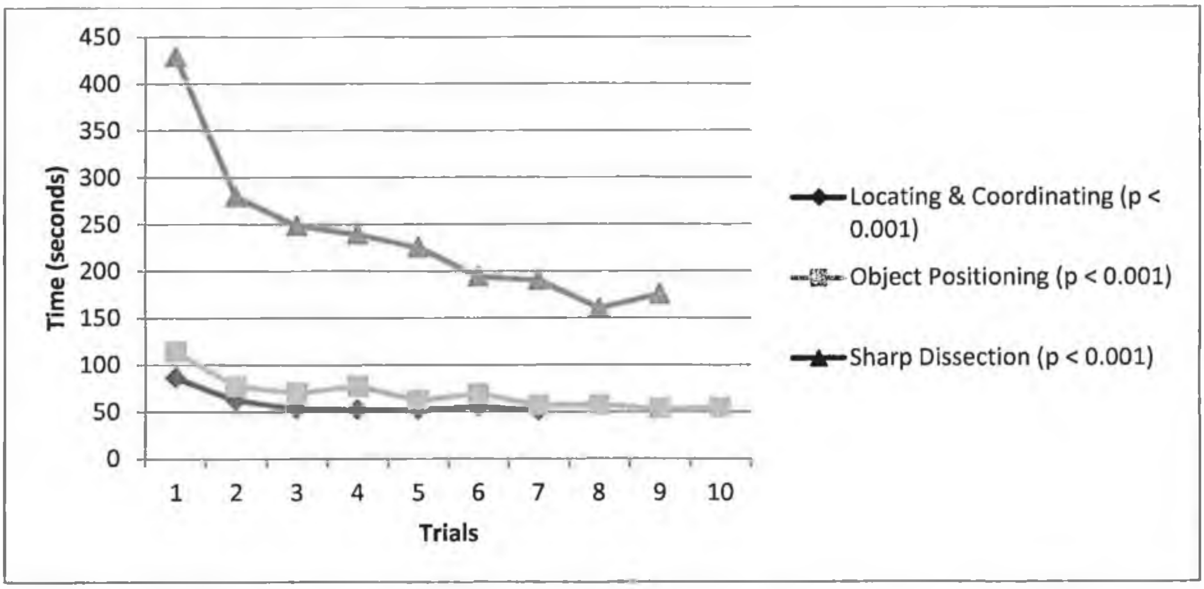
We found significant correlations for both HST groups for the laparoscopic tasks (table 4.12). There was a significant relationship found between group B and the endoscopy tasks. There was no significant relationship found for the endovascular tasks and depth perception aptitude.

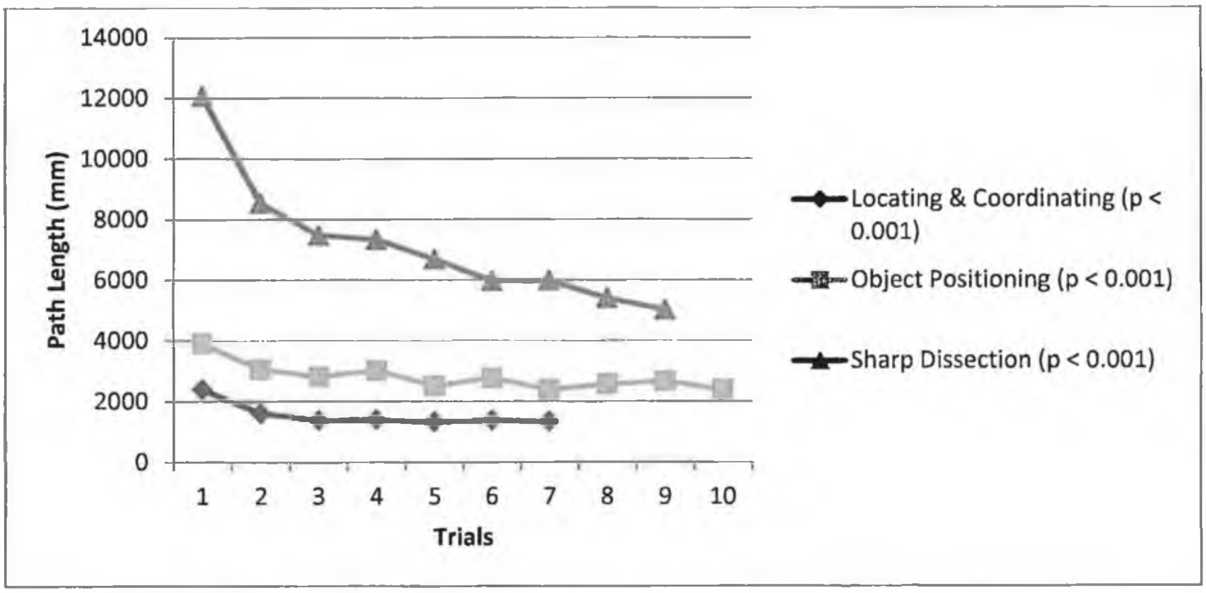
Depth Perception Aptitude	Laparoscopic Surgical Skill	Correlation (R) [p value] Group A	Group B
PicSOr	Locating & Coordinating	- [NS*]	0.70 [0.035]
	Object Positioning	0.80 [0.017]	0.73 [0.025]
	Sharp Dissection	- [NS]	- [NS]
	Endoscopic Surgical Skill		
PicSOr	Endobubble	- [NS]	0.79 [0.012]
	Colonoscopy	- [NS]	0.81 [0.015]
	Endovascular Surgical Skill		
PicSOr	Time Taken	- [NS]	- [NS]
	Renal Artery Guidewire/Catheter	- [NS]	- [NS]
	Errors	- [NS]	- [NS]

Table 4.12 Correlation between Depth Perception Aptitude & Surgical Skill in HST's [NS* = non-significant]

4.4.13 Assessing Proficiency in Surgical Novices

Twenty-six preclinical medical students participated in the proficiency experiment. All the subjects significantly improved in performance with repetition on both the laparoscopic (figure 4.3) and endoscopic tasks (figure 4.4). There was no significant change over time in the laparoscopy error scores (p = 0.436), colonoscopy time (p = 0.194), pain (p = 0.169) and looping of the colon (p = 0.227).





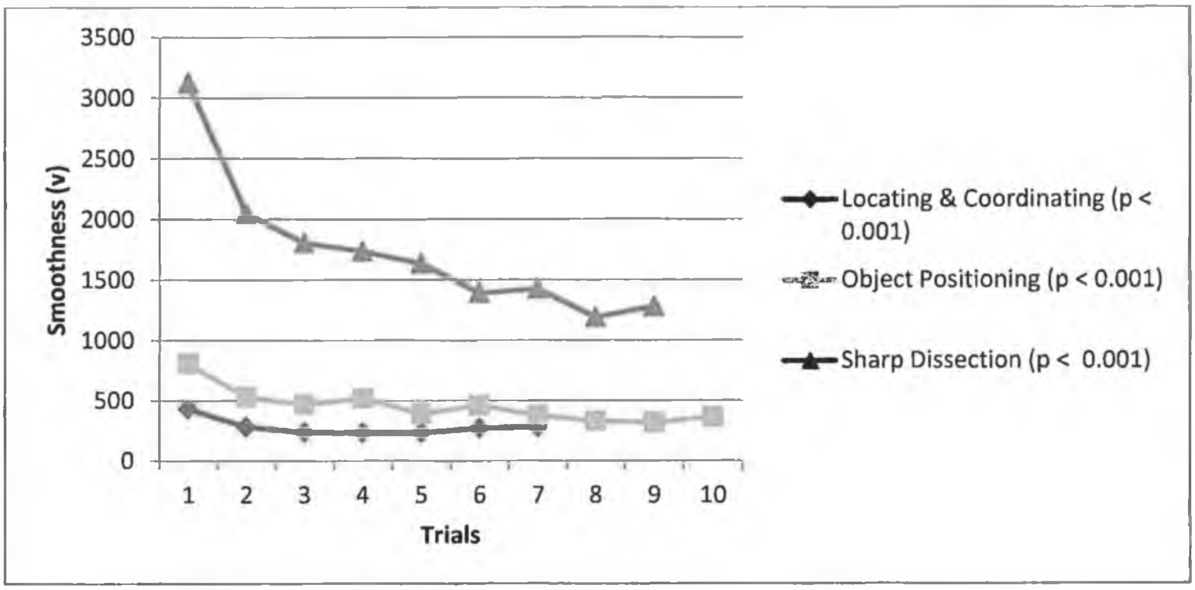
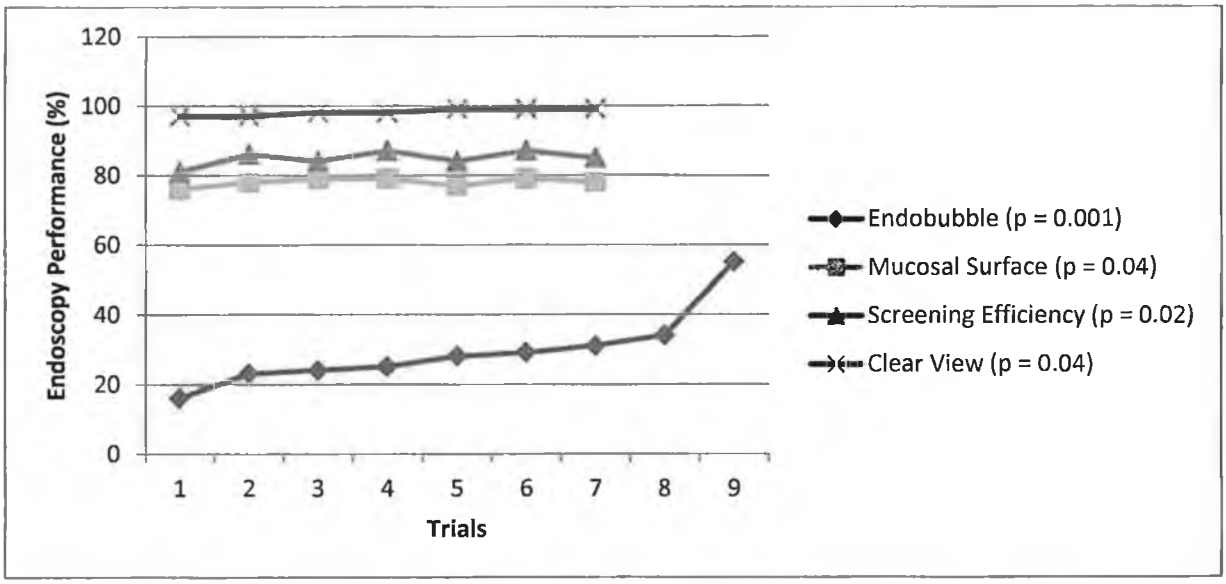


Figure 4.3 Line graph of Laparoscopic Performance over Time; [p values in parenthesis] This figure demonstrates a significant improvement with repetition in the measures of time & motion analysis for the three laparoscopic tasks.



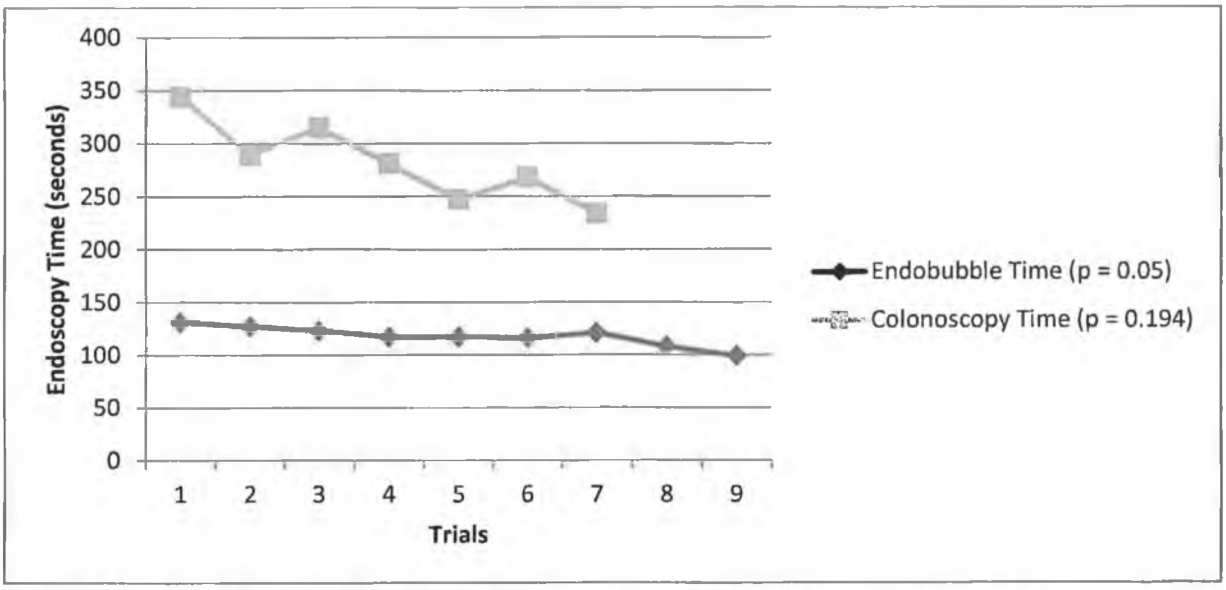
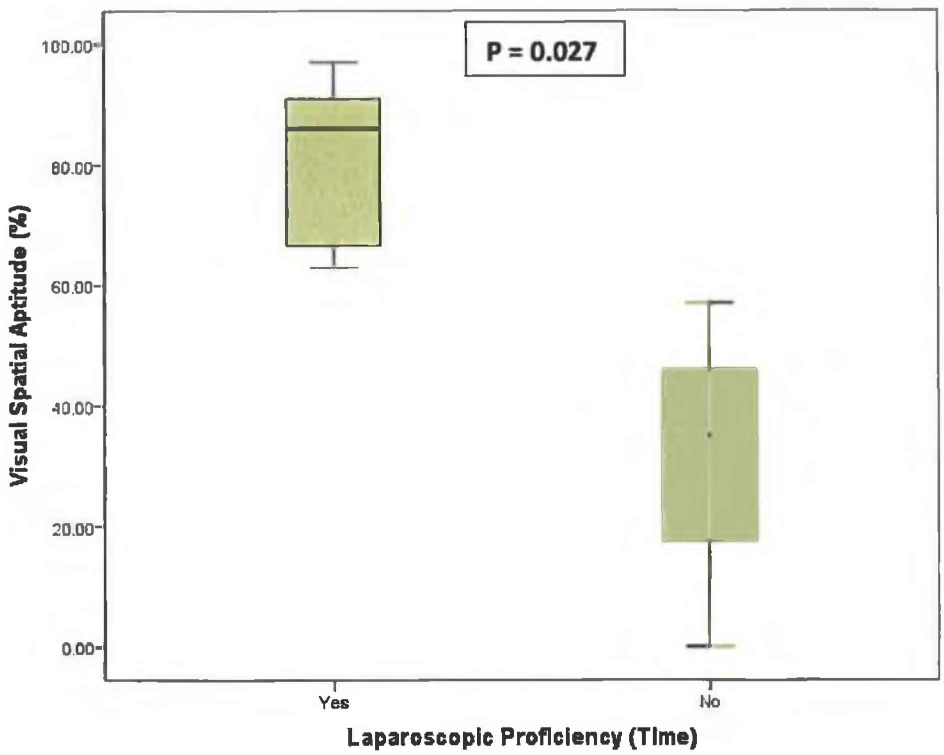
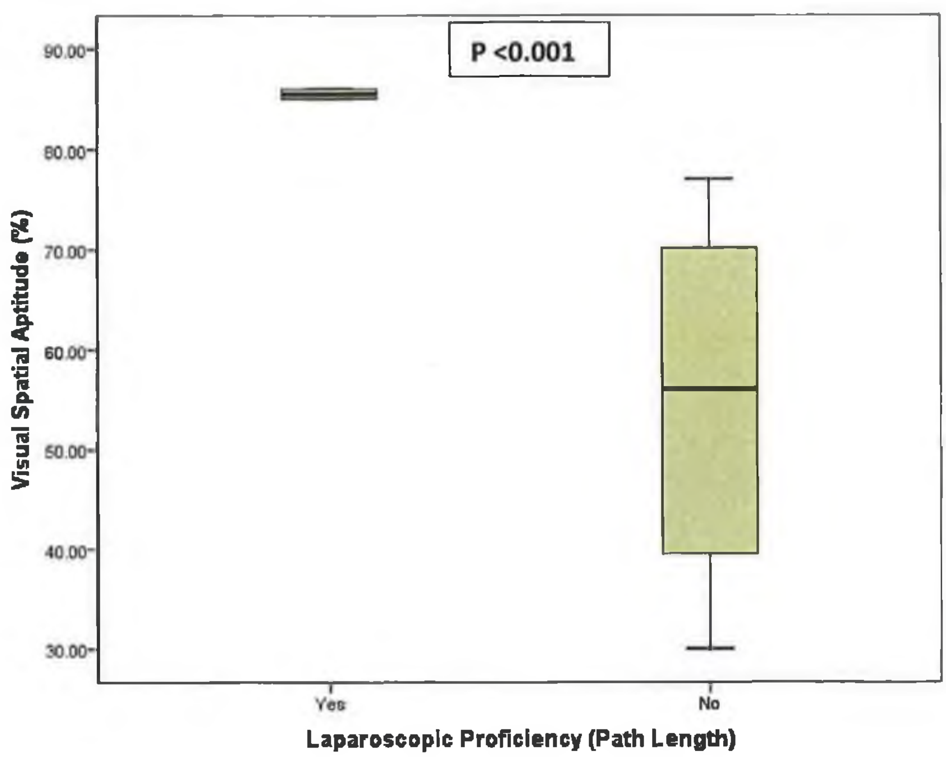


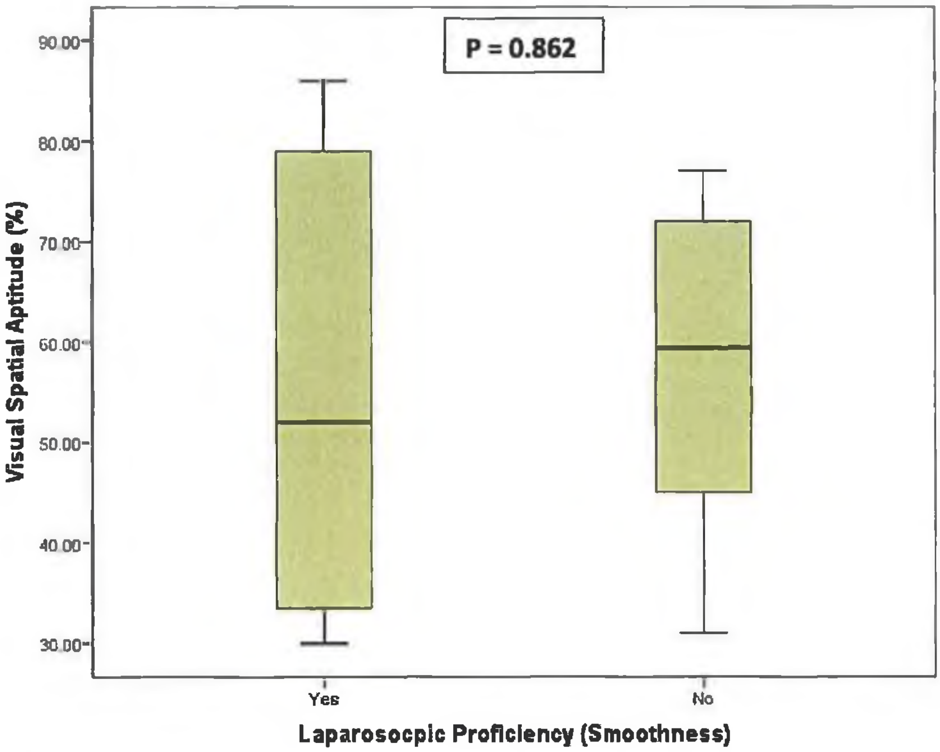
Figure 4.4 Line Graph of Endoscopic Performance over Time; [p values in parenthesis]
This figure demonstrates a significant improvement with repetition in the various endoscopic parameters with the exception of time taken to perform the colonoscopy.

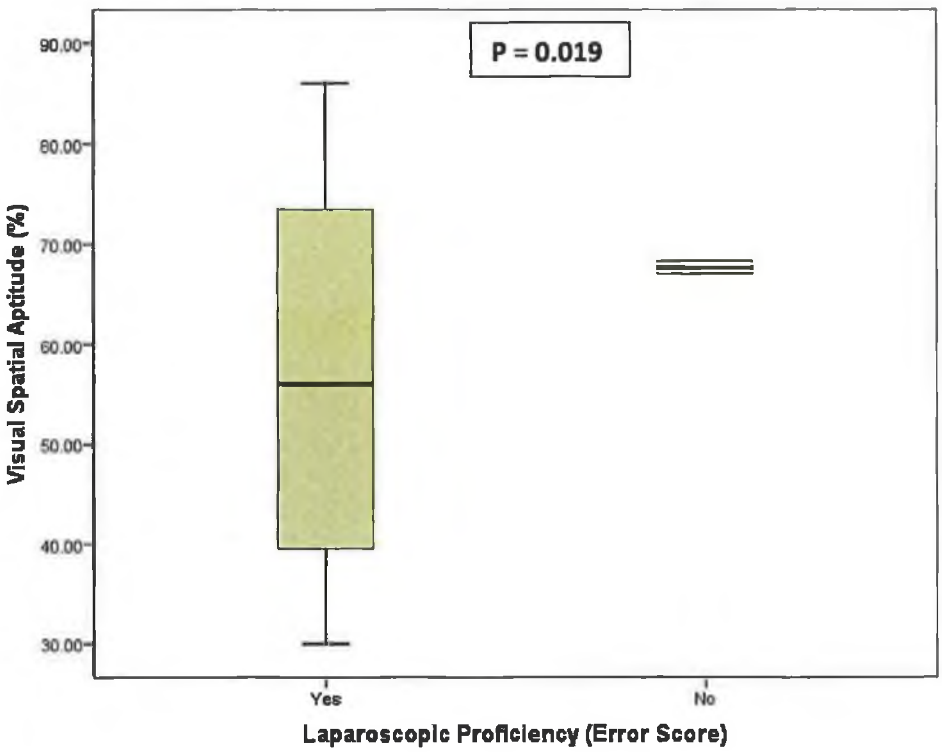
4.4.14 Impact of Aptitude on Ability to Reach Proficiency

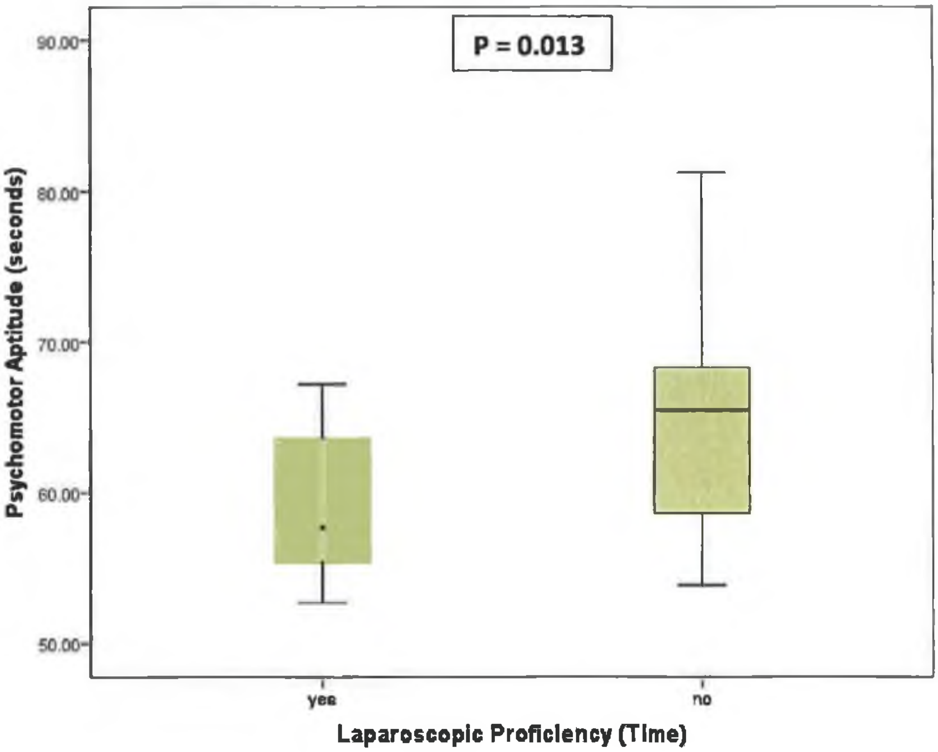
We assessed the relationship between aptitude and ability to reach the predefined proficiency goals. The results demonstrated that aptitude did impact on the ability of subjects to achieve proficiency in all the laparoscopic tasks (figure 4.5). In the case of the endoscopic tasks depth perception aptitude was the only aptitude to predict performance in the endobubble module (figure 4.6).

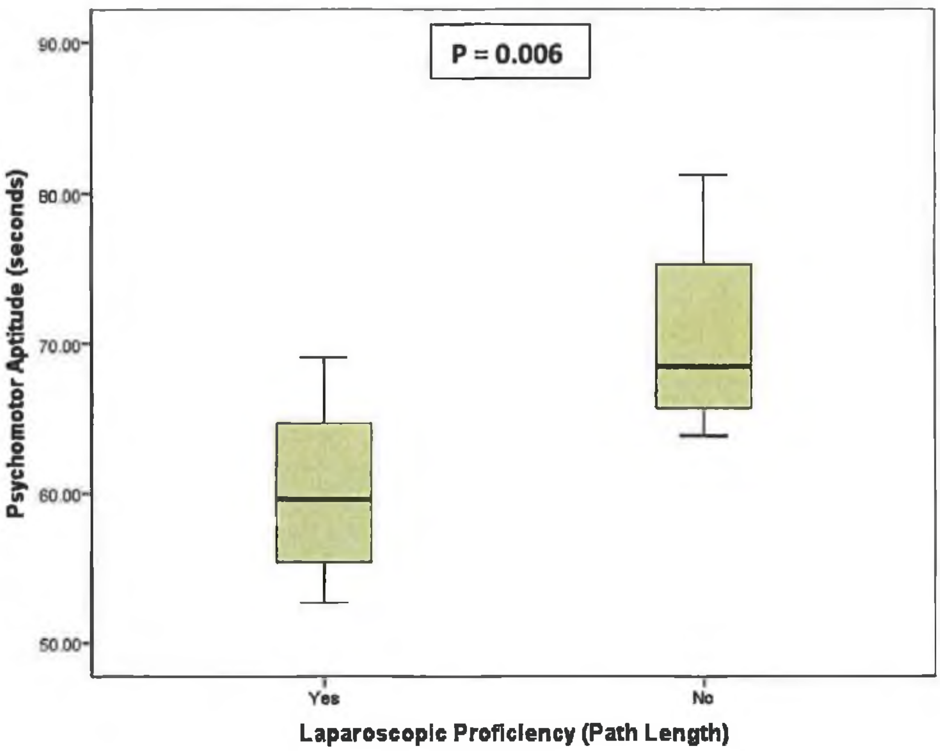

P = 0.027
100.00
80.00
60.00
40.00
20.00
0.00
Visual Spatial Aptitude (%)
Yes
No
Laparoscopic Proficiency (Time)

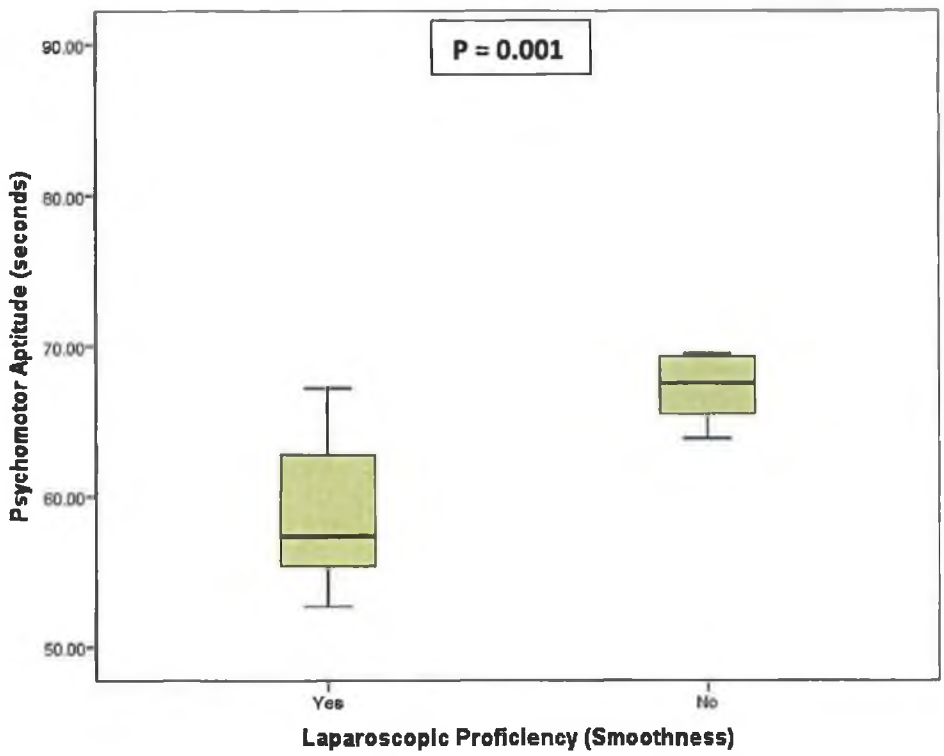

P <0.001
90.00
80.00
70.00
60.00
50.00
40.00
30.00
Visual Spatial Aptitude (%)
Yes
No
Laparoscopic Proficiency (Path Length)

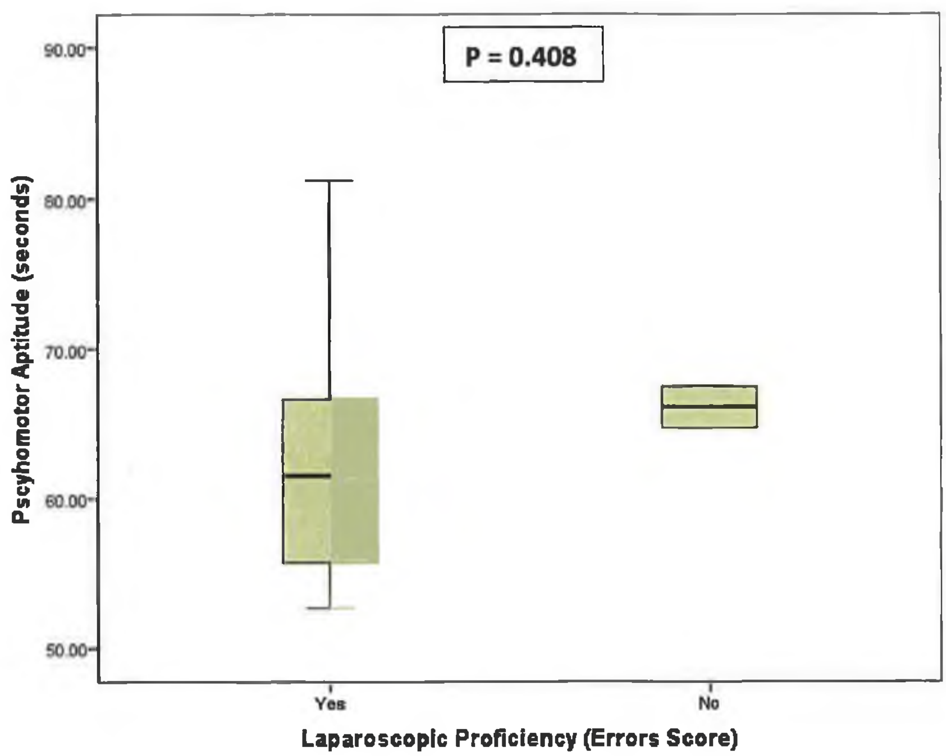

P = 0.862
90.00
80.00
70.00
60.00
50.00
40.00
30.00
Visual Spatial Aptitude (%)
Yes
No
Laparosocpic Proficiency (Smoothness)

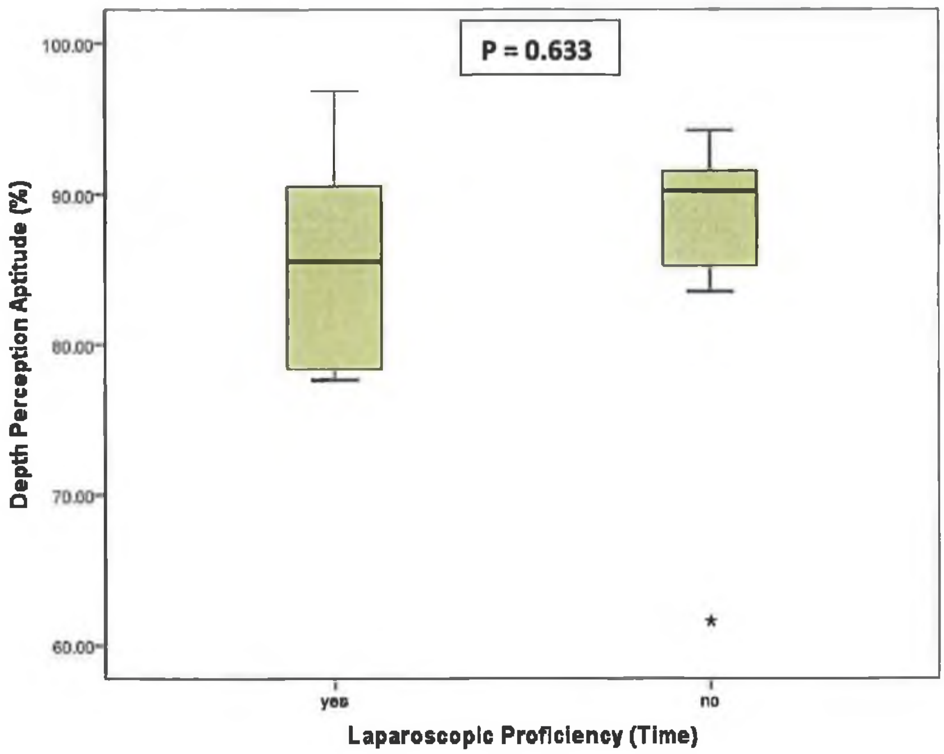

P = 0.019
90.00
80.00
70.00
60.00
50.00
40.00
30.00
Visual Spatial Aptitude (%)
Yes
No
Laparoscopic Proficiency (Error Score)

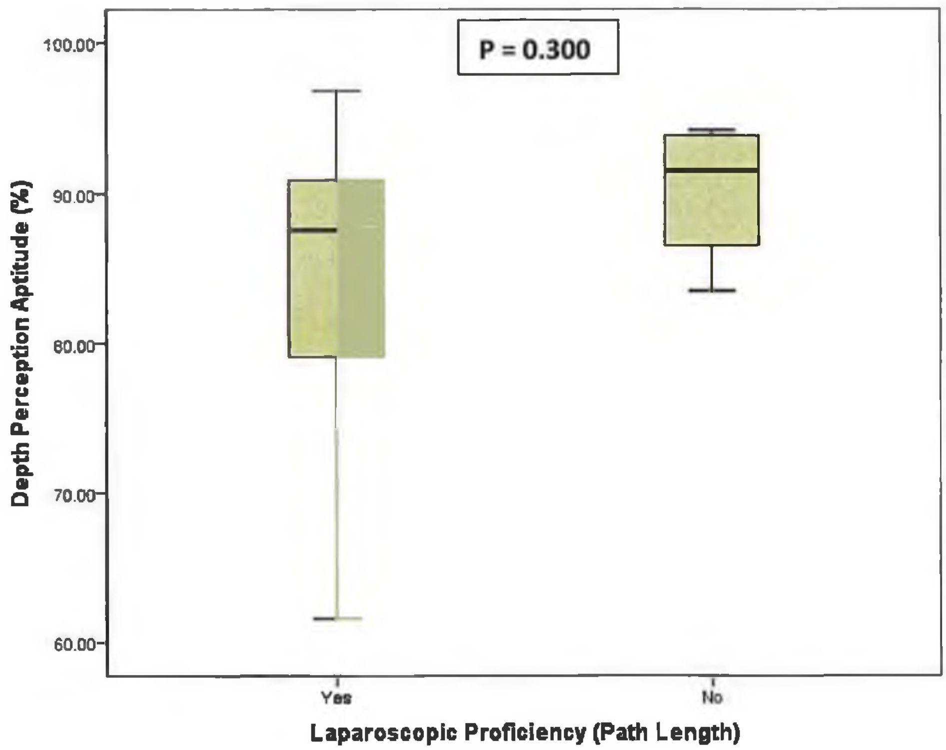

P = 0.013
90.00
80.00
70.00
60.00
50.00
Psychomotor Aptitude (seconds)
yes
no
Laparoscopic Proficiency (Time)


P = 0.006
90.00
80.00
70.00
60.00
50.00
Psychomotor Aptitude (seconds)
Yes
No
Laparoscopic Proficiency (Path Length)


P = 0.001
90.00
80.00
70.00
60.00
50.00
Psychomotor Aptitude (seconds)
Yes
No
Laparoscopic Proficiency (Smoothness)


P = 0.408
90.00
80.00
70.00
60.00
50.00
Psychomotor Aptitude (seconds)
Yes
No
Laparoscopic Proficiency (Errors Score)


P = 0.633
100.00
90.00
80.00
70.00
60.00
Depth Perception Aptitude (%)
yes
no
Laparoscopic Proficiency (Time)


P = 0.300
100.00
90.00
80.00
70.00
60.00
Depth Perception Aptitude (%)
Yes
No
Laparoscopic Proficiency (Path Length)

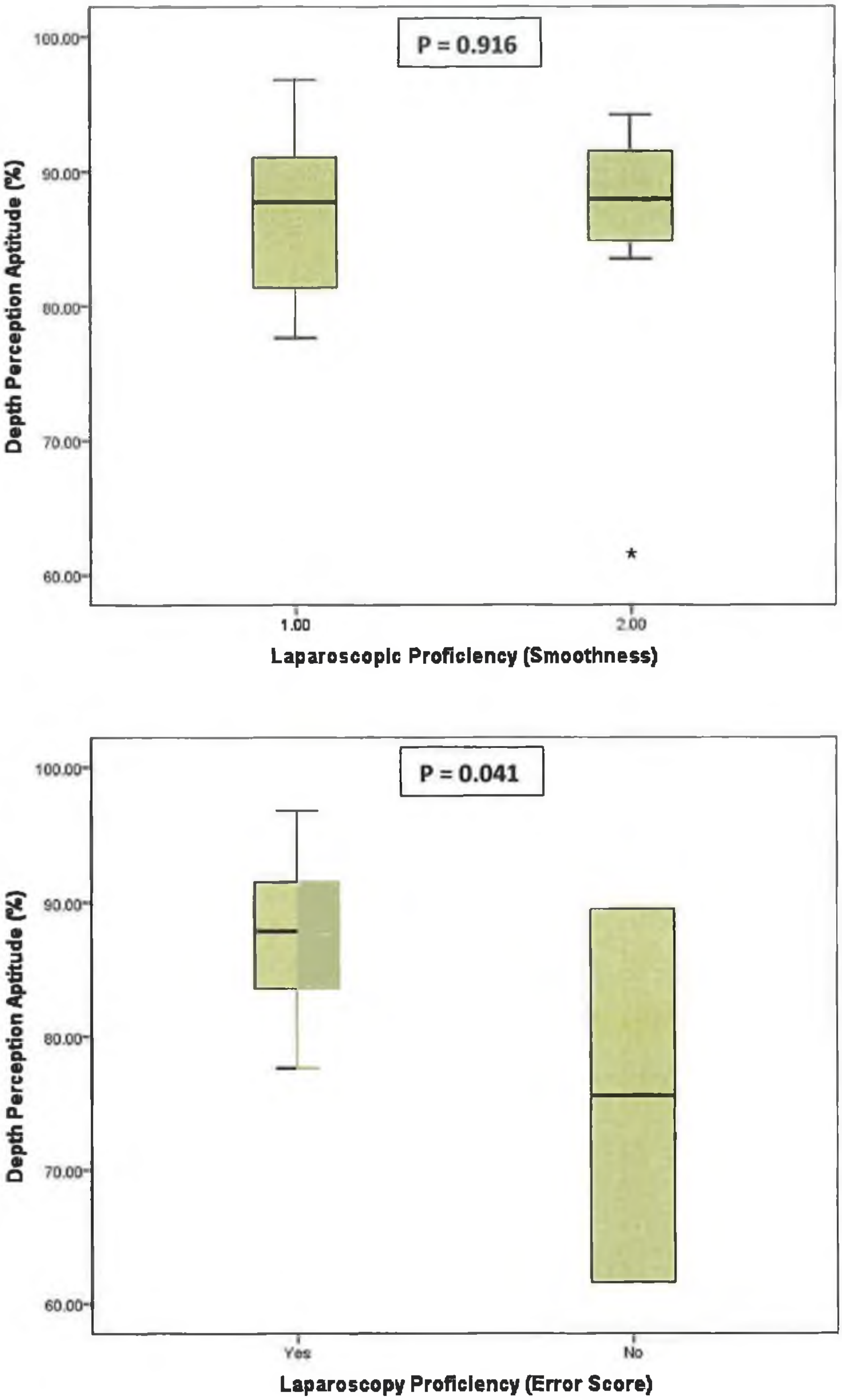


Figure 4.5 Relationship between Aptitude & Ability to Reach Laparoscopic Proficiency; [Yes = medical students that reached laparoscopic proficiency, No = medical students that didn't reach laparoscopic proficiency] The above figure shows that those students that reached laparoscopic proficiency had a significantly higher aptitude than those that didn't.

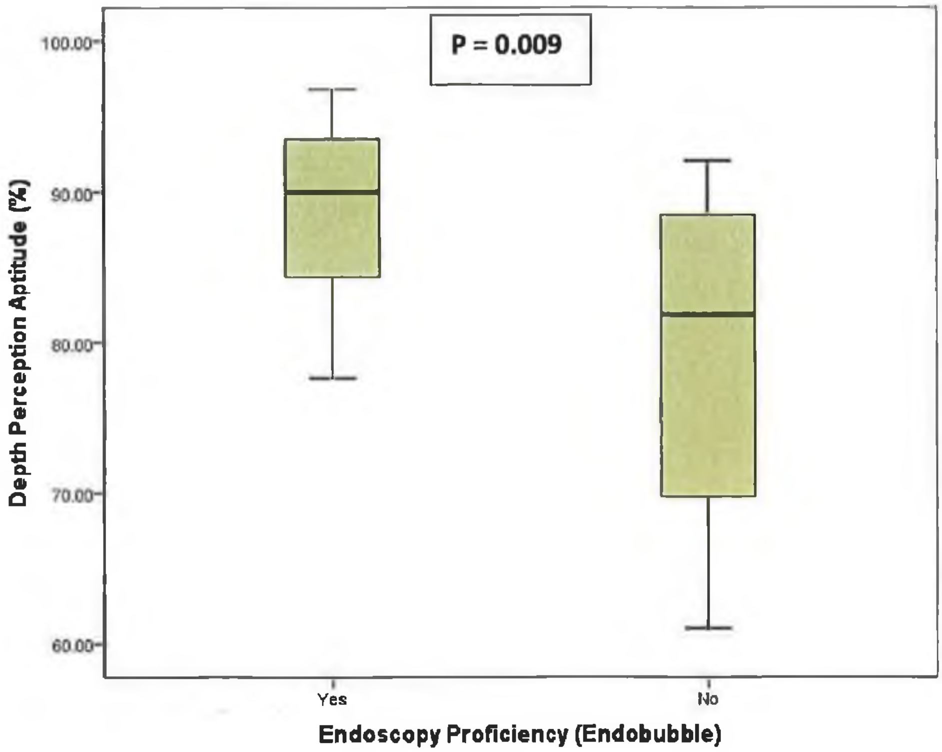


Figure 4.6 Relationship between Aptitude & Ability to Reach Endoscopic Proficiency; **[Yes = medical students that reached endoscopic proficiency, No = medical students that didn't reach endoscopic proficiency]** This figure shows that those students that reached endoscopic proficiency had a significantly higher depth perception aptitude than those that didn't.

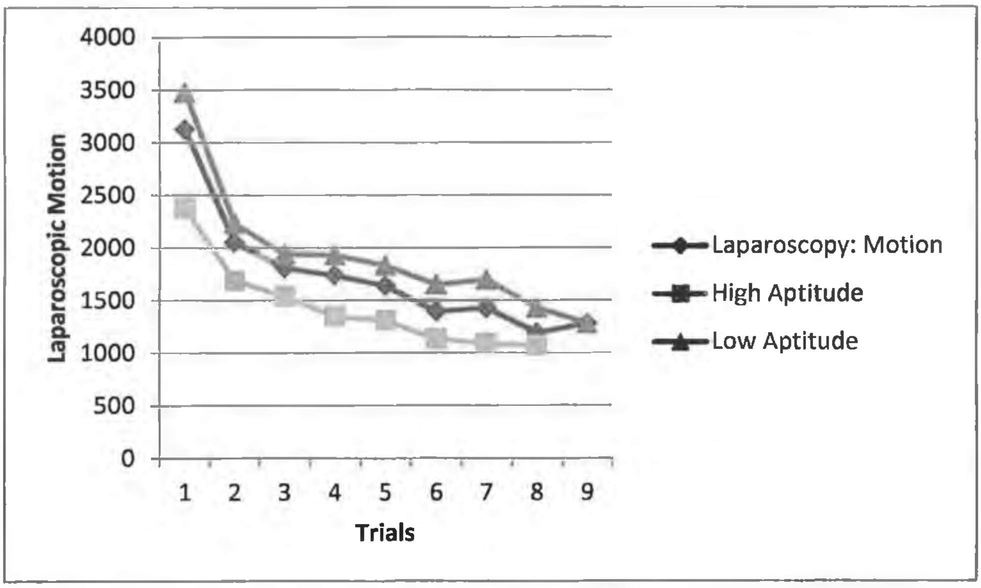
In those medical students that reached proficiency, we also examined the relationship between the number of trials taken to reach proficiency and aptitude score. The results found that visual spatial aptitude and depth perception aptitude correlated significantly with the number of trials taken to reach proficiency (table 4.13). The medical students that took less trails to reach proficiency had higher aptitude scores.

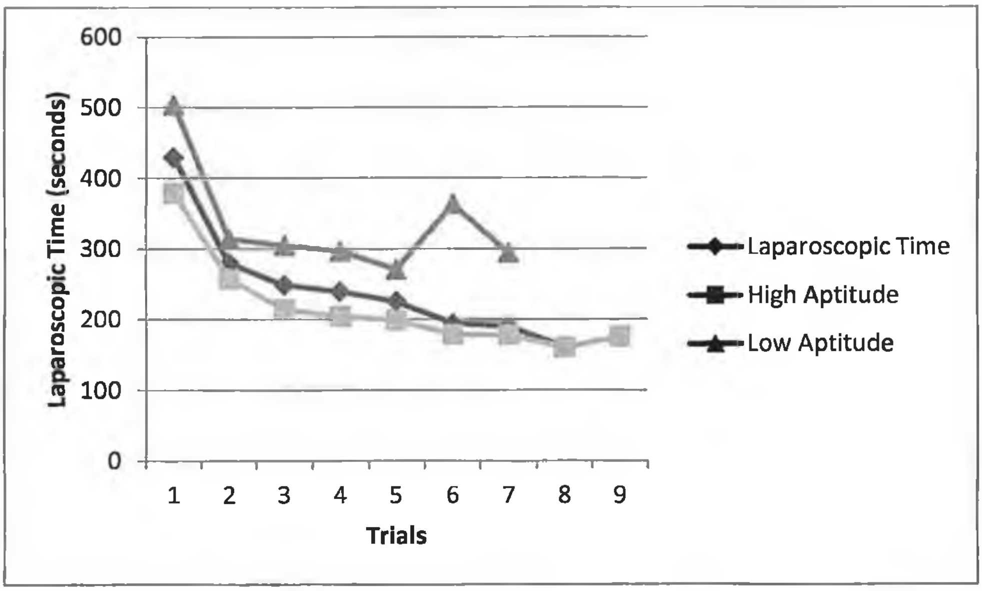
	Visual Spatial		Psychomotor		Depth Perception	
Laparoscopy	**R**	**[p value]**				
Time	0.536	[p = 0.04]	-	[NS*]	-	[NS]
Path Length	0.942	[p = 0.017]	-	[NS]	-	[NS]
Smoothness	0.664	[p = 0.036]	-	[NS]	-	[NS]
Error Score	-	[NS]	-	[NS]	0.561	[p = 0.01]
Endoscopy						
Endobubble	0.981	[p = 0.019]	-	[NS]	-	[NS]
Colonoscopy	0.858	[p = 0.029]	-	[NS]	0.612	[p = 0.002]

Table 4.13 Correlation between Number of Trials Taken to Reach Proficiency & Aptitude; **[NS* = non-significant]**

4.4.15 Learning Pathways in Basic MIS Tasks

Based on our findings we developed some preliminary learning curves for the basic MIS surgical tasks (figure 4.7).





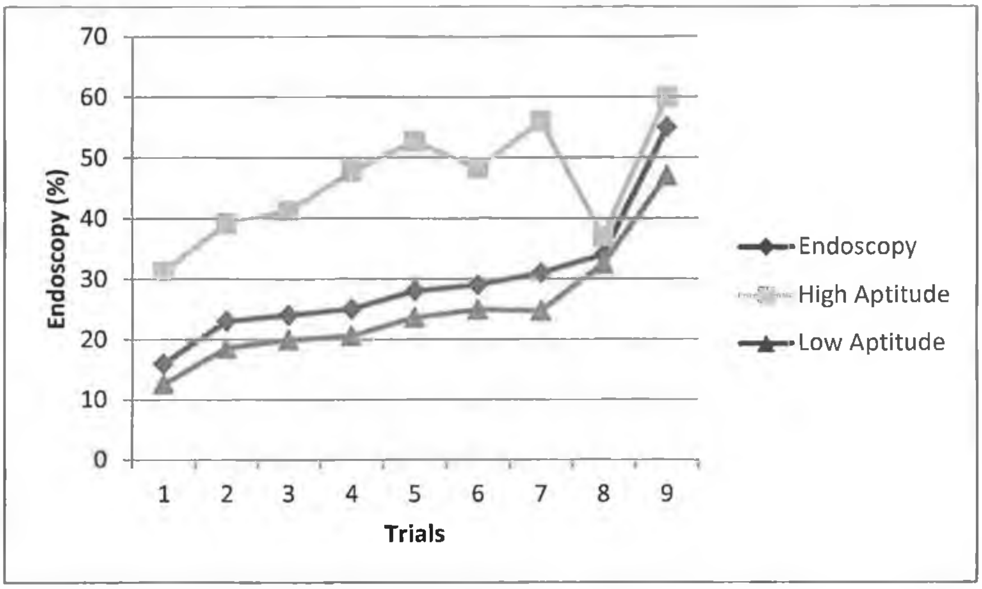


Figure 4.7 Learning Curves for Basic MIS Tasks; On each graph there are three learning curves. The curve labelled laparoscopy time/motion or endoscopy represents the standard learning curve where aptitude has not been considered. The other two curves represent the performance over time of those with high & low aptitude levels.

4.5 Discussion

In this chapter we evaluated the effect of aptitude on basic minimally invasive surgical performance across three levels of surgical experience (novice, junior trainee, senior trainee). We also aimed to evaluate whether aptitude impacts on the ability of the novice trainee to reach a predefined proficiency level.

We evaluated aptitude across a spectrum of surgical experience levels. The results show that overall there was no significant difference in aptitude distribution (visual spatial & psychomotor) across the three levels of experience. This demonstrates that our sample was sufficiently heterogeneous with respect to visual spatial and psychomotor aptitude and thus was reassuring for this study as we wished to investigate the relationship between various levels of aptitude and performance. The only exception to this was the test of depth perception (PicSOr) where the HST's scored higher than the BST's, who in turn scored higher than the medical students. This is similar to the findings in the previous chapter where we found that surgical trainees had a higher level of depth perception than a group of controls.

There was a significant difference in surgical performance on the minimally invasive tasks based on experience level, with those trainees in higher training performing better than those trainees with basic experience who in turn performed better than the novice group. This pattern is to be expected and adds support to the construct validity of the basic MIS tasks and the metrics generated by the simulators (Pellen et al, 2009).

Of interest we found that there was a significant gender difference in two of the aptitudes measured. Females scored significantly higher on the psychomotor test and males scored significantly higher in the test of depth perception. Our findings support previous studies that have demonstrated a similar pattern for both these tests (Bornstein, 1985; Thompson et al, 1987; Ruff & Parker, 1993; Maccoby & Jacklin, 1974).

The primary aim of this study was to investigate whether there is a correlation between aptitude and performance. The results demonstrate that there is an association between aptitude level and performance outcomes in the basic minimally invasive skills assessed. This is in keeping with previous studies that have looked at certain surgical skills in isolation with smaller sample sizes, for example in; laparoscopic tasks (Hassan et al, 2007; Hedman et al 2006), endoscopic tasks (Enochsson et al, 2006; Ritter et al, 2006), endovascular tasks (Van Herzeele et al, 2010), knot tying (Brandt & Davies, 2006) and more complex open tasks (Wanzel et al 2003).

In our study the association between aptitude and performance was greatest in frequency and most consistent in the group of medical students. Visual spatial, psychomotor and depth perception aptitude were positively associated with performance on all the basic MIS tasks. In the group of BST's there was also significant and positive associations found. However, not all of the various aptitudes correlated significantly with all the MIS tasks. Again there were positive associations found for group A & B of the HST subjects, but to a lesser extent than in the case of the BST trainees. It is interesting to note that in the HST group, the results differentiated between those trainees in group A, that had less surgical experience than those in group B. The results suggest that aptitude has the strongest association with performance when the subject is a novice and is beginning to learn a new task. It seems that this relationship diminishes as the trainee increases in experience. Our findings support those of Wanzel et al (Wanzel et al, 2003). They found a positive association between aptitude and performance in their novice group of subjects but not for their group of expert surgeons. They suggested that practice and experience may supplant the influence of aptitude on performance over time. As a follow on from these results we decided that it would be pertinent to further examine this theory by looking at the relationship between aptitude and training.

Although the association between aptitude and performance changes as experience is gained, aptitude still has a role. In the HST's it was frequently the more technically demanding tasks that displayed a positive association (laparoscopy; sharp dissection, endoscopy; endobubble). It would be interesting to investigate the relationship between aptitude and performance outcomes in a more technically demanding MIS task in a group of surgical trainees who have sufficient experience in basic MIS techniques. This is explored further in Chapter 5.

When we gave a set of predefined performance goals to a group of surgical novices and measured their performance outcomes on both basic laparoscopic and endoscopic tasks we found that aptitude did seem to play a significant role. All subjects did improve over time but some subjects improved quicker than others and other subjects started at a different baseline point than others, with the result that they reached the predefined proficiency levels faster. Those subjects that achieved the predefined proficiency levels in laparoscopy had higher levels of visual spatial, psychomotor and depth perception aptitude and those that reached the proficiency level in endoscopy had a higher level of depth perception aptitude. Visual spatial and depth perception aptitude also correlated with the number of trials taken to reach proficiency, with those candidates having a higher level of aptitude taking fewer repetitions. Again our findings corroborate those of previous studies (Van Herzeele et al, 2010; Stefanidis et al, 2006, Ritter et al, 2006). Another study assessing aptitude looked at three experience groups (novices intending on a career in surgery, trainee surgeons, expert surgeons) and compared them to a normative population sample (Boom-Saad et al, 2008). They found that all three experience groups had a significantly higher level of aptitude than the population norm. They concluded that ability is present at baseline before training rather than occurring as a result of training.

In conclusion aptitude has a role in predicting the baseline ability of surgical novices in basic MIS tasks. It also has an effect on ability to reach predefined proficiency goals and training duration in basic laparoscopic and endoscopic tasks in surgical novices. Finally the influence of aptitude on predicting baseline ability seems to diminish with increasing surgical experience, however, its impact has the potential to persist when a task is more technically demanding even when the subject has significant surgical experience.

Chapter 5

Aptitude Assessment and Performance Outcomes in Advanced Minimally Invasive Surgical Tasks

5.1 Introduction

Despite the many advantages for the patient, laparoscopic surgery is a technically demanding field and is associated with a significant learning curve (Tekkis et al, 2005; Schlata et al, 2001).

As the surgical procedure becomes increasingly complex so too do the learning challenges for the surgeon in laparoscopic techniques. In particular a protracted learning curve has been demonstrated in advanced laparoscopic techniques such as laparoscopic colectomy.

Laparoscopic colectomy was first described in the literature in 1991 (Jacobs et al, 1991). The benefits of laparoscopic resection are well recognised (Leung et al, 2004; Zhou et al, 2004; Breukink et al, 2006). There have also been reports of a reduction in cost associated with laparoscopic colectomy (Braga et al, 2007; Ridgeway et al, 2007; Delaney et al, 2003). There is now plenty of evidence supporting the oncological safety and efficacy of laparoscopic colorectal surgery (COST, 2004; Veldkamp et al, 2005; Jayne et al, 2007). In 2006, NICE recommended that laparoscopic resection should be performed as an alternative to open resection in individuals with colorectal cancer in whom both open and laparoscopic approaches are suitable (NICE TA105, 2006).

However the disadvantage of laparoscopic colorectal resection lays in the difficult and steep learning curve a trainee must surpass in order to become proficient in this technique. In laparoscopic colorectal surgery the number of necessary resections required to overcome the steepest part of the learning curve has been estimated to be between 15 and 62 cases (Tekkis et al, 2005; Simons et al, 1995). Operative time is one of the main parameters effecting laparoscopic colectomy performance. A greater length of time has been demonstrated to be required to perform a laparoscopic colectomy when compared to a traditional open approach (COST, 2004). This is a factor that reflects the technical difficulty of the procedure.

Another difficulty encountered when learning more complex laparoscopic procedures is the lack of opportunity afforded trainees to perform these surgeries on patients (Charron et al, 2007). It is more difficult to train surgeons in laparoscopic techniques using the apprenticeship model. Due to the nature of laparoscopic surgery the teaching surgeon cannot directly guide the hands of the trainee nor can they intervene as easily if a problem arises.

The length of time it takes to perform a laparoscopic colorectal resection in the early part of the learning curve is a factor affecting trainees. Training in surgery has been further impaired by changes in working hour regulations and ethical considerations about subjecting the patient to the steepest part of the learning curve (Kennedy, 2001; Kohn et al, 1999; EWTD, 2004). Also both the NICE and ACPGBI guidelines recommend that laparoscopic resection for colorectal cancer only be carried out by surgeons that have undergone preceptorship training (ACPGBI, 2007; NICE TA105, 2006).

Therefore the current challenge in surgical education is to ensure that surgical trainees are afforded all the appropriate opportunities to learn and practise minimally invasive techniques. This should extend from the very basic skills such as learning to coordinate and manipulate laparoscopic instruments to the teaching of the steps and potential pitfalls associated with advanced procedures such as laparoscopic colectomy. Over the last decade the need for the trainee surgeon to master advanced laparoscopic skills such as laparoscopic colectomy combined with a decrease in the number of cases afforded the resident has increased the importance of simulators and other teaching modalities such as specially designed courses. This has resulted in the establishment of simulation laboratories and curricula for learning laparoscopic skills (Peters et al, 2004; Satava et al, 2001). Guidelines have also been published for the running of laparoscopic colectomy courses (Fleshman et al, 2006).

The skills required to perform advanced laparoscopic procedures such as laparoscopic colectomy are desirable for future colorectal surgeons. As a result it is worthwhile to give consideration to other factors that may have an influence on the trainee's ability to learn complex laparoscopic procedures. These include the evaluation of aptitudes such as psychomotor and visual spatial aptitude. These innate abilities have been previously shown to impact on surgical ability (Stefandis et al, 2006; Ritter et al, 2006). We have also demonstrated in Chapter 4 that aptitude plays an important role in learning basic minimally invasive techniques particularly when a task is novice to a trainee. We plan to explore the role that aptitude has in learning advanced minimally invasive skills.

Other factors, such as, the influence of assisting or observing on learning and prior surgical experience on learning advanced laparoscopic procedures need to be addressed in an objective manner also. Parameters including the simulator generated metrics, tray errors scored in a blinded manner by colorectal experts and results from a MCQ test will be used as performance outcomes as they are all objective measures.

The primary aim of this study was to investigate the impact of aptitude, in particular visual spatial and psychomotor aptitude, on the ability to perform a laparoscopic sigmoid colectomy during an advanced laparoscopic simulator based teaching course. The secondary aims of the study were to explore whether directly observing and assisting during the procedure or prior surgical experience impacted upon the performance of a laparoscopic sigmoid colectomy.

5.2 Objectives

5.2.1 Hypothesis Underlying the Objectives

Psychometric factors that have been identified as important in minimally invasive surgery are visual spatial, depth perception and psychomotor aptitude. Everybody's pattern of aptitude is different and this we believe has an impact on the learning curve and on an individual's ability to perform minimally invasive skills.

As a follow on from examining the influence of aptitude on performance in basic MIS skills we aimed to evaluate the impact of these same psychometric factors on performance in an advanced procedure. Prior studies in this field have focused on basic skills or a single skill. No study has determined the effect of aptitude on a complete and advanced procedure such as a sigmoid colectomy. We aimed to determine the pattern of aptitude that affects laparoscopic sigmoid colectomy performance.

Trainees that learn advanced MIS techniques have prior experience in basic and intermediate MIS skills. It therefore is reasonable to expect that an individual's prior operative experience in MIS should impact on their ability to perform an advanced procedure. The influence of prior experience in open techniques could also be predicted to affect ability to perform an advanced MIS procedure. Case volume has historically been accepted as a marker of performance ability. In the literature studies have reported associations between case volume and patient morbidity and mortality. These are performance outcomes however that can be confounded by uncontrollable factors such as pre-operative morbidities and patient selection. However, no studies have examined case volume or operative experience in the setting of purely objective outcomes such as the metrics generated by a simulator. We aimed to assess the influence of operative experience on objective measures of performance.

Directly observing or assisting a complex procedure allows a trainee to become familiar with the potential pitfalls and errors that can occur. We aimed to assess the influence of assisting or observing on performance outcomes.

Self-awareness and insight into personal ability is an important trait. Learning in the postgraduate setting is very much self-directed and therefore a trainee needs to be able to accurately predict their own ability in order for learning to be successful. Over estimating or under estimating skill ability can have a negative impact on the learning curve (Kruger et al, 1999) and therefore we aimed to assess the level of insight the trainees had in performing laparoscopic colectomy.

5.2.3 Detailed Objectives

Objective 1:-To evaluate the relationship between aptitude and performance outcomes in an advanced minimally invasive technique.

We demonstrated in Chapter 4 that aptitudes relevant to minimally invasive techniques (psychomotor, visual spatial and depth perception) play an important role in learning basic minimally invasive skills. We wished to extend our evaluation of the role of these psychometric aptitudes in MIS to advanced techniques. Through an augmented reality simulator based course that was designed to specifically teach the steps of a laparoscopic colectomy we aimed to measure trainee performance using the objective metrics generated by the simulator, MCQ results and tray errors. We also aimed to measure the psychomotor and visual spatial aptitude of the trainees. We then aimed to determine the relationship between these psychometric parameters and the performance outcomes to evaluate whether an individual's aptitude impacts on the initial learning curve in an advanced MIS procedure.

Objective 2:- To investigate the influence of prior operative experience on performance outcomes in an advanced minimally invasive technique.

It stands to reason that an individual's prior operative experience, both with open surgery and minimally invasive techniques, has a positive influence on performance in specific MIS procedures. We aimed to quantify the prior operative experience in both open and MIS, basic and more complex operative procedures of the trainees participating in the laparoscopic colectomy course and to investigate the influence of this prior operating experience on performing a laparoscopic sigmoid colectomy.

Objective 3:- To determine if there is a relationship between observing/assisting and performance outcomes in an advanced minimally invasive technique.

There has been limited research into the relationship between observing or assisting (for example camera holding) and performance in MIS. We aimed to determine if those candidates that first observed or assisted another trainee performing a laparoscopic colectomy did significantly better than those trainees that did not observe or assist the same procedure. We examined two of the performance outcomes; tray errors and simulator metrics to determine this.

Objective 4:- To evaluate trainee's ratings on the perceived technical difficulty of an advanced minimally invasive technique.

We aimed to assess the trainee's perception of the technical difficulty in performing a laparoscopic colectomy pre and post performing the procedure themselves. We also aimed to evaluate their insight into their own personal ability along with their opinion on how relevant psychometric aptitude is to minimally invasive techniques.

5.3 Materials and Methods

5.3.1 Recruitment of Participants

The simulator based laparoscopic colectomy course was aimed at surgical trainees in year three and above of higher surgical training. The course was advertised on the RCSI website. In addition to this surgical trainees in year three and above of higher surgical training were emailed as a group to further advertise the course. The course was held over a one day period at the National Surgical Training Centre in RCSI.

The candidates gave written informed consent allowing all data collected throughout the course to be used for research purposes. It was made clear that all information gathered would be stored and presented in an anonymous format.

5.3.2 Participant Demographics

The course could accommodate only ten participants. Candidates were enrolled in the course on a first come first serve basis.

In order to meet the inclusion criteria candidates were required to have prior experience in laparoscopic techniques. They were required to have performed greater than twenty basic laparoscopic and intermediate laparoscopic procedures and less than five advanced laparoscopic procedures. The definition of what was considered a basic, intermediate and advanced laparoscopic procedure is outlined in table 5.1. They were excluded if they had performed greater than five advanced laparoscopic procedures without supervision. As a result the course participants were considered to be novice with respect to advanced laparoscopic techniques, in particular to laparoscopic sigmoid colectomy.

Basic Laparoscopic Procedures	Diagnostic Laparoscopy Laparoscopic Appendicectomy
Intermediate Laparoscopic Procedures	Laparoscopic Cholecystectomy Laparoscopic Inguinal Hernia Repair
Advanced Laparoscopic Procedures	Laparoscopic Nissan's Fundoplication Laparoscopic Splenectomy Laparoscopic Colectomy

Table 5.1 Breakdown of Basic, Intermediate & Advanced Laparoscopic Procedures

5.3.3 The Simulator Used

The ProMIS simulator (Haptica, Ireland) was used for the course. This simulator has been described previously in chapter 2. It is a hybrid of virtual reality modules and modules with haptic feedback and therefore is an augmented reality simulator. It consists of a box trainer that is connected to a laptop where the graphics are displayed.

The module used for the course was the laparoscopic colectomy task. This module has been previously demonstrated to have content and construct validity (Neary et al, 2008). The module requires the addition of a synthetic anatomy tray (Limbs and Things, Bristol, UK). The module consists of nine steps (table 2.3). There are two modes that can be used for the laparoscopic colectomy module – "teach me" or "test me". The "teach me" mode gives both verbal instructions for each step and also onscreen graphical demonstrations. This mode also contains short video clips of the particular step being performed in the real life setting, thus promoting clinical correction. In the "test me" mode the onscreen graphical cues are removed. The "test me" mode was used for the duration of the course.

The ProMIS simulator was also used for the warm up session. During the warm up session the candidates performed the basic laparoscopic tasks described previously in Chapter 2. These were the locating and coordination task, the object positioning task and a sharp dissection task.

5.3.4 Aptitude Assessment

Visual spatial aptitude and psychomotor aptitude were assessed at the start of the course. These aptitudes and their relevance to minimally invasive techniques have been described in Chapter 2.

Two different aspects of visual spatial aptitude; spatial orientation and spatial scanning were examined. Spatial orientation was assessed using the card rotations test and spatial scanning was assessed using the map planning test. Both of these tests were taken from the Kit of Factor Referenced Cognitive Tests (Ekstrom et al, 1976). Psychomotor aptitude was assessed using the Grooved Pegboard (Dikmen et al, 1999).

5.3.5 Course Procedure

The course was divided into three parts; a didactic session, a warm up session on the simulators and performance of laparoscopic sigmoid colectomy.

The didactic session consisted of a series of lectures given by the expert faculty. Firstly there was an overview of the anatomy of the sigmoid colon, and then the steps of the procedure were taught. This was followed by a lecture that highlighted the potential critical errors associated with each step of the procedure. Video slides of a real life operation were used to augment the teaching session. The trainees' knowledge was tested at the end of the didactic session by a ten question MCQ.

Following the didactic teaching the trainees were allowed a warm up session on the laparoscopic simulators. The purpose of the warm up session was to allow the candidates to become familiar with the simulator and to practice instrument handling. Each trainee had the opportunity to perform three of the core basic modules on the ProMIS; the locating and coordination task, the object positioning task and the sharp dissection task. At this stage the candidates were also shown how to use the harmonic scalpel and the circular and liner staplers.

Finally a laparoscopic sigmoid colectomy was demonstrated on the simulator by one of the expert faculty. The candidates then performed a laparoscopic sigmoid colectomy. They operated in pairs with one trainee acting as the assistant and observer for the first tray and the roles were reversed for the second tray.

In total there were five operating stations. At each station there was a simulator, two trainees and one faculty member.

5.3.6 Performance Assessment

The MCQ results of the candidates were recorded.

Objective metrics generated by the simulator for both the warm up tasks and for each step of the laparoscopic colectomy were recorded. These metrics are time (minutes), instrument path length (millimetres) and instrument path smoothness (velocity).

The anatomy trays were assessed by blinded experts at the end of the course. The trays were scored on a set of thirteen predefined and previously validated errors (Neary et al, 2008).

5.3.7 Statistical Analysis

Data was analysed using the SPSS 18.0 software (SPSS Inc, Chicago, Ill). The data was assessed for normality of distribution using the one sample Kolmogorov Smirnov test. It was determined that it was acceptable to retain the null hypothesis. Pearson's correlation coefficient was used to determine whether there was a relationship between performance on the simulators and the aptitude scores and between the warm up session and performance on the laparoscopic colectomy tray. The paired-samples t-test was used to investigate the difference in mean scores on the pre and post-training questionnaire. The independent-samples t-test was used to evaluate the relationship between assisting and operating. One-way ANOVA was used to determine the association between operative experience and performance on the laparoscopic colectomy. A p value of <0.05 was considered significant.

5.4 Results

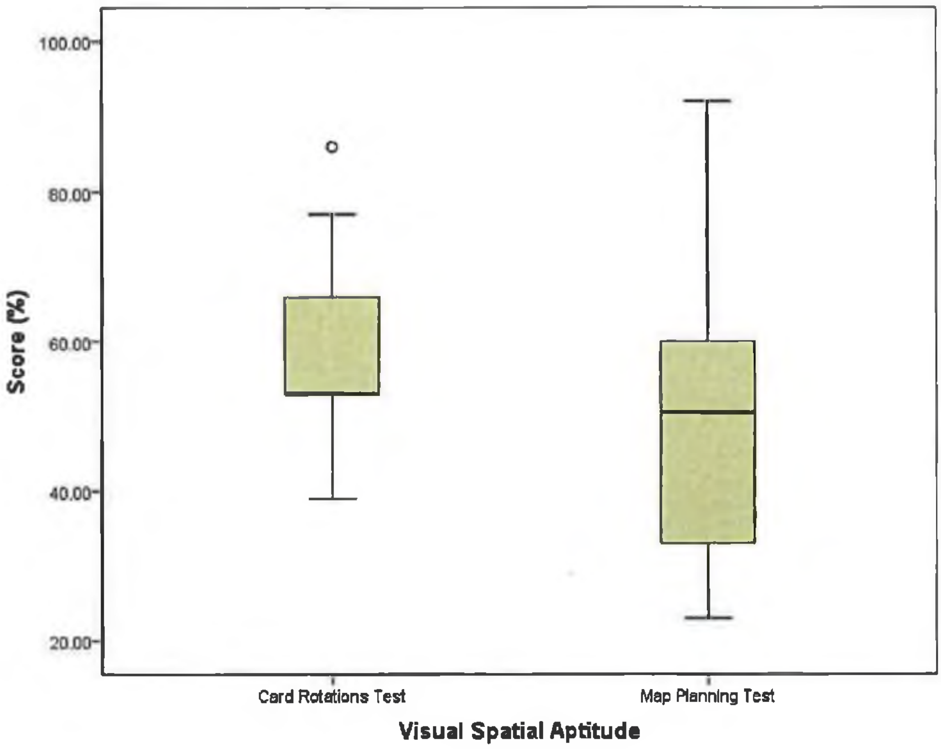
5.4.1 Participant Demographics

Ten male surgical registrars participated in the course. Demographics for the participants are displayed in table 5.2.

	Range	Mean	Standard Deviation
Training Year	3-6	4.9	1.52
Age	32-40	35	3.7
Glove size	6.5-8.5	7.45	0.47
Corrected vision (Y:N)	8:2		

Table 5.2 Demographic Details of the Course Participants

The range of scores, mean scores and standard deviations are shown for the aptitude assessments, the warm up session and performance on the laparoscopic sigmoid colectomy in figure 5.1, 5.2 & 5.3.



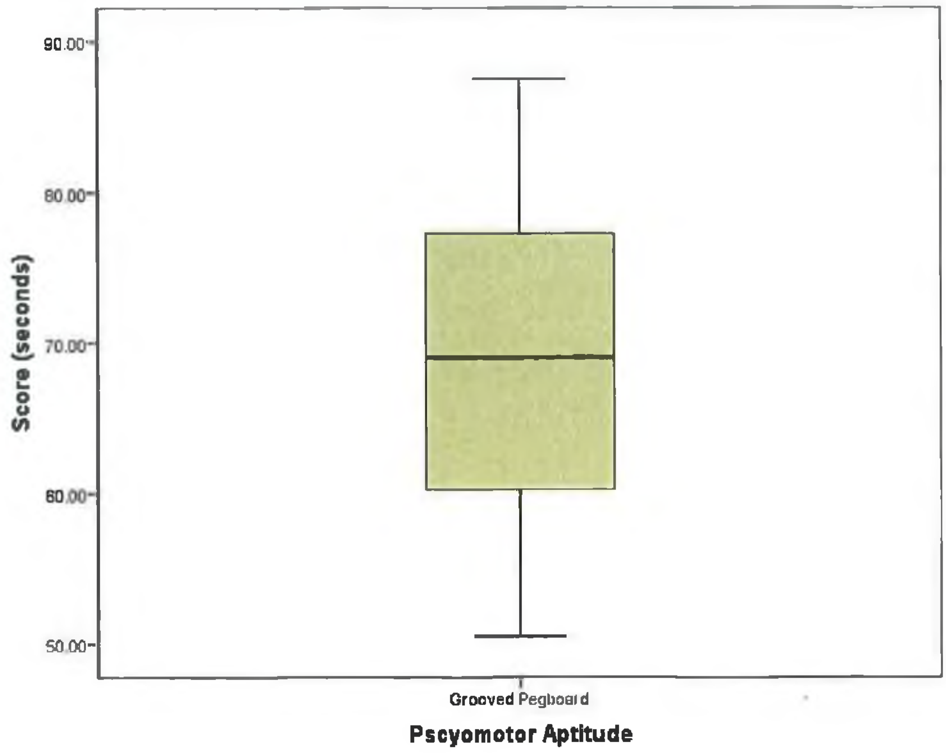
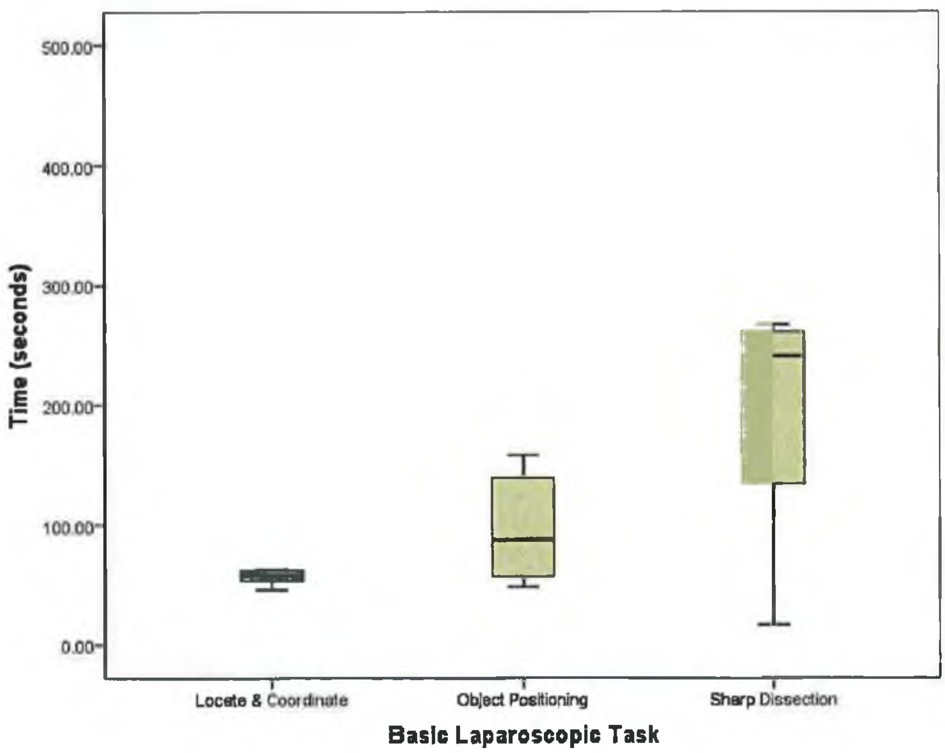


Figure 5.1 Distribution of Aptitude Scores; These boxplots demonstrate the range of scores on the two visual-spatial tests of aptitude and the psychomotor test of aptitude.



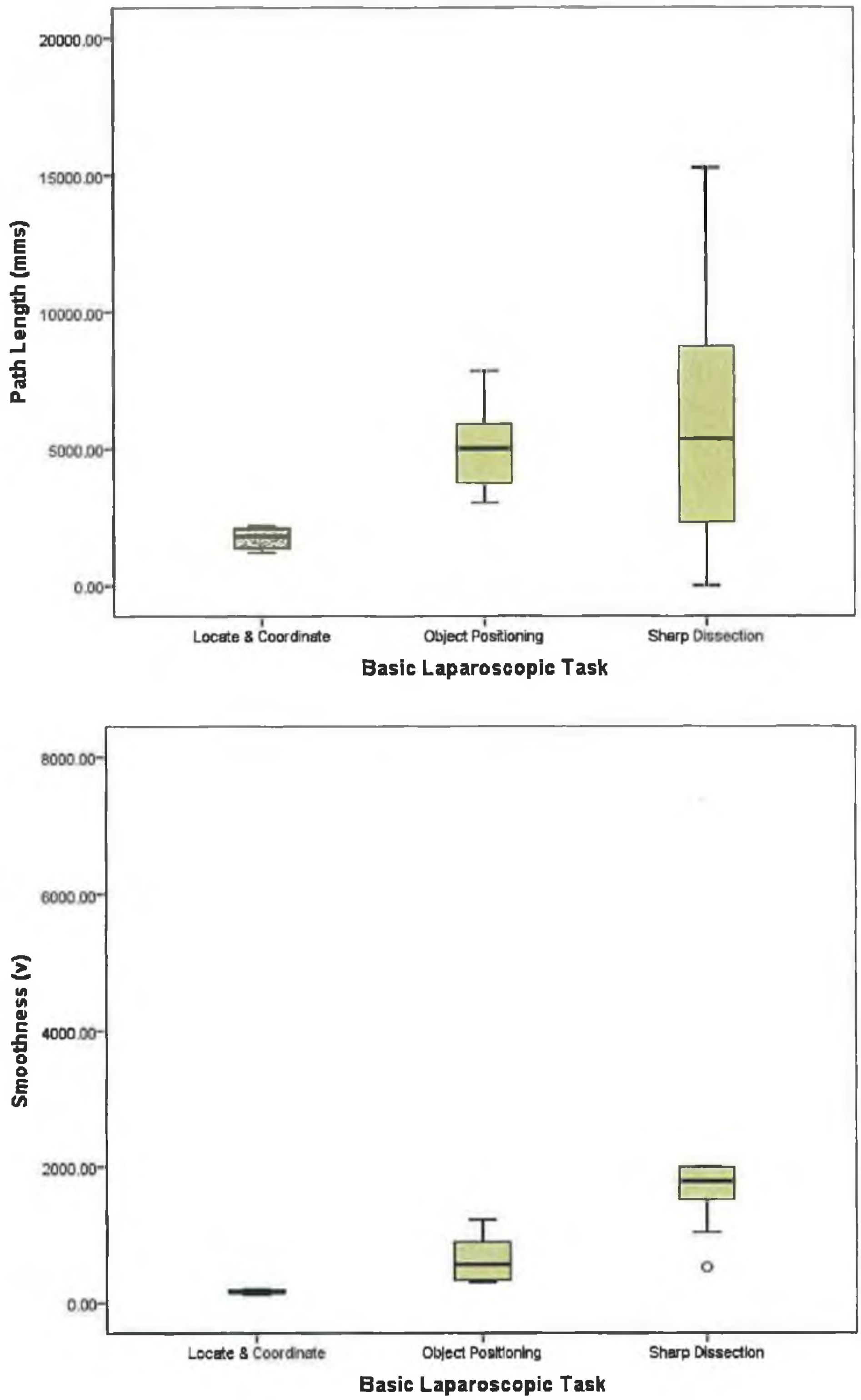
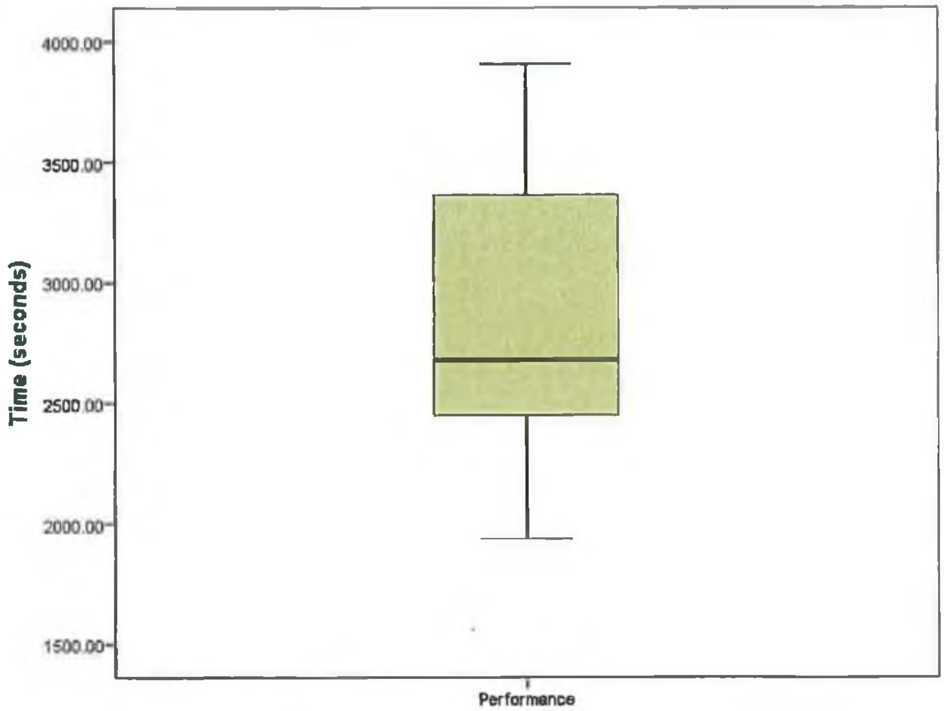
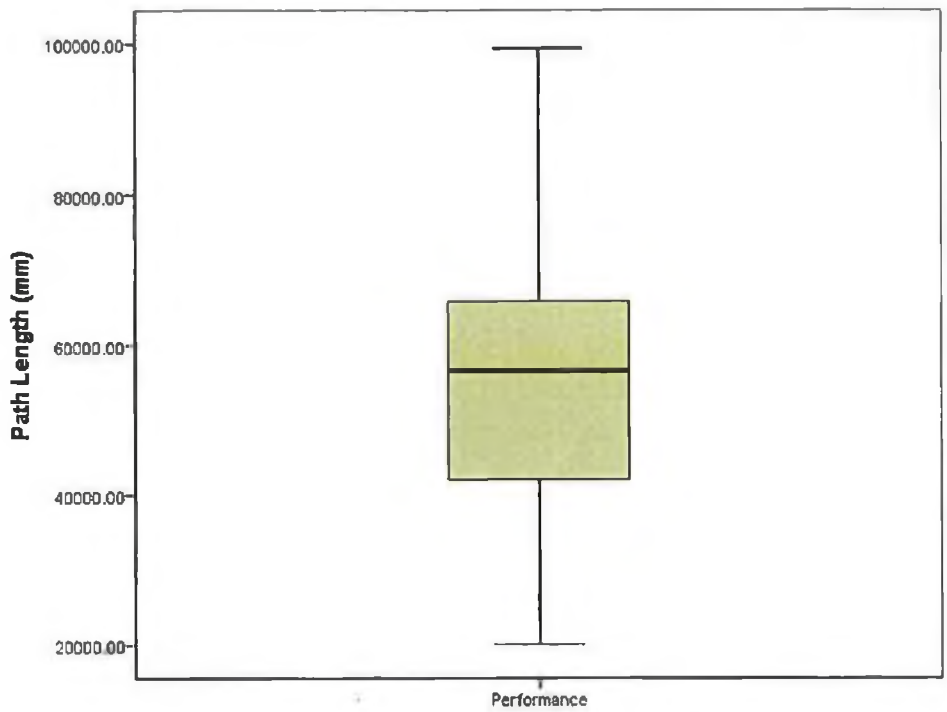


Figure 5.2 Performance on the Basic MIS Tasks; The above boxplots demonstrate performance on the basic MIS laparoscopic tasks in terms of time & motion analysis.



Laparoscopic Sigmoid Colectomy



Laparoscopic Sigmoid Colectomy

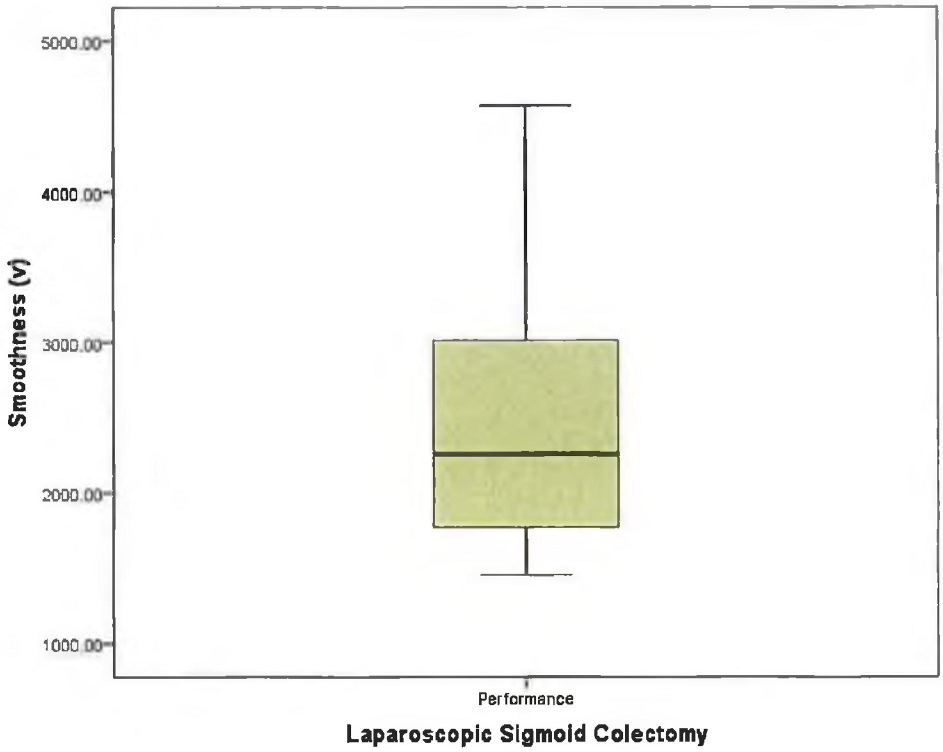


Figure 5.3 Performance on Laparoscopic Sigmoid Colectomy; The above boxplots demonstrate performance on laparoscopic sigmoid colectomy in terms of time & motion analysis.

5.4.2 Aptitude and Basic Laparoscopic Skills Performance

Pearson's correlation coefficient was used to determine the relationship between aptitude and performance on the basic laparoscopic skills (or warm up session). We found a significant correlation between aptitude and surgical performance (table 5.3).

Visual spatial aptitude correlated significantly with performance on both the locating and coordination task and the sharp dissection task. Psychomotor aptitude correlated significantly on the object positioning warm up task. All of the associations had a correlation coefficient of $r > 0.65$, which is considered to be a strong relationship. The results suggest that there is a relationship between aptitude and performance outcomes as trainees that scored higher on the aptitude assessments performed better on the warm up tasks.

5.4.3 Aptitude and Laparoscopic Sigmoid Colectomy Performance

Pearson's correlation coefficient was used to investigate the relationship between aptitude and performance on the laparoscopic sigmoid colectomy. We found a significant correlation between aptitude and surgical performance (table 5.3).

Aptitude	Laparoscopic Task	Correlation coefficient (R)	p value
Visual Spatial	**Locate & coordinate:**		
	Time	0.77	0.04
	Path Length	0.78	0.04
	Smoothness	0.77	0.03
	Object Positioning:		
	Time	-	NS*
	Path Length	-	NS
	Smoothness	-	NS
	Sharp Dissection:		
	Time	-	NS
	Path Length	-	NS
	Smoothness	0.69	0.04
	Colectomy:		
	Time	-	NS
	Path Length	-	NS
	Smoothness	0.77	0.04
	Tray Errors	0.67	0.04
Psychomotor	**Locate & coordinate:**		
	Time	-	NS
	Path Length	-	NS
	Smoothness	-	NS
	Object Positioning:		
	Time	0.77	0.009
	Path Length	0.81	0.005
	Smoothness	0.82	0.004
	Sharp Dissection:		
	Time	-	NS
	Path Length	-	NS
	Smoothness	-	NS
	Colectomy:		
	Time	0.87	0.005
	Path Length	-	NS
	Smoothness	0.84	0.03
	Tray Errors	-	NS

Table 5.3 Correlation between Aptitude & Laparoscopic Performance

Visual spatial aptitude correlated significantly with performance on laparoscopic colectomy path smoothness. Visual spatial aptitude also correlated significantly with the number of tray errors. Psychomotor aptitude correlated significantly with both performances on laparoscopic sigmoid colectomy time and path smoothness. The associations had a correlation coefficient of $r > 0.7$, which again is considered to be a strong relationship. The results again suggest that there is a relationship between aptitude and performance on the laparoscopic sigmoid colectomy as trainees that scored higher on the aptitude assessments performed better on the laparoscopic colectomy.

5.4.4 Correlation between Basic Laparoscopic Skills and Laparoscopic Colectomy

Pearson's correlation coefficient was used to examine the relationship between performance on the basic laparoscopic skills and performance on the laparoscopic colectomy. We found that performance on the warm up session (basic laparoscopic skills) correlated significantly with performance parameters on the laparoscopic colectomy (table 5.4). This was the case for path length and path smoothness but there was no significant association found between time on the laparoscopic colectomy and performance on the basic laparoscopic skills.

Laparoscopic Colectomy	**Basic Laparoscopic Task**	**Correlation coefficient (R)**	**P value**
Path Length	Locating & Coordination	0.88	0.04
	Object Positioning	-	NS
	Sharp Dissection	0.92	0.003
Path Smoothness	Locating & Coordination	-	NS
	Object Positioning	0.77	0.04
	Sharp Dissection	-	NS

Table 5.4 Correlation between Basic Laparoscopic Skills & Laparoscopic Colectomy Performance

5.4.5 MCQ Result and Laparoscopic Colectomy Performance

Pearson's correlation coefficient was used to determine the relationship between performance on the MCQ test at the end of the didactic session and performance on the laparoscopic colectomy module. It was found that there was a significant correlation; with $r = 0.85$ ($p = 0.008$), between the MCQ result and path length performance on the laparoscopic colectomy tray.

5.4.6 Tray Errors and Laparoscopic Colectomy Performance

Tray errors were assessed by two experts that were blinded as to the identity of the trays. The experts used a set of predefined, validated thirteen errors (Neary et al, 2008). The range of tray errors was 2-6, mean number was 3.9, and the standard deviation was 3.1. Inter-rater reliability between the two assessors was determined using Cronbach's alpha and was found to be 0.79.

We found a significant relationship between the number of tray errors and time to complete the laparoscopic colectomy. This was assessed using Pearson's correlation coefficient where $r = 0.83$, $p = 0.001$. There was no significant relationship found for the other simulator metrics of path length and smoothness.

5.4.7 Prior Experience and Performance on Laparoscopic Colectomy

One way ANOVA was used to determine the association between operative experience and performance on laparoscopic sigmoid colectomy. The results demonstrated a significant association between prior experience and performance on the laparoscopic colectomy tray. Those trainees that reported having performed a greater number of open sigmoid colectomies ($p = 0.04$), basic laparoscopic procedures ($p = 0.02$) and intermediate laparoscopic procedures ($p = 0.03$) performed better on the laparoscopic colectomy tray in terms of path length, path smoothness and number of tray errors when compared to those trainees that reported having less surgical experience in these areas.

We found no significant relationship between aptitude and prior level of experience.

5.4.8 Assisting/Observing and Laparoscopic Colectomy Performance

The independent-samples t-test was used to determine the relationship between assisting or observing and laparoscopic colectomy performance. The results demonstrated that there was no significant difference in performance between those trainees that had assisted first on the laparoscopic sigmoid colectomy, thus having the opportunity to observe the procedure along with the potential pitfalls and errors, and those trainees that operated first. This was true for the simulator generated metrics of time, path length and smoothness and also for the number of tray errors.

5.4.7 Trainee Insight and Laparoscopic Colectomy Performance

The trainees were asked to complete a pre-training and post-training questionnaire that rated the technical difficulty of performing an uncomplicated laparoscopic sigmoid colectomy. Their answers were analysed using the paired-samples t-test for repeated measures. There was a significant decrease in the mean score from the pre-training rating to the post-training rating (p = 0.025) with trainees rating the technical difficulty of performing a laparoscopic colectomy as less on the post-training questionnaire. There was no significant difference in the mean score on how the trainees rated their own personal ability to perform a laparoscopic colectomy unsupervised following the course (p = 0.11). There was no significant relationship found between how the trainees rated their own ability to perform a laparoscopic colectomy and their actual performance.

Prior to commencing the course the trainees were also asked to rate, using a five point Likert scale, what they felt the importance of aptitude is in relation to laparoscopic surgery. Greater than 90% rated aptitude as important, with 64% of these rating it as very important. The remaining 10% rated innate aptitude as somewhat important for laparoscopic surgery. None of the trainees rated innate aptitude as not important for minimally invasive surgery.

5.5 Discussion

Our primary objective was to evaluate the effect of aptitude on performance on the simulator. The results demonstrate that psychometric aptitude (visual spatial and psychomotor) correlated significantly with both performance on the warm up session and performance on the laparoscopic sigmoid colectomy. This shows that those trainees with a higher visual spatial and psychomotor aptitude performed better than those trainees with a lower aptitude.

We also demonstrated that the performance on the warm up session correlated significantly with performance on the laparoscopic colectomy. These results are predictable as those trainees that outperformed others on the warm up session would have been expected to perform better on the laparoscopic colectomy tray also.

Our results are quite novel as no prior study has demonstrated a significant relationship between psychometric aptitude and performance of an advanced laparoscopic procedure. Most studies have focused on basic skills or specific tasks and none have reported a significant association for all the steps of a complete procedure (Stefandis et al, 2006; Aora et al, 2005; Keehner et al, 2004). The correlations we have shown also demonstrate that the relationship is a relatively strong one (range: r = 0.67 – 0.87).

The results have demonstrated that although the trainees had experience in basic and intermediate laparoscopic techniques when it came to learning a more advanced skill set (laparoscopic colectomy) their fundamental visual spatial and psychomotor aptitudes still played a role. This indicates that even with experience in laparoscopy, when learning a new technique aptitude influences ability to perform technical tasks.

The second objective was to evaluate the relationship between prior operative experience and performance. Our results demonstrate that previous experience in both open surgery and laparoscopy had a significant impact on laparoscopic colectomy performance in terms of path length, smoothness and number of tray errors. Time was not a significant parameter. These results stand to reason as one would expect the greater the experience in laparoscopic techniques the easier it would be to perform a more complex procedure in comparison to a trainee that had more basic laparoscopic operative experience. In the case of greater prior open sigmoid colectomy experience, possibly the advantage provided to the trainee, was a greater knowledge and understanding of the procedural steps, regional anatomy and a greater familiarity with the use of the instruments including the stapling devices. Our results support those of previous studies (Essani et al, 2009; Leblanc et al, 2010a).

It is interesting that the performance outcome measures of path length and smoothness were significantly associated with experience. This was also true for the warm up session where the results demonstrated a correlation between both these parameters and laparoscopic colectomy performance. Time was not a significant parameter indicating that when compared to motion analysis it is not as good a quality marker. However, one could interpret this, as the outcome measure of time having no significance until a later stage of the learning curve.

It has been shown that teaching trainees basic skills in laparoscopy before moving on to more advanced minimally invasive skill sets shortens the learning curve and is also associated with significant cost savings (Stefandis et al, 2010). Our results concur with these findings. There may be a role for ensuring that trainees demonstrate the ability to reach a predefined standard in basic laparoscopic skills before enrolling in an advanced training course. The question is whether a logbook assessment is adequate or whether formal assessment of ability should take place.

The third objective was to examine whether observing or assisting at an advanced laparoscopic procedure resulted in the trainee performing better than a trainee that was not afforded this initial opportunity. The results did not demonstrate that assisting or observing the procedure made a significant difference on performance. This may be due to the fact that the simulator generates metrics that indicate the level of skill of the operator and their technical performance in terms of instrument usage. These were assessed by time, path length and smoothness. This result perhaps is not surprising as psychometric aptitude is a set parameter and the reflected skill set therein should be independent of any observational tuition. This is in contrast to a study by Snyder and colleagues (Snyder et al, 2011). They found trainees that observed a minimally invasive procedure performed better than those trainees that watched an instructional video.

We found the same result for tray errors which was a little more unexpected. Although tray errors do reflect care in technique and instrument dexterity they also measure knowledge of the procedural steps and reflect familiarity with the potential pitfalls of the tray. Overall our results with respect to this could be said to add weight to the argument that in the case of laparoscopic surgery it is more challenging to teach a trainee using the apprenticeship model (Rosser et al, 1998; Choy & Okrainec, 2010). The trainee that assisted for the first case would have had the opportunity to note where the operating trainee made errors and had difficulty. This however did not seem to convey any advantage when it came to their performance.

Our results are in contrast to those of previous studies (LeBlanc et al, 2010b; Chmarra et al, 2007). Leblanc and colleagues found that both the objective metrics and error rate on the trays were better in the group of trainees that had observed or assisted initially. They concluded that familiarity with the simulator can play a role in performance (LeBlanc et al, 2010b). Only one other study has looked at the influence of camera holding and observation on performance. They again showed an improvement in objective metrics (Chmarra et al, 2007).

When we examined tray errors with respect to the objective performance outcomes of the simulator we found that it was time only that demonstrated a significant relationship with the error rate. We found that the longer the trainee took to complete the procedure the greater the number of errors they were likely to have made. This possibly reflects the fact that those trainees that took greater time did so because they were struggling with certain steps of the procedure and as a result made a greater number of errors. It is surprising however that the same relationship was not found for both path length and path smoothness but this could be due to the small nature of our sample size. The range and rate of errors found could be explained by the relative inexperience of the participants with respect to laparoscopic sigmoid colectomy but also by the less realistic replication of tissue consistency and anatomic planes when compared to real life.

Our last objective was to determine the degree of insight the trainees had into their performance ability. We found no association between the trainees self-rating of their performance ability and their actual performance outcomes. Having a level of insight or awareness of one's own ability is an important factor that impacts an individual's learning capacity (Kruger et al, 1999; Ward et al, 2003). A number of prior studies have reported a significant relationship between insight and actual performance in surgery (Ward et al, 2003; Wyles et al, 2010; Moorthy et al, 2006). Self-awareness is necessary for effective self-directed learning processes. A lack of insight could negatively impact on the learning curve in advanced laparoscopic techniques.

There is a future anticipated demand in the number of requests for advanced laparoscopic colorectal procedures now that any oncological doubts about the laparoscopic approach have been laid to rest (COST, 2004; Jayne et al, 2007; Veldkamp et al, 2005). As a result a teaching course like this one is an important training opportunity. Training outside of the real life operating theatre allows for a structured educational environment where the element of stress and time pressure is eliminated. Using simulators offers trainees the chance to operate on a physical tray with real surgical instruments that provide realistic tactile feedback. Aside from new psychomotor skills trainees need to be able to learn procedure specific skills. Again a specific training course allows for this.

Training on a simulator does not completely replicate training in real life or on another model, such as a cadaver or animal model (Palter et al, 2010). Prior studies have found that time to perform a complete colectomy on a simulator was reduced in comparison to real life operation time (Leblanc et al, 2010b). Nonetheless learning an advanced procedure on a simulator may allow the trainee gain competency in the specific steps before moving onto further training. In particular simulator training has an advantage for novices, where such training is limited in clinical practice. Simulators do have certain advantages over other training models. They cost less, are easier to transport, are reusable and are easier to access (Leblanc et al, 2010c). It has been proposed that sigmoid colectomy should be the first colectomy to be practised by the surgeon learning these techniques (Jamali et al, 2008).

However, it is clear that there are a number of difficulties associated with a simulation based course for teaching. Our course could only facilitate a small number of trainees (n = 10) as there were only five simulators available. Not many facilities have access to a number of simulators making it difficult to host a training course. The course also required a significant faculty number, where there was one trainer per simulation station. The faculty that participated did so because they had an interest in teaching and were willing to give significant time to the training program. For success, training courses rely on enthusiastic trainers, financial support and time commitment.

In the setting of simulation training for advanced procedures consideration should be given to factors that affect performance. Skill acquisition should be graduated with trainees being required to demonstrate proficiency in basic and intermediate laparoscopic techniques before progressing to advanced skills training. Assessing parameters such as aptitude, experience and insight all contribute to the learning experience. In particular we have demonstrated that aptitude and experience impact on the performance ability of trainees with respect to an advanced laparoscopic procedure. These factors influence the learning curve of the individual and therefore their ability to reach proficiency. In order to maximise training benefits in terms of time and cost efficiency these factors should be plotted into individual learning curves. This would allow a trainee to have an individual training plan with goals specific to their strengths and weaknesses in respect to advanced laparoscopic techniques. The results of this study support the design of individualised training curricula for advanced laparoscopic techniques.

Chapter 6

TAIS as a Tool for Determining Performance Outcomes in Surgical Tasks

6.1 Introduction

Greater than three quarters of the important events occurring during a surgical procedure have been estimated to be related to human factor elements such as decision making (especially during crises or emergencies), communication, team work and leadership. This is in contrast to the expected influence of technical skills and manual abilities. Other human factors which that have been identified as important in surgical practice include self-awareness (i.e. insight), distractibility and ability to perform under pressure.

In the leadership and management setting, the reasons for difficulties within the work place have most often been related to decision-making problems and/or interpersonal conflicts resulting from arrogance, untrustworthiness, insensitivity, inability to confront issues and an inability to delegate (Hogan et al, 1994). One of the biggest predictors of success and when absent the best indicator of problems has been identified as the ability to self-monitor, and therefore to have an accurate perception of one's own strengths and weaknesses (Zaccaro et al, 1991; Ellis, 1988). Recently personality tests have been increasingly employed to aid in employee selection and training.

Recent research has highlighted the importance of the human factor element in surgery (Chodhary et al, 2004; Anjum et al, 2005; www.parliament.uk/healthcom; Kohn et al, 1999). Human factors have particular relevance in minimally invasive surgery as this is an area of surgery which is considered to be inherently more stressful than open surgery (Bergeur et al, 2001).

Minimally invasive techniques are more stressful due to the additional visual spatial, perceptual and psychomotor challenges faced by the surgeon (Gallagher et al, 2003). The technical complexity of a procedure and the associated learning curve also add to the pressure to perform. A study carried out by Hassan demonstrated that poor stress coping ability correlated with poor laparoscopic performance (Hassan et al, 2006).

Personality testing is used widely for employee selection (Rothstein & Goffin, 2006). The data has shown that well-constructed personality measures are valid predictors of job performance (Hogan et al, 1996). Interest has been expressed in the literature in using this for surgical selection (Bann & Darzi, 2005; Gilligan et al, 1999). To date however no institute has formally evaluated how human characteristics could impact on surgical performance. In particular no psychometric test that specifically evaluates an individual's ability to perform under pressure has been examined in relation to surgery.

The TAIS or The Attentional and Interpersonal Style Inventory is a psychometric test that was developed specifically to measure the building blocks of performance (Nideffer, 2007). It was designed as an instrument to provide highly specific performance relevant feedback to individuals who must be able to perform at high levels of pressure, the prime example being the operating theatre environment.

The core competencies identified by the TAIS are; concentration skills, intra-personal behaviours and interpersonal behaviours. It determines the types of situations in which an individual will perform well and not so well in but it also determines the types of mistakes that they are most likely to make under highly stressful conditions. The TAIS is outlined in greater detail in both Chapters 1 & 2.

Objectively measuring human factor elements that are relevant to surgery and in particular to minimally invasive surgery is a novel endeavour. One of the aims of this thesis was to further evaluate the TAIS and the role it may have in both selection and training for MIS.

6.2 Objectives

6.2.1 Hypothesis Underlying the Objectives

Performance outcomes in the field of medicine are affected by cognitive and personality characteristics (Doherty & Nugent, 2011). The ability to perform under pressure and to have a good level of attentional ability is vital in surgery in general. It has been shown that performing minimally invasive procedures is inherently more stressful than traditional surgery (Bergeur et al, 2001; Hassan et al, 2006). This makes these factors relevant in minimally invasive techniques. We aim to determine if certain personality characteristics, in particular ability to deal with stress and distractibility, influence performance in MIS. We also wish to determine if there is an overall difference in distribution of certain personality characteristics between a group of students, junior trainees and senior surgical trainees.

6.2.2 Detailed Objectives

Objective 1:- To Examine the Distribution of Personality Characteristics Across a Range of Experience Levels

We aimed to evaluate the personality characteristics of a group of medical students, basic surgical trainees and higher surgical trainees using the TAIS inventory. Previous studies have demonstrated significant differences in personality traits among surgical trainees, medical students and trainees from other medical specialties (Hoffman et al, 2010). We aimed to examine whether there is a difference in the distribution of personality traits between the groups. We hypothesised that the medical student group would have a more heterogeneous distribution of traits in comparison to the surgical trainees who may have a different pattern in traits such as in performance under pressure, competitiveness and distractibility.

Objective 2:- To Determine if Personality Traits Influence MIS Task Performance

We aimed to determine whether there is an association between various personality traits and performance of laparoscopic, endoscopic and endovascular surgical tasks in a simulated setting. We aimed to evaluate this in a group of medical students, BST and HST trainees. The profile patterns of particular interest were; confidence, energy, competitiveness, extroversion, anxiety, distractibility and performance under pressure.

Objective 3:- To Determine if Personality Traits Influence Surgical Skill Performance in a Stressful Environment

We aimed to establish whether there is an association between personality traits and surgical performance in a stressful environment. We aimed to assess the surgical skill performance of a group of BST's on both open bench models and the laparoscopic simulator in an examination format (objective structured examination of technical skill). We then aimed to determine whether there is an association between performance and various personality traits. Again, the profile patterns of interest were; confidence, energy, competitiveness, extroversion, anxiety, distractibility and performance under pressure.

6.3 Materials and Methods

6.3.1 Recruitment of Participants

The participants were recruited as outlined in chapter 2, Materials and Methods. Participation was voluntary. The candidates were chosen at random from the responses received.

The volunteers gave written informed consent to take part in the study. It was made clear to them that all data collected would be stored in an anonymous format.

The assessments were performed at the National Surgical Training Centre, The Royal College of Surgeons in Ireland, 121 St. Stephen's Green, Dublin 2.

Ethical approval for the study was awarded by the Research Ethics Committee of the RCSI.

6.3.2 Participant Demographics

There were three groups of volunteers; medical students, basic surgical trainees (BST) and higher surgical trainees (HST). In total 17 medical students, 16 BST and 17 HST trainees took part in the MIS skill assessment. Demographic details are displayed in table 6.1. The inclusion and exclusion criteria are outlined in chapter 2, Materials and Methods.

	MIS Skill Assessment			**BST Surgical Skill Assessment**
	Medical Student	**BST**	**HST**	**BST**
Age Range (mean, SD)	19-26 (20.64, 1.69)	25-31 (26.87, 1.78)	29-39 (33.64, 2.62)	-
Gender M : F	8 : 9	13 : 3	15 : 2	41 : 15
Dominant hand R : L	17 : 0	15 : 1	17 : 0	-
Satisfactory result Yes : No	-	-	-	49 : 7

Table 6.1 Participant Demographics

In addition all BST Year 2 trainees (n = 56) undergoing compulsory structured assessment of their operative surgical skills (open & laparoscopic) were invited to complete the TAIS. Completion of the TAIS was voluntary and was separate to their surgical skills assessment. In total all 56 trainees consented to completing the TAIS. Their demographic details are displayed in table 6.1.

6.3.3 The Attentional and Interpersonal Style Inventory (TAIS)

The TAIS or the attentional and interpersonal style inventory was designed as a psychometric instrument to provide highly specific performance relevant feedback to individuals who must be able to perform under high levels of pressure.

The ability to shift focus of concentration from broad to narrow and external to internal in response to the changing demands of a situation is required for success in performance. This ability to shift focus is affected by an individual's preferred or dominant style of attention and other personality characteristics including their level of emotional arousal. The TAIS is a psychological tool that was specifically designed to assess behaviour competencies or the "building blocks" of performance. The parameters measured by the TAIS are detailed in appendix II.

The TAIS was administered to the three groups of volunteers in a paper based format. Each candidate was asked to complete the 144 items of the TAIS where their answers reflected an honest report of themselves. A five point Likert style scale was used where the candidates were asked to indicate the frequency with which a particular item described their behaviour. The response options were: never, rarely, sometimes, frequently or always. The candidates were informed that the TAIS, similar to most psychological assessments, has measures in place to control for any individual who either over or under estimates their own ability. No time constraint was placed when completing the assessment.

The completed TAIS questionnaires were then sent to MHS Assessments, the company that hold the license for this psychometric assessment. MHS Assessments scored each individual assessment and the results with a detailed profile were forwarded to RCSI. All the data was made anonymous and entered into a database for analysis.

6.3.4 Surgical Skills Assessment

Minimally invasive surgical skills were assessed using simulators. The areas examined were laparoscopy, endoscopy and endovascular skill.

Laparoscopic skill was tested on the ProMIS (Haptica, Ireland). Each candidate was asked to perform a series of tasks – locating and coordinating, object positioning and a sharp dissection task. Objective metrics such as time, instrument motion and errors were recorded. Additional metrics such as the number of times the candidate dropped a bead in the object positioning task and the number of perforations to the glove in the sharp dissection task were also noted.

Endoscopic skill was tested using the GI Mentor II (Simbionix, USA). On this simulator each candidate performed a colonoscopy case (Module 1, Case 1). The time to reach the caecum, time spent with a clear view, percentage mucosa viewed, looping of the colon and patient pain were recorded in the colonoscopy task.

Endovascular skill was assessed on the VIST (Mentice, Gothenburg, Sweden). The candidates were instructed to insert a standard guidewire and catheter into the left renal artery and then to remove the catheter out over the guidewire while keeping the guidewire steadily in place. The time to complete this was recorded. The candidates were also video recorded while performing this task. A camcorder recorded their hand movements while manipulating the instruments and another camcorder recorded the movements of the instruments on the screen. The video recordings were anonymous. They were scored by two blinded experts using a modified version of OSATS (appendix IV).

The BST's that underwent compulsory assessment of their operative surgical skills were examined in a structured three station OSCE based format. The stations were as follows; bowel anastomosis (bench model, Limbs & Things, Bristol, UK), sapheno-femoral junction ligation (bench model, Limbs & Things, Bristol, UK), & basic laparoscopic skills (as described previously, ProMIS simulator, Haptica, Dublin, Ireland). The trainees were examined by consultant trainers. A procedure specific checklist in combination with OSATS was used to score each candidate. A satisfactory assessment mark was required to allow progression in the training program. As the assessment was part of the trainees' continuous assessment, the score achieved and their ranking were also entered into their training record.

Further detail is available on the various minimally invasive tasks and the simulators used for the study in chapter 2, Materials and Methods.

6.3.5 Statistical Analysis

Data was analysed using the SPSS 18.0 software (SPSS Inc, Chicago, Ill). Data was assessed for normality of distribution using the K-S independent test. One way between groups multivariate analysis of variance (MANOVA) was used to examine the relationship between TAIS personality characteristics and the surgical technical skill performance parameters measured. Between subjects effects were considered after applying a Bonferroni adjusted alpha level of 0.007. This was the level at which data was considered to be statistically significant.

6.4 Results

6.4.1 Participant Demographics

In total 50 candidates took part in the MIS skill assessment (16 medical students, 17 Basic Surgical Trainees and 17 Higher Surgical Trainees) (table 6.1). Figure 6.1 is a graphical representation of the mean scores for each parameter the TAIS measures.

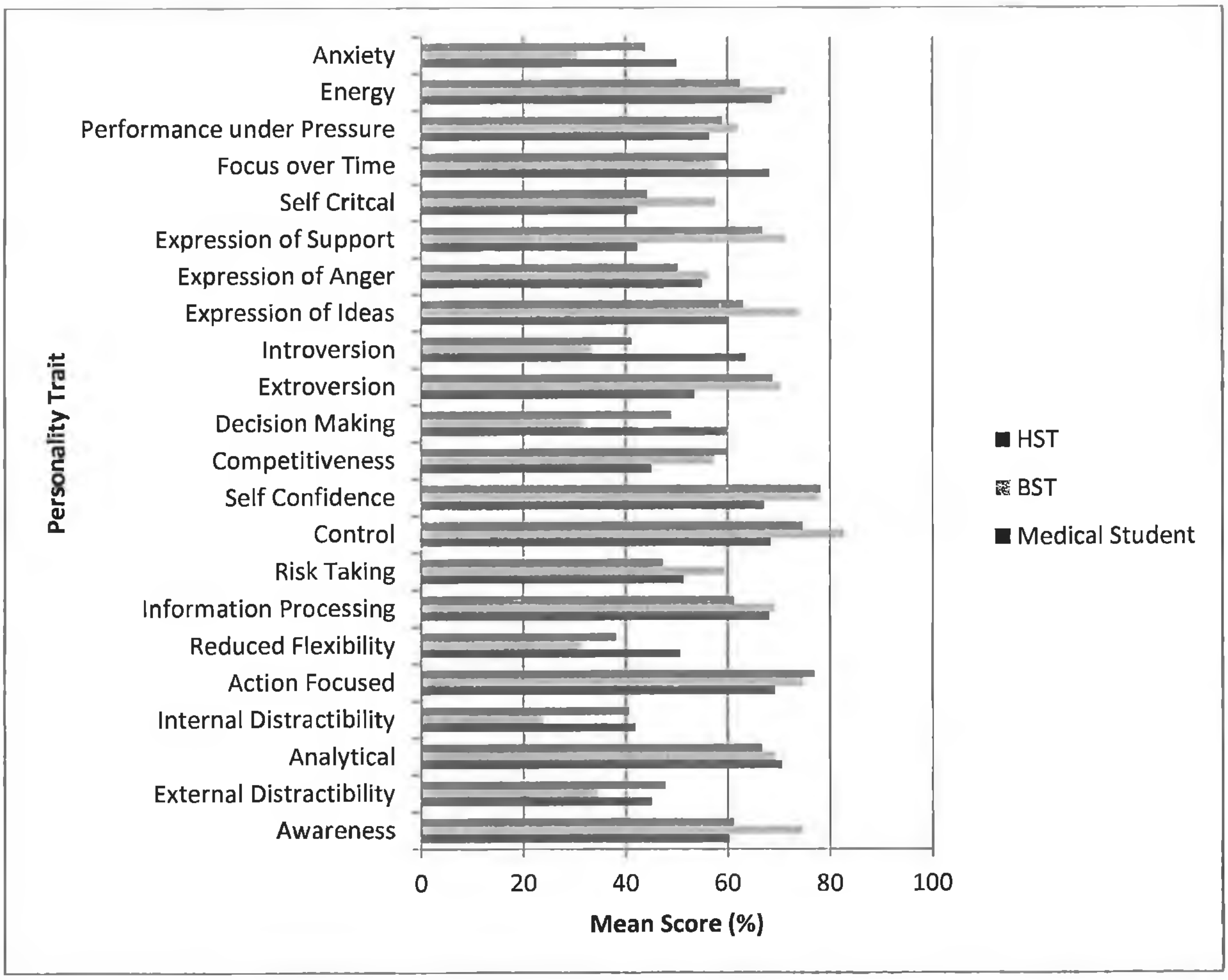


Figure 6.1 Personality Trait Scores for the Participants in the MIS Skills Assessment; This figure shows the mean scores on each of the personality traits measured by the TAIS for the group of medical students, BST's & HST's. There was no significant difference in the distribution of personality traits for the three groups.

The mean score for the personality traits of all the BST trainees (n = 56) involved in the operative surgical skills assessment can be seen in figure 6.2. The scores for the three stations assessed are displayed in table 6.2.

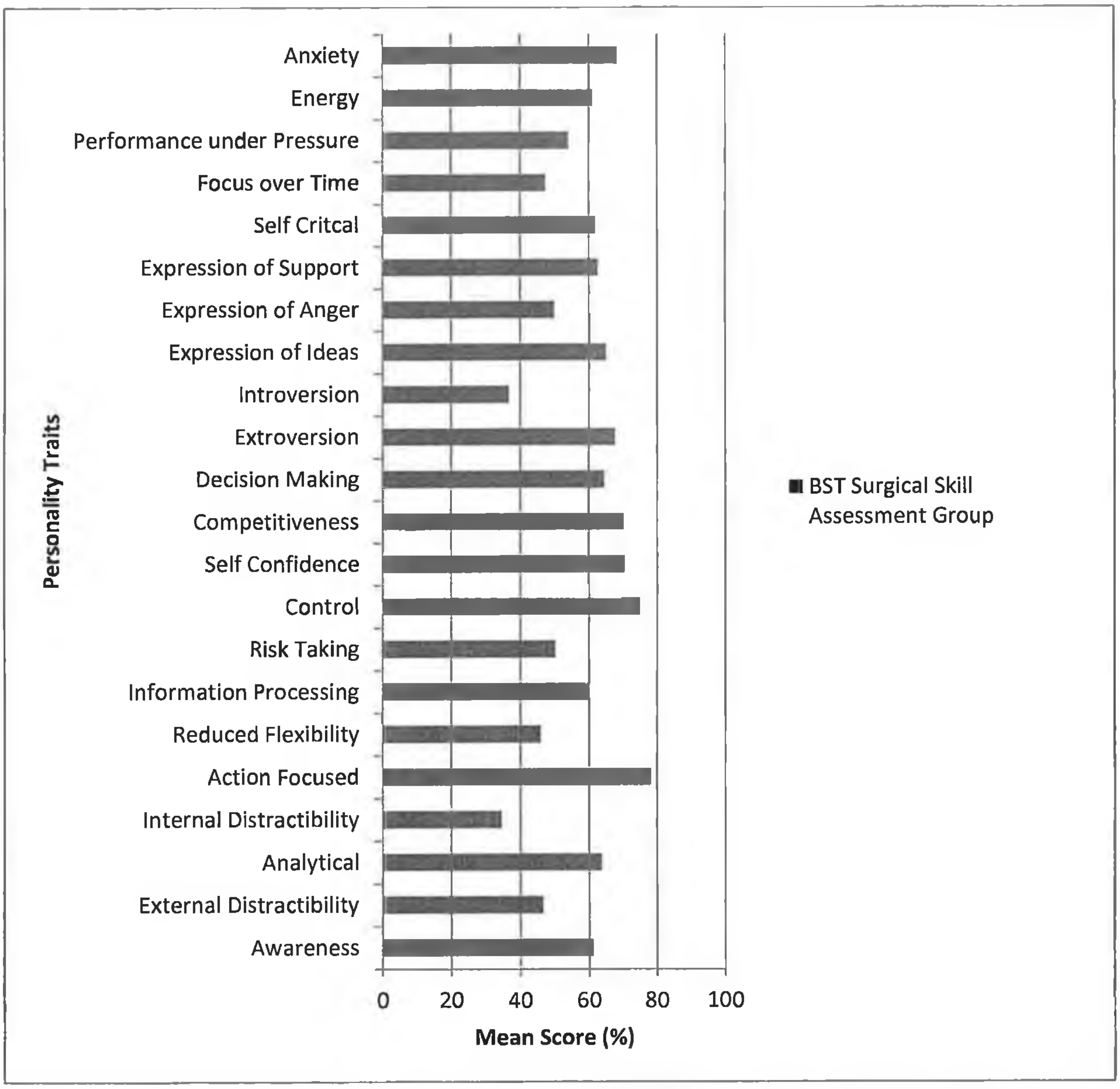


Figure 6.2 Personality Trait Scores for the BST Trainees that had their Surgical Skills Assessed; This figure shows the mean scores on each of the personality traits measured by the TAIS for the BST trainees that had their surgical skills assessed.

OSCE Station	% Score: Range (mean, SD)
Bowel Anastomosis	32-100 (80, 14.38)
Sapheno-femoral Junction Ligation	33-100 (76, 17.91)
Basic Laparoscopic Skills	44-98 (70, 12.75)
Overall Score	49-93 (75, 11)

Table 6.2 Scores for the BST Surgical Skills Stations Assessed

6.4.2 The Distribution of TAIS Personality Characteristics

We aimed to determine whether there was a difference in personality characteristics between a group of medical students, BST's and HST's. Using one way between groups multivariate analysis of variance (MANOVA) we found that there was a significant difference between the groups on the combined dependent variables (Pillai's trace = 1.364, p = 0.029). When the results for the dependent variables were considered separately, after applying a Bonferroni adjusted alpha level of 0.007, we found however, that none of the dependent variables reached statistical significance.

6.4.3 Association between TAIS Personality Traits & MIS Performance

We aimed to evaluate whether there was an association between personality traits as measured by the TAIS and performance on laparoscopic, endoscopic and endovascular tasks on surgical simulators. We assessed medical students, BST's and HST's. We looked specifically at seven TAIS parameters; confidence, energy, competitiveness, extroversion, anxiety, distractibility and performance under pressure.

A one-way between groups multivariate analysis of variance (MANOVA) was performed to evaluate the association between the seven TAIS personality parameters and laparoscopic, endoscopic and endovascular performance (table 6.3). We found that competitiveness was the only trait associated with laparoscopic performance (Pillai's Trace = 0.191, p = 0.045), both confidence (Pillai's Trace = 0.637, p = 0.001) and distractibility (Pillai's Trace = 0.800, p = 0.0001) were associated with endoscopic performance. None of the personality traits were associated with endovascular performance.

When we looked separately at those dependent variables that were statistically significant, using a Bonferroni adjusted alpha level of 0.007; we found that the only difference to reach statistical significance was looping in endoscopy (table 6.4). An inspection of the mean scores indicated that those candidates with a low level of confidence (mean = 23, SD = 48.87) and a high level of distractibility (mean = 11.09, SD = 24.08) looped the colon more frequently than those candidates with a high level of confidence (mean = 2.32, SD = 10.29) or a low level of distractibility (mean = 4.77, SD = 26.16).

	Laparoscopic Performance		
TAIS Trait	**Pillai's Trace**	**P value**	**Partial Eta squared**
Confidence	0.03	0.890	0.03
Energy	0.099	0.424	0.099
Competitiveness	**0.191**	**0.045**	**0.191**
Anxiety	0.059	0.647	0.059
Distractibility	0.072	0.545	0.072
Performance under pressure	0.083	0.485	0.083
Extroversion	0.098	0.312	0.098
	Endoscopic Performance		
Confidence	**0.637**	**0.001**	**0.637**
Energy	0.415	0.102	0.415
Competitiveness	0.426	0.088	0.426
Anxiety	0.353	0.204	0.353
Distractibility	**0.800**	**0.0001**	**0.800**
Performance under pressure	0.210	0.284	0.210
Extroversion	0.227	0.226	0.227
	Endovascular Performance		
Confidence	-	-	-
Energy	-	-	-
Competitiveness	0.784	0.205	0.784
Anxiety	0.655	0.428	0.655
Distractibility	0.642	0.450	0.642
Performance under pressure	0.504	0.882	0.504
Extroversion	0.844	0.118	0.884

Table 6.3 Multivariate Analysis of Variance: TAIS Traits & MIS Performance; [values in red are statistically significant]

	Competitiveness	
Laparoscopy	**P value**	**Partial Eta squared**
Time	0.104	0.054
Path Length	0.036	0.088
Smoothness	0.019	0.110
Error	0.360	0.017
	Confidence	
Endoscopy		
Mucosal surface	0.107	1.087
Clear view	0.042	0.134
Pain	0.013	0.196
Looping	0.0001	0.511
Local Pressure	0.452	0.020
	Distractibility	
Mucosal surface	0.053	0.136
Clear view	0.043	0.149
Pain	0.057	0.132
Looping	0.0001	0.514
Local Pressure	0.049	0.141

Table 6.4 Between Subjects Effects: TAIS Traits & MIS Performance; [values in red are statistically significant]

6.4.4 Association between TAIS Personality Traits & Surgical Skill Performance in a Stressful Environment

We aimed to evaluate the association between personality traits and surgical performance in a pressurised OSCE setting in a group of 56 second year BST's. Again we specifically examined seven TAIS parameters; confidence, energy, competitiveness, extroversion, anxiety, distractibility and performance under pressure.

A one way between groups multivariate analysis of variance was performed (MANOVA) (table 6.5). The results demonstrated that energy was the only personality trait associated with OSCE performance (Pillai's Trace = 0.171, p value = 0.028). When we looked separately at energy, using a Bonferroni adjusted alpha level of 0.007; we found that the only difference to reach statistical significance was performance on the bowel anastomosis (table

6.6). The mean scores suggest that those candidates with a higher level of energy performed better on the bowel anastomosis station (mean = 83.91, SD = 12.54) in comparison to those candidates that had a lower level of energy who did not perform as well on the bowel anastomosis station (mean = 71.11, SD = 15.46).

	OSCE Performance		
TAIS Trait	**Pillai's Trace**	**P value**	**Partial Eta squared**
Confidence	0.137	0.067	0.137
Energy	**0.171**	**0.028**	**0.171**
Competitiveness	0.055	0.431	0.055
Anxiety	0.004	0.982	0.004
Distractibility	0.017	0.840	0.017
Performance under pressure	0.084	0.233	0.084
Extroversion	0.131	0.079	0.131

Table 6.5 Multivariate Analysis of Variance: TAIS Traits & BST Surgical Skill Performance; [values in red are statistically significant]

	Energy	
OSCE Station	**P value**	**Partial Eta Squared**
Bowel anastomosis	**0.002**	**0.170**
Sapheno-femoral junction ligation	0.269	0.024
Basic laparoscopic skills	0.730	0.002

Table 6.6 Between Subjects Effects: TAIS Traits & BST Surgical Skill Performance; [values in red are statistically significant]

6.5 Discussion

In this chapter we set out to evaluate the role of the TAIS, a personality assessment tool, in determining performance outcomes in surgical tasks. We examined the distribution of personality characteristics in medical students, BST's and HST's. We also investigated whether there was an association between performance outcomes in various surgical tasks and seven of the TAIS personality characteristics.

When we evaluated the distribution of personality characteristics and compared the medical students, BST's and HST's to each other we found that there was no significant difference between the three groups. Previous studies have shown greater levels of conscientiousness amongst surgical residents when compared to medical students and population norms (Hoffman et al, 2010). Other studies have shown consistently higher levels of traits considered to be of advantage for decision-making amongst surgeons (McGreevy & Wiebe, 2002).

The term surgical personality refers to the hypothesis that surgeons share certain personality traits (Borges & Swickes, 2002; Thomas, 1997). In fact it has been demonstrated that there is a perceived "surgical personality" or surgical stereotype amongst other healthcare professionals (Warschkow et al, 2010). However, this has also been shown to be significantly different to actual personality on assessment (Warschkow et al, 2010). Our results on the one hand may be surprising as one might hypothesise that those trainees better suited, for example, to working under pressure may self-select into surgical training and moreover remain within surgery. However, they may also be viewed as reassuring as personality diversity is important and desirable within any one specialty. Our findings suggest that within our sample there isn't a specific surgical personality type.

We found that when we looked at how seven of the TAIS profile patterns affected performance in MIS tasks that the only significant result was in endoscopy. Here the results demonstrated that both distractibility and confidence significantly impacted on the number of loops formed during the colonoscopy module. The scores suggested that those trainees with a high level of confidence and a low level of distractibility performed better. We found no significant results for either laparoscopy or endovascular performance. In contrast to the other tasks the colonoscopy module could be considered to be more technically demanding especially when it comes to progression without looping the colonoscope. This may explain why an association was found here.

The confidence factor is a cluster of TAIS scales which gives a good indication as to how positive or negative the subject is and their responses were. When working with highly effective individuals it is unusual to have low scores in this factor. The distractibility factor looks at the ability of the individual to focus on the task at hand and not get distracted by the environment around them and their own thoughts and feelings. They are able to exert tight control over their focus of concentration and their emotions thus restricting the expression of anger and impulsivity.

One of the limitations of the above experiment was the fact that the environment in which the participants performed the MIS tasks was without constraints, was relaxed and stress free. Previous studies have found an association between surgical performance and stress (Beurgeur et al, 2001; Hassan et al, 2001). As the TAIS specifically measures ability to perform under pressure we concluded that we would need to better test the TAIS and this theory. As a follow on from the above experiment we decided to evaluate surgical skill performance outcomes (both open and minimally invasive) in the more pressurised setting of an exam.

When we examined the same seven personality profile patterns in relation to performance in an objective structured assessment of technical skills we found that the only significant result was for the first exam station; bowel anastomosis. The results showed an association between energy levels and performance, with those trainees with a higher level of energy performing better on this task. The higher the respondents on this particular TAIS cluster of scales the more they seem to enjoy a very busy, changing and challenging work environment. Higher scores on the energy factor are typically quick learners. However, individuals with a high confidence score may be at risk of taking on too many tasks at once.

Overall the results did not demonstrate a concrete relationship between personality and performance in a stressful environment. However, over the past number of years factor analytic studies of a wide range of multi-scale personality inventories (such as; TAIS, 16PF, Myers Briggs, California Personality Inventory) have identified five general factors which are common to all of them (Barrack & Mount, 1991). These are known as the "Big Five". We choose the TAIS for this study as it was designed to specifically measure the building blocks of performance (Nideffer, 2007). It is also reported to reflect the traits that are also measured by the "Big Five" (Nideffer 2007).

We decided to evaluate a summary of the score profiles which show how the respondents scored on six profile patterns (table 6.7). The associated scales that the profile patterns represent typically correlate with each other. We choose to examine a summary as we were limited in analysis by our sample size. Although the profile patterns that we looked at reflected the parameters that were of interest to us we feel that our results may be at risk of reflecting a generalisation rather than differentiating between the different measures of personality. Future studies could consider looking at each trait separately.

Profile Pattern	Associated Scales
Confidence	BET, BIT, INFP, CON, SES, EXT, IEX, PAE
Energy	BET, BIT, INFP
Competitiveness	CON, SES, PO
Anxiety	OIT, RED, OBS
Distractibility	OET, OIT, NAR, BCON, NAE
Performance under pressure	PUP
Extroversion	EXT, INT, PAE

Table 6.7 TAIS Profile Patterns and their Associated Scales

Personality characteristics have been found to be associated with academic and workplace performance (Higgins et al, 2007; Noftle & Robins, 2007; Schmidt & Hunter, 1998). Within the field of medicine conscientiousness is one of the "Big Five" traits that has most commonly been reported to be associated with performance. It is described as separating individuals who are hard-working, focused and persevering from those who are impulsive, irresponsive and undependable. On the TAIS conscientiousness is reflected in subject's scores on scales measuring the willingness to make personal sacrifices to accomplish goals and objectives (focus over time) and the ability to concentrate in high pressure situations (performance under pressure). This is why we choose to look at performance under pressure separately as our seventh parameter. However, unlike other studies, we did not find any association of significance for this characteristic. We are unable to explain this finding and can only speculate as to the reasoning behind our results – is it that the TAIS is an inappropriate tool for predicting surgical performance or maybe personality profiling has no role in predicting technical performance in surgery in general?

Although overall our study did not demonstrate a detailed link between various personality characteristics as measured by the TAIS and surgical technical performance we believe that personality profiling still has a role in surgical training. The importance of self-monitoring and self-awareness has been demonstrated (Zaccaro et al, 1991; Ellis, 1988). Therefore, personality testing is a tool that can enable trainees better understand their individual strengths and weaknesses and those of their colleagues (Swanson, 2010). Knowing one's own and one's colleagues personality type can help reduce miscommunication (Bradley & Hebert, 1997; Ang, 2002). The benefit of being attuned to one's personal emotional state allows for more co-operative interpersonal relationships and aids in coping with stress within the work environment (Stratton et al, 2005). All these factors are acknowledged to be vital for the surgical trainee.

Chapter 7

Non-Surgical Skills and Minimally Invasive Surgical Performance

7.1 Introduction

Certain attributes may confer an advantage when learning minimally invasive techniques. Some of the attributes that have been associated with ease of learning in minimally invasive surgery are fundamental aptitudes and personality factors both of which we have described in earlier chapters. Another set of attributes that require consideration are certain non-surgical skills. These non-surgical skills include extra-curricular activities such as musical ability, participation in competitive sport and playing video games.

Musical performance demands complex cognitive and motor operations. There has been little in the way of research into the role of musical ability on surgical skills (Enochssson et al, 2004; Schlickum et al, 2009). However non-surgical studies have demonstrated structural brain differences in musicians when compared to non-musicians (Münte et al, 2002; Karni et al, 1995; Amunts et al, 1997) and an association between musicians and motor and visual spatial skills (Costa-Giomi, 1999; Foregeard et al, 2008).

It is acceptable therefore to suggest that musical ability is an area relevant to surgical training. In particular it is applicable to minimally invasive surgical techniques where dexterity in both hands and a greater degree of visual spatial and perceptual ability is required when compared to open surgery. Taking into account the type of instrument, the number of years' experience in playing music and other factors such as distinctions achieved in examinations could play an important role in determining what trainees expected ability should be and how quickly they should progress.

Video game playing has been shown to be associated with increased hand-eye coordination, spatial visualisation and mental rotation (Griffith et al, 1983; De Lisi & Wolford, 2002; Dorval & Pepin, 1986; Green et al, 2003). Playing video games can be the first exposure to a graphical user interface that an individual encounters (Rosser et al, 2007). It has been demonstrated that video game players are able to react more quickly to visual stimuli than people who do not play video games (Castel et al, 2005).

Previous studies have shown that laparoscopic technical ability can be predicted by video game usage (Grantcharov et al, 2005; Schlickum et al, 2008). Similar to playing video games, in minimally invasive surgery the operator is looking at the screen and not their hands, with the result that they have to translate 2D object movements into 3D. Playing video games allows a novice to become familiar with a 2D monitor and allows them to acquire the basic hand-eye coordination skills required for minimally invasive techniques.

The exact role of video game playing in minimally invasive surgical techniques has yet to be elicited. Examining whether trainees play video games, the type of game they play, the number of hours per week they spend playing and whether they have completed a game or achieved the maximum score and comparing these elements to their MIS skills may allow us to determine a trainees skill ability.

Sport is the one extra-curricular activity of the three we plan to examine that has the least available information in terms of published studies on the relationship between sport and surgical skill performance. It is easy to accept that there is a significant relationship between sporting performance and psychomotor and spatial ability. The literature suggests that sport may be considered a spatial activity and therefore engaging in sport increases the capacity of the individual to implement and relate to mental imagery (Ozel et al, 2004). It has also been shown to affect the speed at which an individual can process information from a constantly changing environment. Studies have demonstrated that athletes are better at performing spatial and psychomotor tasks than non-athletes (Ozel et al, 2004; Kioumourtzoglou et al, 1998). The nature of the sport played has also been demonstrated to influence the way perceptual and spatial abilities differentiate elite athletes from novices (Kioumourtzoglou et al, 1998a).

As spatial and motor activities are closely linked to sporting ability it is reasonable to expect that surgical trainees participating in sport may have a learning advantage when it comes to certain minimally invasive procedures. In surgery one study showed that when learning and performing an advanced task such as laparoscopic suturing those trainees with sporting ability performed better than those without (Harper et al, 2007).

No study has examined the impact of three different non-surgical skills – video game playing, musical ability and playing competitive sport on an array of minimally invasive tasks. One of the aims of this study was to explore the relationship between these various non-surgical skills with ability to perform minimally invasive surgical tasks.

7.2 Objectives

7.2.1 Hypothesis Underlying the Objectives

Personal attributes, such as playing a musical instrument, sport or video games, have been demonstrated to affect an individual's spatial and psychomotor ability (Amunts et al, 1997; Green et al, 2003; Ozel et al, 2004). Therefore their role in surgery and in particular in MIS should be given consideration. It is hypothesized that part-taking in certain extra-curricular activities should in turn influence ability to perform various minimally invasive skills. Using the same cohort of subjects we aim to investigate if extra-curricular activities have any effect on ability to perform basic minimally invasive skills in an effort to evaluate the impact they may have on the learning curve.

7.2.2 Detailed Objectives

Objective 1:- To evaluate whether non-surgical skills influence ability to perform minimally invasive surgical tasks

We aimed to evaluate the extra-curricular activities of a group of medical students, basic surgical trainees and higher surgical trainees by means of a self-report survey. Three areas of non-surgical skill were examined; musical ability, sporting ability and video game playing. We also aimed to assess MIS surgical skill in the same cohort of subjects. We aimed to then explore the relationship between MIS performance and extra-curricular activities.

7.3 Materials and Methods

7.3.1 Recruitment of Participants

As outlined in chapter 2, a general e-mail was circulated to all the medical students attending RCSI in the pre-clinical years one to three, all the basic surgical trainees and higher surgical trainees in general surgery throughout Ireland. Posters were also displayed in the National Surgical Training Centre. Participation was voluntary. Participants were randomly selected from the responses received.

The candidates gave written informed consent allowing all data collected to be used for research purposes. It was made clear that all information gathered would be stored and presented in an anonymous format.

All assessments were performed at the National Surgical Training Centre, The Royal College of Surgeons in Ireland, 121 St. Stephen's Green, Dublin 2.

7.3.2 Participant Demographics

In total 40 medical students, 20 basic surgical trainees and 20 higher surgical trainees volunteered to take part in the study.

The inclusion and exclusion criteria for the study participants have been previously outlined in chapter 2, Materials and Methods.

7.3.3 Evaluation of Non-Surgical Skills

The three non-surgical skills that we decided to evaluate in further detail were – musical ability, sporting ability and video game playing. The participants were asked to complete a detailed survey. Questions included whether they had ever partaken in the three extra-curricular activities outlined above, whether they still were involved in these extra-curricular activities and a quantification of their past and current involvement (for example, number of hours per week spent playing an instrument). The volunteers were also asked to give details about the level of ability achieved and whether they participated in the activity at a competitive level.

7.3.4 Surgical Skills Assessment

Minimally invasive surgical skills were assessed using simulators. The areas examined were laparoscopy, endoscopy and endovascular skill.

Laparoscopic skill was tested on the ProMIS (Haptica, Ireland). Each candidate was asked to perform a series of tasks – locating and coordinating, object positioning and a sharp dissection task. Objective metrics such as time, instrument motion and errors were recorded. Additional metrics such as the number of times the candidate dropped a bead in the object positioning task and the number of perforations to the glove in the sharp dissection task were also noted.

Endoscopic skill was tested using the GI Mentor II (Simbionix, USA). On this simulator each candidate performed the endobubble task and a colonoscopy case (Module 1, Case 1). The number of balloons burst, time to complete the task and the number of times the candidate hit the side wall were noted in the endobubble task. The time to reach the ceacum, percentage mucosa viewed, looping of the colon, patient pain and overall screening efficiency were recorded in the colonoscopy task.

Endovascular skill was assessed on the VIST (Mentice, Gothenburg, Sweden). The candidates were instructed to insert a standard guidewire and catheter into the left renal artery and then to remove the catheter out over the guidewire while keeping the guidewire steadily in place. The time to complete this was recorded. The candidates were also video recorded while performing this task. A camcorder recorded their hand movements while manipulating the instruments and another camcorder recorded the movements of the instruments on the screen. The video recordings were anonymous. They were scored by two blinded experts using a modified version of OSATS.

Further detail is available on the various minimally invasive tasks and the simulators used for the study in chapter 2, Materials and Methods.

7.3.6 Statistical Analysis

A database was constructed using SPSS (version 18.0 software, Chicago, Ill). The relationship between playing video games, musical instruments and sport at a competitive level and surgical skill was assessed using the either the Chi-square test or the Independent t-test, where the dependent variable was the objective metrics generated by the simulators. Parameters such as hours per week played were correlated with surgical skill outcome using Pearson's correlation coefficient. One way ANOVA was used to determine the difference in surgical skill between the various types of games, musical instruments and sport played. A p value of <0.05 was considered significant.

7.4 Results

7.4.1 Participant Demographics

In total eighty volunteers took part in the study. Table 7.1 outlines the number of participants that reported playing musical instruments, sport and video games and table 7.2 demonstrates the type of sport, musical instrument and video game that the subjects played.

	Medical Students (N = 40)	BST's (N = 20)	HST's (N = 20)	P Value
Video Games:				
Yes	21	9	4	NS*
No	19	11	16	
Musical Instrument:				
Yes	29	15	12	NS
No	11	5	8	
Sport:				
Yes	21	12	14	NS
No	19	8	6	

Table 7.1 Non-surgical Skills of Participants; [NS* = non-significant]

Sporting Discipline	No. of Candidates	Musical Instrument Type	No. of Candidates
Tennis	6	Piano	34
Basketball	8	String	6
Football	20	Wind	7
Rugby	13	Guitar	9
		Video Game Type	
		Car Racing	13
		Fighting/Shooting	9
		Football/Sport	12

Table 7.2 The Type of Sport, Music & Video Games Played

7.4.2 Non-Surgical Skills and MIS Performance

Those candidates that reported playing video games performed better in the laparoscopic, endoscopic and endovascular tasks in comparison to those candidates that did not play video games (table 7.3). The subjects that reported playing a musical instrument performed better in the endoscopy and endovascular tasks (medical students and BST's). There was no significant association found for laparoscopic skill. The candidates (medical students and BST's) that reported playing sport at a competitive level performed better in laparoscopy, endoscopy and endovascular tasks in comparison to those candidates that did not play sport at a competitive level.

	Medical Students	BST's	HST's
Video Games			
Laparoscopy	NS*	0.004	0.001
Endoscopy	0.003	0.008	NS
Endovascular	0.028	NS	0.013
Musical Instrument			
Laparoscopy	NS	NS	NS
Endoscopy	0.012	0.014	NS
Endovascular	0.04	NS	NS
Sport			
Laparoscopy	0.04	0.04	NS
Endoscopy	0.003	0.03	NS
Endovascular	NS	0.03	NS

Table 7.3 Non-surgical Skill and MIS Performance Outcomes [values displayed are p values, NS* = non-significant]

We took a closer look at those candidates that reported taking part in the three extra-curricular activities. We found that the number of hours spent playing video games per week did not significantly impact on performance. The type of video game played did affect performance with a sport based video game more frequently resulting in better performance outcomes than either a car racing game or a fighting/shooting game ($p = 0.03$). We found that the medical students who played video games and who reported achieving maximum scores performed better in laparoscopy ($p = 0.04$) and colonoscopy ($p = 0.01$). The number of hours per week spent playing a musical instrument affected performance in endoscopy in the medical students (Endobubble: $r = 0.411$, $p = 0.03$, Colonoscopy: $r = 0.412$, $p = 0.033$) and laparoscopy in the BST's ($r = 0.608$, $p = 0.021$). The number of years spent playing a musical instrument were found to be significant for all three tasks for the group of medical students ($p = 0.03$) and the BST's ($p = 0.02$). The type of musical instrument was also significant with those that played piano performing better ($p = 0.019$). Those candidates that reported either achieving a distinction or winning a prize as a result of their musical ability also performed significantly better in laparoscopy, endoscopy and endovascular tasks. The type of sport played was significant for endoscopy (football) and laparoscopy (rugby & basketball).

7.5 Discussion

The results demonstrate that extra-curricular activities are an important part of our candidate's lifestyle. Greater than half of all the candidates that participated in the study reported playing competitive sport and a musical instrument. Video game playing was more popular amongst the medical students and this may reflect their younger generation.

With respect to MIS performance our study has shown that extra-curricular activities do significantly influence ability to perform surgical tasks. In turn more specific factors such as the type of musical instrument, video game and sport played, the number of years spent playing a musical instrument and ability to achieve a distinction or prize in music all impacted on performance in various MIS tasks.

We found a positive relationship between endoscopic and endovascular skill and musical ability. We also found that the number of years spent playing a musical instrument; the type of instrument played and achieving a distinction influenced the performance outcomes of the laparoscopic, endoscopic and endovascular tasks. There is limited and conflicting evidence in the literature with regards surgical skill and musical ability. Boyd and colleagues demonstrated that musical experience correlated with performance on a laparoscopic suturing task in surgical novices (Boyd 2008). Madan showed in a group of medical students who performed a laparoscopic task that non-surgical skills such as video games and musical ability did not significantly increase performance (Madan 2005, Madan 2008).

Glaser found that those with a history of playing musical instruments for 10 years at least performed better at a novice level on an endoscopic sinus surgery simulator (Glaser 2005). Our findings support these results. However in Glaser's article when the candidates reached the intermediate level the relationship lost its significance. This suggests that at novice level prior experience in these fields is important but as experience is gained the relationship loses its significance. Our results demonstrated a similar pattern where the main effects were seen amongst the novice group of the medical students and the group of BST's that had moderate MIS experience. However it is interesting to note that ability to achieve a musical distinction or prize was still relevant to performance in endoscopy and endovascular tasks in the group of experienced HST's.

The results we found in relation to playing sport are similar to those published by Harper and colleagues (Harper 2007). We report that those subjects that played sport at a competitive level did significantly better on all the MIS tasks in comparison to those candidates that didn't. We also found that the type of sport played was significant with those candidates that played football performing better on the endoscopic tasks and those that played basketball or rugby performing better on the laparoscopic tasks. A wide spectrum of sporting disciplines was assessed as part of our study. Future studies within each sporting discipline for specific player roles may yield interesting data. We believe that further studies investigating the association between sporting ability and surgical skill are required before a more solid conclusion can be drawn.

There are a number of previous studies involving video game playing that support our findings (Shane 2008). Hislop and colleagues found that the time to complete an endovascular task was improved by hours of video games played per week (Hislop 2006). This was true of a range of subjects, novice to expert, in endovascular surgery. In contrast our results did not demonstrate any significant association between hours per week playing video games and MIS performance. Grantcharov et al also examined the relationship between laparoscopic skill and video games and they reported that fewer errors were made by those with video game experience (Grantcharov 2005).

Hogle and colleagues found in a group of residents that the rate of achieving competency on the LapSim basic skills module correlated with a history of video game playing (Hogle 2008). However this did not translate into an improved clinical performance. Their results suggest that video game playing may not have a role beyond the initial stage in learning the skills required for minimally invasive techniques. Despite this the earliest part of the learning curve is the steepest and if this could be overcome by using technology such as video games in a controlled laboratory setting it should be embraced.

Video games are more accessible than ever and increasing in complexity. It is logical to assume that future generations of surgical trainees will have prior experience with playing video games and our results show that evaluating this experience may allow prediction of baseline MIS skill.

The one thing that playing video games, musical instruments and sport at a competitive level have in common is the need for deliberate practice. Deliberate practice is the idea of practice for the specific purpose of improving a core skill (Ericsson 1993). It involves intensive repetition and highly focused feedback. All competing musicians and athletes spend hours each day developing and maintaining their basic skills despite having a natural talent for their chosen field. Once again in the field of minimally invasive surgery practice is required to maintain and hone surgical skills. Therefore the important factor that separates out those candidates that are involved in extra-curricular activities from those that are not may be certain characteristics of personality such as commitment ability and discipline.

We are conscious that we relied on the candidates' inherent insight into the level of their extra-curricular activity prowess. This is invariably inaccurate and is a limitation of our study. Estimation of video game playing expertise was non quantifiable however in the arena of sport and music this was possible. Candidates verified their level of achievements by documentation of representative honours in sports, and distinctions in musical instrument proficiency.

Being able to predict the baseline skill or starting point of a trainee in minimally invasive techniques may prove useful when it comes to designing and implementing a training curriculum. Therefore the assessment of non-surgical skills like musical ability, video game playing and participation in competitive sport is a worthwhile consideration.

Chapter 8

Discussion & Future Work

8.1 The Aims of the Thesis

The aim of this thesis was to evidence the importance of factors such as visual-spatial, perceptual and psychomotor aptitude, personality characteristics and non-surgical skills in minimally invasive surgery and to empirically demonstrate how individual differences in ability are related to minimally invasive surgical performance. This has become relevant due to recent changes in the training structure in surgery and also due to an increasing demand for the minimally invasive approach. As a result there has been a need identified to investigate those factors that may allow an individual's learning curve in minimally invasive techniques to be mapped out before they start their training pathway.

Previous theories and research have illustrated the underlying importance of these factors in allowing the individual overcome the various physical and cognitive difficulties imposed when learning minimally invasive techniques. These studies therefore have illustrated how and why individual differences are likely to influence performance in MIS techniques thus providing a theoretical foundation for the experiments we aimed to conduct. The literature also guided us as to which assessment tools (aptitude and personality) would be most suitable for use in our experiments.

8.2 Summary of Main Findings

- The visual spatial, psychomotor and perceptual aptitudes of surgical trainees were compared to a non-surgical control group. The results demonstrated that the surgical trainees had a greater level visual spatial and depth perception aptitude when compared to the control group.

- The relationship between aptitude and performance in basic MIS tasks was explored. The results demonstrated a significant association between visual spatial, perceptual and psychomotor aptitude for the medical students, BST and HST trainees in laparoscopy, endoscopy and endovascular techniques.

- The relationship between aptitude and performance in a more complex MIS task (laparoscopic colectomy) was explored amongst HST trainees. The results demonstrated a significant association between visual spatial and psychomotor aptitude and MIS performance.

- The volume of previous cases (laparoscopic & open) performed also influenced performance in laparoscopic colectomy, with those trainees with a greater case volume performing better.

- In evaluating ability to reach predefined proficiency goals it was found that those trainees with a higher level of psychometric aptitude achieved these goals in a shorter time frame when compared to those trainees with a lower level of aptitude.

- A diverse distribution of personality characteristics was demonstrated across the medical students, junior and senior surgical trainees.

- Certain personality traits were found to have a significant association with performance. In endoscopy those trainees with a lower level of distractibility and a higher level of confidence were found to perform better. In the bowel anastomosis task those trainees with a higher level of energy were found to perform better.

- Non-technical skills (musical ability, playing video games and sport) were demonstrated to influence performance in basic MIS tasks, with the type of instrument, sport and video game played, the number of years spent playing an instrument and whether or not a distinction was achieved in music being important factors.

8.3 General Conclusions

One of the areas that we investigated in detail was psychometric aptitude (visual-spatial, depth perception and psychomotor). Psychometric assessment has been advocated as a possible means of measuring the importance of some of the psychological factors mediating MIS performance. We found some interesting results.

Firstly when we looked at whether surgical trainees shortlisted for higher surgical training had a different aptitude distribution to a non-surgical control group we found that the surgical trainees had a higher level of visual-spatial and depth perception aptitude in comparison to controls. This raised the question as to whether self-selection into surgical training plays a significant role. But it also raised the question as to whether these abilities are truly innate or whether an individual's fundamental ability can improve with increasing surgical experience and exposure to image based procedures. This theory however, would be in contrast to what the psychological and surgical literature on psychometric assessment has shown to date. In the same study we also found a significant relationship between aptitude and surgical skill performance (general surgery and plastic and reconstructive surgery trainees). This would indicate that these abilities are indeed fundamental and that the effects of aptitude may be masked by surgical experience but they are still present and of relevance. These results encouraged us to further explore the relationship between aptitude and surgical performance.

There are many benefits associated with the minimally invasive approach and these have been widely demonstrated. On the other hand there are specific complications associated with image based surgery. These complications and difficulties can be traced back to psychological factors. In particular there are three distinct areas that are linked to image based procedures – visual-spatial, depth perception and psychomotor. The spatial difficulties are mainly down to image distortion (due to magnification, camera view limitations, false proximity). As MIS surgery primarily occurs in cognitive space the normal physical spatial cues are of little use. In depth perception this is where the brain relies on pictorial and depth cues to reconstruct 3D detail from a 2D monitor. Finally the psychomotor difficulties can be attributed to reduced tactile feedback, the fulcrum effect and reduced movement variability.

Therefore the idea that psychological assessment could make a significant contribution in understanding the mechanisms of learning and performance in MIS is an important one. When we delved further into psychometric assessment and MIS performance we found that there was a significant association between the two. This was true for both basic and more advanced MIS tasks. We found for basic laparoscopic, endoscopic and endovascular tasks that visual-spatial, depth perception and psychomotor aptitude influenced performance. This was the case for three levels of ability – the surgical novice (medical student), the junior surgical trainee (BST) and the senior surgical trainee (HST). Interestingly the results demonstrated that the most frequent and consistent associations were for the medical students with the effect diminishing as surgical experience increased. This would indicate that for the surgical novice where a procedure is being approached for the first time and where the learning curve is the steepest the impact of psychometric factors is greatest. This idea is further supported by the fact that where a significant relationship was found between aptitude and performance in the HST group this was most commonly associated with what would be considered the more technically demanding surgical tasks. Even-though the frequency of associations between aptitude and performance in the basic MIS tasks reduced as experience increased the relationship still persisted. This led us to examine whether the effect of aptitude persists when a senior experienced trainee learns a more technically demanding procedure.

As the surgical procedure becomes increasingly complex so too do the learning challenges for the surgeon in laparoscopic techniques. In particular a protracted learning curve has been demonstrated in advanced laparoscopic techniques such as laparoscopic colectomy. We found that when we looked at a group of experienced surgical trainees and trained them in an advanced laparoscopic procedure (laparoscopic sigmoid colectomy) that aptitude still played a role in their learning curve. Although these trainees had experience in open sigmoid colectomy and basic and intermediate level MIS techniques they were relative novices with respect to laparoscopic sigmoid colectomy. The fact that visual-spatial and psychomotor aptitude still resulted in a significant association is interesting. No study to date has demonstrated an association between aptitude and a technically advanced procedure. It was also interesting to find that the volume of cases that the trainee had performed (open sigmoid colectomy, basic and intermediate laparoscopic procedures) had an effect on their laparoscopic sigmoid colectomy performance.

In addition to evaluating baseline performance in simple MIS tasks we also examined the impact of psychometric aptitude on ability to reach a set of predefined proficiency goals in laparoscopy and endoscopy. We found again that aptitude influenced the learning curve. Those trainees with a higher level of aptitude were able to reach proficiency and were able to achieve the goals in a faster time frame. A high level of aptitude shortened the steep part of the learning curve but it is also important not to dismiss the fact that each participant improved significantly with repetition. This suggests that aptitude has a role in shortening the learning curve in MIS but even those trainees with a lower baseline level are able to perform to a certain standard - they just need more time and training.

Aside from psychometric aptitude we also looked at another psychological factor – personality. It has been estimated that only 25% of the important events which occur during a surgical procedure are related to manual or technical skills and that 75% relate to human factors such as decision making (especially during crises or emergencies), communication, team work and leadership. Other human factors which are important in surgical practice include self-awareness (i.e. insight), distractibility and ability to perform under pressure.

Minimally invasive techniques are more stressful due to the additional visual spatial, perceptual and psychomotor challenges faced by the surgeon. The technical complexity of a procedure and the associated learning curve also add to the pressure to perform. Studies have shown that ability to cope with stress can affect performance outcomes in MIS. We aimed to investigate the effect of personality on ability to perform MIS tasks and performance in a stressful environment. The personality assessment tool (TAIS) we used in particular looks at ability to perform under pressure.

The first result we found was that the distribution of personality characteristics throughout a group of medical students, BST's and HST's was diverse. Unlike other studies we did not demonstrate a "surgical personality" amongst our trainees. We then evaluated seven of the TAIS profile patterns and compared them to surgical performance. The only significant result was in endoscopy. Here the results demonstrated that both distractibility and confidence significantly impacted on the number of loops formed during the colonoscopy module. The scores suggested that those trainees with a high level of confidence and a low level of distractibility performed better.

One of the limitations of the above experiment was the fact that the environment in which the participants performed the MIS tasks was without constraints, was relaxed and stress free. As the TAIS specifically measures ability to perform under pressure we concluded that we would need to better test the TAIS and this theory. When we looked at surgical performance in a stressful environment we found an association between energy levels and performance, with those trainees with a higher level of energy performing better on this task. Overall the results did not demonstrate a concrete relationship between personality and performance in a stressful environment.

Although overall our study did not demonstrate a detailed link between various personality characteristics as measured by the TAIS and surgical technical performance we believe that personality profiling still has a role in surgical training. The importance of self-monitoring and self-awareness has been demonstrated in previous studies. We believe that further research needs to be carried out to properly evaluate the role of personality in surgical performance.

The last factor that we aimed to assess was the role that certain non-surgical skills play in MIS performance. We looked specifically at three extra-curricular activities – musical ability, playing competitive sport and video game playing. Our study showed that extra-curricular activities do significantly influence ability to perform surgical tasks. In turn more specific factors such as the type of musical instrument, video game and sport played, the number of years spent playing a musical instrument and ability to achieve a distinction or prize in music all impacted on performance in various MIS tasks.

However the results seemed to suggest that with increasing experience the strength of the association diminished. This suggests that at novice level prior experience in these fields is important but as experience is gained the relationship loses its significance. However it is interesting to note that ability to achieve a musical distinction or prize was still relevant to performance in endoscopy and endovascular tasks in the group of experienced HST's. Similar to our results from evaluating aptitude and performance outcomes it would seem that the effect of baseline ability in non-surgical skills persists.

Overall the thesis has helped provide evidence of the association between psychometric, personality and non-surgical skill factors with well-established measures of MIS performance. It has consolidated substantial support for the role of these factors in the development, interpretation and performance of MIS tasks. It has demonstrated the validity of psychometric assessment as a means of evaluating potential in MIS.

What relevance does this have for surgical training? Can these findings be applied to our current training structures? By assessing the baseline fundamental ability of the surgical trainee there is the potential to identify those trainees that may require greater training time and investment when learning MIS techniques. Therefore assessing these factors has value for the training programme as it will allow the design of individualised training curricula and learning curves. It is also of value to the trainee as it allows them a degree of insight into their abilities, their strengths and weaknesses and it gives them a realistic idea of what may be required of them to reach certain goals in training. Minimally invasive procedures are fast becoming the mainstay of modern day surgery. As the demand for MIS procedures increase there will be greater pressure on training programmes and trainees to ensure proficiency based progression in these techniques. As a result the significant relationship between natural ability and technical performance will become increasingly relevant.

The main limitation of this thesis is the relatively small sample sizes used for the experiments. The decision to use a small sample size was a practical one as the subjects recruited were asked to perform a large number of tasks which were time consuming and labour intensive. As a result we were unable to use either regression analysis or factor analysis to elucidate a predictive function for the relationships between the various psychometric assessments and the measures of MIS performance. This was due to the low statistical power that would inevitably have resulted.

Another factor to consider, also related to the sample size, is the statistical limitation imposed by the use of multiple analyses. As a result this could lead to concern that some of the findings may be at risk of reflecting subgroup evaluation rather than a truly positive outcome.

In the TAIS experiment we were also limited by our relatively small sample size. The TAIS measures 16 different and specific personality characteristics. We were limited to using six summary characteristics and one specific characteristic (performance under pressure) for data analysis. Although the profile patterns that we looked at reflected the parameters that were of interest to us we feel that our results may be at risk of reflecting a generalisation rather than differentiating between the different measures of personality. Future studies involving a larger sample size could consider looking at each trait separately.

Another limitation to the thesis is that all the experiments were conducted in the simulator laboratory. We did not have any clinical aspect to our studies therefore we have not demonstrated transferability of our results to the real life setting of the operating room. It could be stated that due to this no parallels can be drawn between our simulator based conclusions and real life operating room performance.

Finally, we did not investigate performance or demonstrate the effect of aptitude on the ability to reach proficiency on an index or a complete procedure. Instead we demonstrated the impact of aptitude on basic MIS tasks. While the tasks that we used are very relevant at the early stage of the learning curve because they look at the ability of the trainee to manipulate instruments and interact with a 2D monitor it would be important to examine the influence of psychological factors (aptitude and personality) in the setting of a full procedure. This would then allow us to design procedure specific learning curves.

8.4 Future Work

One proposal for a future study is the re-evaluating of aptitude in those surgical trainees that have completed their training. This would be in order to determine if their visual spatial, perceptual and psychomotor ability have improved with training and may lay to rest the question on whether or not these abilities are truly innate.

Another future study could look at the impact of psychometric aptitude on ability to reach proficiency in specific procedures. This would then allow procedure specific learning curves to be described. Our results need to be reproduced in the day to day clinical setting of the operating room. This would give significant credence to our current findings.

Further work needs to be carried out on the TAIS and the association of personality characteristics with performance. In particular a study examining a greater sample size that is truly performing under stress would be ideal. An area that we are planning on looking at is the role of personality characteristics and performance in a human factors examination.

Appendix I. Visual-spatial Aptitude Tests

I.1 Card Rotations Test

CARD ROTATIONS TEST — S-1 (Rev.)

This is a test of your ability to see differences in figures. Look at the 5 triangle-shaped cards drawn below.

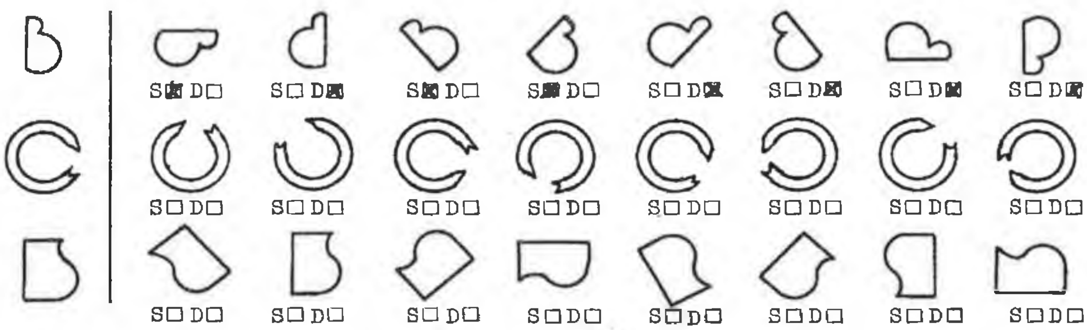
All of these drawings are of the same card, which has been slid around into different positions on the page.

Now look at the 2 cards below:

These two cards are not alike. The first cannot be made to look like the second by sliding it around on the page. It would have to be flipped over or made differently.

Each problem in this test consists of one card on the left of a vertical line and eight cards on the right. You are to decide whether each of the eight cards on the right is the same as or different from the card at the left. Mark the box beside the S if it is the same as the one at the beginning of the row. Mark the box beside the D if it is different from the one at the beginning of the row.

Practice on the following rows. The first row has been correctly marked for you.



Your score on this test will be the number of items answered correctly minus the number answered incorrectly. Therefore, it will not be to your advantage to guess, unless you have some idea whether the card is the same or different. Work as quickly as you can without sacrificing accuracy.

You will have 3 minutes for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

I.2 Cube Comparisons Test

CUBE COMPARISONS TEST -- S-2 (Rev.)

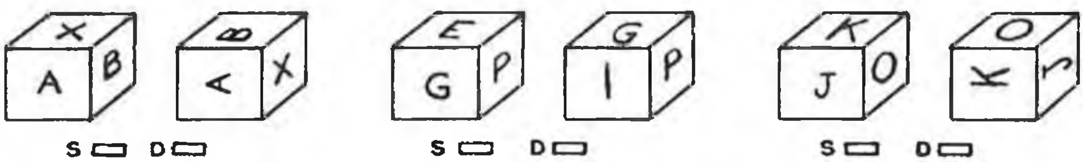
Wooden blocks such as children play with are often cubical with a different letter, number, or symbol on each of the six faces (top, bottom, four sides). Each problem in this test consists of drawings of pairs of cubes or blocks of this kind. Remember, there is a different design, number, or letter on each face of a given cube or block. Compare the two cubes in each pair below.

The first pair is marked D because they must be drawings of different cubes. If the left cube is turned so that the A is upright and facing you, the N would be to the left of the A and hidden, not to the right of the A as is shown on the right hand member of the pair. Thus, the drawings must be of different cubes.

The second pair is marked S because they could be drawings of the same cube. That is, if the A is turned on its side the X becomes hidden, the B is now on top, and the C (which was hidden) now appears. Thus the two drawings could be of the same cube.

Note: No letters, numbers, or symbols appear on more than one face of a given cube. Except for that, any letter, number or symbol can be on the hidden faces of a cube.

Work the three examples below.



The first pair immediately above should be marked D because the X cannot be at the peak of the A on the left hand drawing and at the base of the A on the right hand drawing. The second pair is "different" because P has its side next to G on the left hand cube but its top next to G on the right hand cube. The blocks in the third pair are the same, the J and K are just turned on their side, moving the O to the top.

Your score on this test will be the number marked correctly minus the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you have some idea which choice is correct. Work as quickly as you can without sacrificing accuracy.

You will have 3 minutes for each of the two parts of this test. Each part has one page. When you have finished Part 1, STOP.

DO NOT TURN THE PAGE UNTIL YOU ARE ASKED TO DO SO.

I.3 Map Planning Test

MAP PLANNING TEST — SS-3

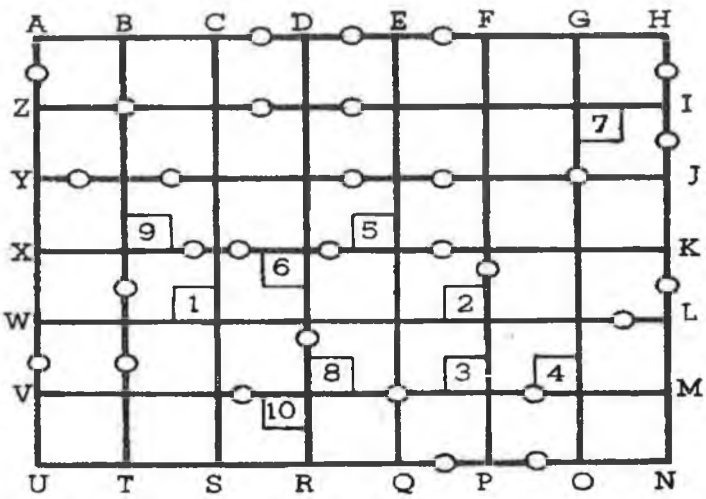
This is a test of your ability to find the shortest route between two places as quickly as possible. The drawing below is a map of a city. The dark lines are streets. The circles are road-blocks, and you cannot pass at the places where there are circles. The numbered squares are buildings. You are to find the shortest route between two lettered points. The number on the building passed is your answer.

Rules: 1. The shortest route will always pass along the side of one and only one of the numbered buildings.

2. A building is not considered as having been passed if a route passes only a corner and not a side.

3. The same numbered building may be used on more than one route.

Look at the sample map below. Practice by finding the shortest route between the various points listed at the right of the map. The first problem has been marked correctly.



The shortest route from:	Passes building:
1. A to Z	1
2. E to S	
3. P to J	
4. V to K	
5. O to F	
6. G to M	
7. D to Q	
8. F to T	

The answers to the other practice problems are as follows: 2 passes 5; 3 passes 3; 4 passes 2; 5 passes 4; 6 passes 4; 7 passes 6; 8 passes 5.

Your score on this test will be the number of right answers. It will not be to your advantage to guess unless you have some idea which route is correct. Work as rapidly as you can without sacrificing accuracy.

You will have 3 minutes for each of the two parts of this test. Each part has one page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

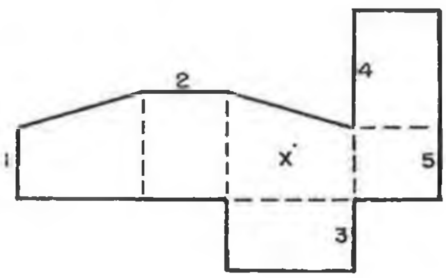
DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

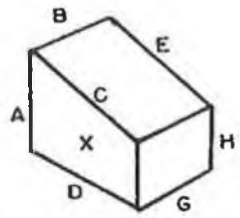
I.4 Surface Development Test

SURFACE DEVELOPMENT TEST — VZ-3

In this test you are to try to imagine or visualize how a piece of paper can be folded to form some kind of object. Look at the two drawings below. The drawing on the left is of a piece of paper which can be folded on the dotted lines to form the object drawn at the right. You are to imagine the folding and are to figure out which of the lettered edges on the object are the same as the numbered edges on the piece of paper at the left. Write the letters of the answers in the numbered spaces at the far right.

Now try the practice problem below. Numbers 1 and 4 are already correctly marked for you.





1:	H
2:	
3:	
4:	C
5:	

NOTE: The side of the flat piece marked with the X will always be the same as the side of the object marked with the X. Therefore, the paper must always be folded so that the X will be on the outside of the object.

In the above problem, if the side with edge 1 is folded around to form the back of the object, then edge 1 will be the same as edge H. If the side with edge 5 is folded back, then the side with edge 4 may be folded down so that edge 4 is the same as edge C. The other answers are as follows: 2 is B; 3 is G; and 5 is H. Notice that two of the answers can be the same.

Your score on this test will be the number of correct letters minus a fraction of the number of incorrect letters. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 6 minutes for each of the two parts of this test. Each part has 2 pages. When you have finished Part 1 (pages 2 and 3), STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Appendix II. TAIS Scales

Scale	Characteristics of People with High Scores	Characteristics of People with Low Scores
Awareness (BET)	Read the environment well & trust their intuitive abilities. React quickly & instinctively to situations. Under pressure may fail to slow down long enough to consider the consequences of their actions.	Either lack confidence in their ability to read & react to their environment or see much of what goes on in the environment as irrelevant & a distraction preferring to spend time involved in their own thoughts.
External Distractibility (OET)	Difficulty staying focused because they are unable or unwilling to filter task-irrelevant stimuli. Scores may be elevated because of lack of motivation or due to inability to identify the discriminate or task-relevant cues.	Do not become distracted by task irrelevant external stimuli.
Analytical/Conceptual (BIT)	Confident in ability to think logically, to problem solve, to see cause & effect relationships between events. Under pressure may think too much & may behave as if identifying & developing a solution to a problem is the same as implementing the solution. As a result they may take on too many problems or challenges & fail to follow through.	Either lack confidence in their analytical skills or feel that another type of concentration is more important (eg. to stay focused on the development of a particular skill).
Internal Distractibility (OIT)	Difficulty staying focused because they are unable or unwilling to inhibit their own internal, task-irrelevant thoughts & feelings.	Do not become distracted by their own task irrelevant thoughts and feelings.
Action/Focused (NAR)	Increased tolerance for repetition or redundancy. More comfortable with & find more enjoyment in practising, rehearsing & refining skills. They are concerned about quality & take pride in doing things right. Under pressure they may struggle to effectively prioritise becoming a bit rigid & inflexible in their approach to an issue or problem, getting too deep into details & not recognising when to ease up.	Lack confidence in their ability to stay focused on a task, become bored easily and try to avoid engaging in activities that are highly redundant.
Reduced Flexibility (RED)	Tendency to either become so internally focused that they lose awareness of things going on around them, or	Do not become overly focused on either external or internal stimuli. They retain the ability to make task relevant shifts from

	so externally focused & reactive that they fail to think about consequences before they act. This breakdown in the ability to shift from an external to an internal focus or vice versa can be due to a lack of motivation or lack of emotional control.	an external to an internal focus or vice versa.
Information Processing (INFP)	Quick learners, lot of energy & enjoy a challenging & changing environment. They can become bored easily & may have a tendency to take on too many challenges at one time.	More comfortable in a structured and predictable environment.
Orientation Towards Rules & Risks (BCON)	See themselves as less constrained by convention, & more willing to think outside the box. They are also less inhibited when it comes to expressing anger or frustration. Under pressure political sensitivity may become lost.	More rule bound & more controlled when it comes to expressing anger or other emotions.
Control (CON)	Both want to be in control in important situations & to see themselves as actually being in control. These respondents are willing to take initiative & to assume a leadership role. Under pressure they may have difficulty compromising or following the lead of others.	Better team players & are much less comfortable in situations where they are expected to take the initiative or lead. They perform better when they have a strong supportive leader.
Self-confidence (SES)	Feel good about themselves & have confidence in their abilities. This makes it easier for them to recover from criticism or failure. Under pressure they may have difficulty listening to or responding to criticism because their first instinct in response to a problem or disagreement is to assume that the other person must be wrong.	Lack confidence in their abilities, especially in those areas described by low scores on other TAIS scales (eg intellectual expression). Lack of confidence can lead to a downward performance spiral that is sometimes referred to as "choking".
Physical Competitiveness (PO)	Have a competitive history & enjoy head-head competition with others when physical skills are involved.	Either lack confidence in their ability to compete physically, lack the drive and motivation to compete physically or had not had the opportunity to compete. More common in women than men.
Decision-making Style (OBS)	More concerned about avoiding mistakes & being accurate than they are about failing to complete tasks on	More likely to make decisions quickly & are more willing to take the risk of making decisions with less information than

	time. Under pressure they tend to slow down the decision making process wanting to have more information before making a decision.	high scorers need. Under pressure they lack patience especially with those who tend to slow down the decision making process.
Extroversion (EXT)	Enjoy & need the company of others. They are outgoing & sociable. Under pressure their need for involvement with others may increase to the point of distracting them from tasks that require social isolation for completion.	Either not comfortable in social situations or have less of a need for involvement with others.
Introversion (INT)	Enjoy and need time alone. They are comfortable when they have to work in isolation. Under pressure they may find it difficult to reach out to & involve others in their thinking & problem solving process.	Do not have a significant need for personal space & privacy & may not be as comfortable working in isolation.
Expression of Ideas/Intellectually Competitive (IEX)	Find it easy to express their thoughts & ideas in front of others & enjoy intellectual competition. Under pressure they may find it difficult to remain quiet & to listen & to allow others to express themselves.	Either do not feel a need to express their thoughts & ideas or lack confidence in their ability to express or defend themselves.
Expression of Criticism & Anger (NAE)	Willing to confront issues in a very direct way & believe strongly that people need to face the truth. They do not hide their feelings. Under pressure they may lose the ability to find an appropriate balance between being supportive & being overly forceful or intimidating to others.	Not comfortable expressing anger or negative feelings in a direct way & believe they can accomplish more by being supportive than they can by being confrontational.
Expression of Support & Affection (PAE)	Want to receive & provide others with a lot of positive support & encouragement. They tend to motivate through the use of rewards rather than confrontation or criticism. Under pressure they may have difficulty confronting issues directly & as a result may not make tough decisions quickly enough.	Give & require relatively little in the way of positive support. They tend to be suspicious of the motives of those who give a lot of support & encouragement.
Self-critical (DEP)	Negative opinion of themselves & of their value to others. This scale tends to be more related to current moods than the other scales & high scores may suggest some type of personal crisis.	Suggest the individual is either being overly optimistic & defensive or lacks self-awareness.
Focus Over Time (FOT)	Establish goals & priorities & then make whatever	Seek more balance in their life & are unlikely to sacrifice

	sacrifices (personal/social) that may be required to accomplish these goals.	personal relationships or time with family & friends for the sake of a personal goal.
Performance Under Pressure (PUP)	Comfortable performing under pressure & want to be in a leadership or decision-making position when the pressure is on.	Not as comfortable in & do not seek out high-pressure situations.

Appendix III. Definition of Anatomy Tray Errors

Anatomy tray metric errors	**Error Definition**
Inadequate division of inferior mesenteric vein	Vessel is not: • Divided between its origin at the aorta & its first branch • Transected & the ends sealed with either a complete staple line or two laparoscopic clips • Divided completely & both free ends separated without any residual tissue remnant connecting the free ends
Inadequate division of inferior mesenteric artery	Vessel is not: • Transected completely: the free ends should not be in continuity & there should not be any remnant tissue connecting the divided ends • Sealed using a linear stapler, laparoscopic clip applier or energy delivery device • Divided at a point in proximity to the point of division of the inferior mesenteric artery & proximal to the first tributary from the colonic mesenteric arcade
Mesenteric injury	If the staple line is applied across the mesentery
Inadequate exposure of left ureter	If there is less than 1 cm of the ureter exposed
Inadequate division sigmoid mesentery	Sigmoid mesentery not: • Divided from the point of division of the inferior mesenteric artery to the start of the pelvic brim, i.e. incomplete or discontinuous line of division running from a proximal point of origin located at the point of transection of the origin of inferior mesenteric artery to the junction of the rectosigmoid mesentery • The end point of the line of transection should not be greater than 5cm from the medial aspect of the sigmoid colon and not be greater than 10cm from the right aspect of the pelvic brim
Inadequate mobilisation of left colon	If the lateral attachments of the colon are not completely divided from an origin point located 10cm from the left aspect of the pelvic brim (origin of the left lateral fold of the mesorectum) to within 10cm of the proximal lateral attachments of the descending colon at the splenic flexure (reflection of colonic mesentery from the retroperitoneum of the left paracolic gutter termed the line of Toldt). There should not be any residual retroperitoneal attachments to the colon to prevent complete lateral mobilisation following this dissection.
Inadequate mobilisation of splenic flexure	If the mesentery of the splenic flexure is not divided completely permitting the mobilisation of the splenic flexure to be brought down. The mesenteric attachments at the splenic flexure should be divided to expose the underlying retroperitoneum.

	The line of division should incorporate the point of completion of the lateral colonic mobilisation and extend for a minimum of 10cm to release the attachments of the distal aspect of the transverse colon. The line of dissection should be complete and continuous to facilitate the mobilisation of the splenic flexure.
Inadequate division of mesorectum	If the mesorectum is not divided from the point of completion of the medial division of the sigmoid mesentery to the mid-rectal point. The line of dissection should commence at the junction of the sigmoid mesentery and the origin of the mesorectum. This may be a variable point of origin as it dependent upon the point of completion of the previous medial dissection of the sigmoid mesentery. The line of dissection should extend parallel to the rectum for a minimum of 5cm and leave a >3cm fold of mesorectum intact around the upper rectum. The point of completion of the mesorectal dissection is from the terminal portion of this lateral dissection to within 1cm of the right lateral border of the rectum itself. Similarly the mesorectum should be divided on the contralateral side to complete mobilisation of the mesorectum.
Inadequate rectal transection	If the rectum is not transect completely in a line perpendicular to its longitudinal axis. The staple line should be complete and the lumen of the rectum should not be visible. The staple line should not result in a dog-ear deformity. This occurs when the stapler has been applied for a second time however the line of transection now is aimed proximally towards the sigmoid colon. The resultant dog-ear is a potential point of ischaemia and a technical error. The staple line should not include the ink-marked colonic lesion. The mesorectum should not be incorporated into the stapling line.
Inadequate anastomotic alignment	If the orientation of the descending colon and rectum is not preserved in the final anastomosis. The colorectal anastomosis should not be twisted or lie in the form of a spiral. This should be confirmed by maintaining the rectum in its normal orientation and thereafter identifying the orientation of the descending colon and tracing this orientation down to the colorectal anastomosis itself. The correct orientation of the mesentery of the descending colon maintains the mesentery located at the inferomedial aspect of the bowel. A twist or spiral of the mesentery will result in torsion of the anastomosis when traced down to the anastomosis itself.
Anastomotic tension	If the anastomosis is under excessive tension. This may occur when the lateral mobilisation is incomplete, the splenic flexure has not been mobilised or there has been a very large specimen length extracted without adequate mobilisation. The anastomosis should be capable of being lifted from the retroperitoneum without any tension for a minimum height of 10cm. The anastomosis should be capable of displacement in line with the colon for a length of 10cm in the longitudinal axis.
Anastomosis not centred	If the colorectal anastomosis is not centred in the middle of the rectal transection staple line. The anastomosis should incorporate the rectal transection staple line

	itself. The anastomosis should not incorporate the terminal ends of the rectal staple line.
Visceral injury	If there has been disruption, transection or perforation as characterised by creation of a defect in the structural integrity of the anatomy tray, of the serosa or adventitia of a hollow viscus (e.g. colon, rectum, stomach) or vessel (e.g. aorta, iliac arteries, ureters).

Appendix IV. OSATS (Objective Structured Assessment of Technical Skills)

Respect for Tissue	1 2	3 4	5
	Frequently used unnecessary force on tissue or caused damage by inappropriate use of instruments	Careful handling of tissue but occasionally caused inadvertent damage	Consistently handled tissues appropriately with minimal damage
Time and Motion	1 2	3 4	5
	Many unnecessary moves	Efficient time/motion but some unnecessary moves	Economy of movement & maximum efficiency
Instrument Handling	1 2	3 4	5
	Repeatedly makes tentative or awkward moves with instruments	Competent use of instruments although occasionally appeared stiff or awkward	Fluid moves with instruments and no awkwardness
Knowledge of Instruments	1 2	3 4	5
	Frequently used inappropriate instrument	Knew the name of most instruments & used appropriate one for the task	Obviously familiar with the instruments required & their names
Use of Instruments	1 2	3 4	5
	Consistently placed assistants poorly or failed to use assistants	Good use of assistants most of the time	Strategically used assistant to the best advantage at all times
Flow of Operation	1 2	3 4	5
	Frequently stopped operating or needed to discuss next move	Demonstrated ability for forward planning with steady progression of operative procedure	Obviously planned course of operation with effortless flow from one move to the next
Knowledge of Specific Procedure	1 2	3 4	5
	Deficient knowledge. Needed specific instruction at most operative steps	Knew all important aspects of the operation	Demonstrated familiarity with all aspects of the operation

Appendix V. List of Technical Skills Stations

General Surgery OSCE Stations	Description
Suturing of wound laceration	To close a wound with simple interrupted sutures of the appropriate size
Sapheno-femoral junction ligation	To carry out dissection of the sapheno-femoral junction and vessels; Control all tributaries and ligate and divide the sapheno-femoral junction vessels
Basic laparoscopic skills	To complete two separate tasks on the Promis simulator (Haptica, Dublin, Ireland). The first task involved the bimanual movement of beads to predefined locations and the second involved the excision of a clearly marked triangle from the upper layer of an outstretched rubber glove
Laparoscopic cholecystectomy	To carry out a laparoscopic cholecystectomy. They were also required to describe each stage of the procedure. The examiner acted as a first assistant under the instruction of the candidate
Bowel anastomosis	To carry out an end-to-end bowel anastomosis using a single layer of interrupted extra-mucosal sutures
Inguinal hernia repair	To carry out a Lichtenstein hernia repair before which they had to describe each step of the procedure
OGD	To complete an upper GI endoscopic examination and identify appropriate sedation, including dosage and potential side-effects and also to identify important anatomical structures and landmarks, such as the oesophagogastric junction, antrum, and so on (GI Mentor, Simbionix)
Colonoscopy	To carry out a full colonoscopy and identify any pathology present and then repeat the colonoscopy and carry out any intervention they felt was indicated, for example, polypectomy (GI Mentor, Simbionix)
Plastic Surgery OSCE Stations	
Arterial patch repair	To carry out an arteriotomy 1.5 cm long and trim the edges and then insert a Dacron patch
Tendon repair	To perform a Kessler repair of a divided tendon
Lipoma excision	To precisely excise a lipoma completely and close the remaining defect
Z-plasty	To plan and execute a z-plasty repair
Subcutaneous cyst excision	To complete an excision of a subcutaneous cyst with the appropriate incision and then close the wound with interrupted sutures
Flap formation	To dissect out and form a simple flap
Suturing of wound laceration	To close a wound with simple interrupted sutures of the appropriate size

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LIST OF PUBLICATIONS & PRESENTATIONS

Publications

E. Nugent, P. Neary. **"Technical skill set training in NOTES: How should we approach it?"** *J Laparoendosc Adv Surg Tech A 2011; 21(2): 107-111.*

EM. Doherty, E. Nugent. **"Personality Factors and Medical Training: A Review of the Literature".** *Med Educ 2011; 45 (2): 132-40.*

In Press

E. Nugent, DA. O'Keeffe , H. Hseino, EM. Doherty, P. Neary, O. Traynor. "**Surgical skills and aptitude assessment in applicants for surgical training."** *Submitted to American Journal of Surgery, August 2011.*

E. Nugent, H. Hseino, E. Boyle, OJ. Traynor, P. Neary. **"Learning Advanced Laparoscopic Skills: The Role of Simulation Based Training Courses."** *Submitted to Colorectal Disease, January 2011.*

E. Nugent, H. Hseino, E. Boyle, B. Mehigan, K. Ryan, OJ. Traynor, P. Neary. "**Assessment of the role of aptitude in the acquisition of advanced laparoscopic surgical skill sets: Results from a virtual reality based laparoscopic colectomy training programme."** *Submitted to International Journal of Colorectal Disease, January 2011.*

Oral Presentations

E. Nugent, H. Hseino, D. O'Keeffe, E. Doherty, BD. Dimitrov, K. Ryan, S. Tierney, AK. Hill, WA. Tanner, OJ. Traynor, P. Neary. **"Can Innate Aptitude Assessment Predict Baseline Skill in Minimally Invasive Techniques?"** *Presented at "International Conference on Surgical Education and Training, Dublin, May 2010".*

E. Nugent, H. Hseino, D. O'Keeffe, BD. Dimitrov, K. Ryan, O. Traynor, P. Neary. **"Can Innate Aptitude Assessment Predict Skill Ability in Minimally Invasive Surgery?"** *Presented at "35th Sir Peter Freyer Memorial Lecture, Galway, Sept 2010".*

E. Nugent, H. Hseino, D. O'Keeffe, E. Doherty, BD. Dimitrov, OJ. Traynor, P. Neary. **"Identifying factors that predict ease of skill acquisition in endoscopy training".** *Presented at "Irish Society of Gastroenterology Winter Meeting, Meath, Nov 2010".*

E. Nugent, H. Hseino, D. O'Keeffe, BD. Dimitrov, WA. Tanner, P. Neary, O. Traynor. **"Objective Assessment of Surgical Trainees in Selection for Higher Surgical Training: The Role of Fundamental Aptitude Testing".** *Presented at "Society of Academic and Research Surgery, Dublin, Jan 2011".*

E. Nugent, H. Hseino, N. Shirilla, A. Hafeez, OJ. Traynor, P. Neary. **"Establishing construct validity for basic laparoscopic skill sets on an augmented reality simulator."** *Presented at "36^{th} Sir Peter Freyer Memorial Lecture, Galway, Sept 2011".*

Poster Presentations

E. Nugent, H. Hseino, D. O'Keeffe, BD. Dimitrov, O. Traynor, P. Neary. **"Non-Surgical Skills – Do they Impact on Minimally Invasive Surgical Ability?"** *Presented at "35^{th} Sir Peter Freyer Memorial Lecture, Galway, Sept 2010".*

E. Nugent, E. Boyle, H. Hseino, BD. Dimitrov, B. Mehigan, K. Ryan, A. Tanner, O. Traynor, P. Neary. **"Assessment of the role of aptitude in the acquisition of advanced laparoscopic surgical skill sets: Results from a virtual-reality based laparoscopic colectomy training programme."** *Presented at "Society of Academic and Research Surgery, Dublin, Jan 2011".*

E. Nugent, H. Hseino, E. Doherty, O. Traynor, P. Neary, S. Tierney, W. Torreggiani. **"Endovascular performance: what role does psychometric aptitude play?"** *Presented at "36^{th} Sir Peter Freyer Memorial Lecture, Galway, Sept 2011".*

E. Nugent, N. Shirilla, H. Hseino, A. Hafeez, OJ. Traynor, P. Neary. **"Do case volume, surgical experience and extra-curricular activities affect laparoscopic simulator performance at expert level?"** *Presented at "36^{th} Sir Peter Freyer Memorial Lecture, Galway, Sept 2011".*

E. Nugent, H. Hseino, E. Boyle, O. Traynor, P. Neary. **"Learning Advanced Laparoscopic Skills: The Role of Simulator Based Training Courses."** Presented at "Association of Surgeons Great Britain and Ireland, Bournemouth, May, 2011".