Chapter 1

General introduction and outline of thesis
General introduction

“Learning and teaching are fundamental, implicitly or explicitly, to human adaptation, socialization, culture change, and, at the broadest level, the production and reproduction of culture and society.”

Catherine Pelissier

Learning laparoscopic surgery

Learning curve

Learning, the adaptation or change of a system in response to stimuli, is vital for the existence of humans and the social constructions in which they participate. The first scientific publication on learning and memory dates back more than a century ago. In 1885, the German psychologist Ebbinghaus practiced the memorization of nonsense syllables and was the first to identify a learning curve. He observed that the number of nonsense syllables he could remember increased substantially in the first attempts and that the improvements decreased in size as the number of attempts increased (Figure 1). Essentially, practice leads to cognitive changes that make the performance less effortful, faster and lead to less error. The by Ebbinghaus observed cognitive and psychomotor changes that occur as a response to task repetition have by some authors been referred to as one of the “biggest regularities” in human behaviour.

Figure 1: Learning curves. Blue: task with low difficulty, Red: task with high difficulty.

There are 3 different characteristics that can be distinguished in a learning curve: 1) the baseline performance; the initial performance level which can be influenced by previous experience in similar tasks, 2) the speed of skill acquisition; the shape or ‘steepness’ of the learning curve which is defined by the learning rate and 3) the learning plateau; the asymptotic part of the learning curve that is primarily defined by external factors. The characteristic phases of learning are the same in simple tasks (e.g. pushing a button) as in more complex tasks (e.g. surgery).

The learning curve can mathematically be expressed as performance level as a function of the number of repetitions of the task in a power law:

\[ Performance \ level = P - [(P - B) \times N^\alpha ] \]

,wherein P = learning plateau, B = baseline performance, N = the number of repetitions, and \( \alpha \) is the learning rate. Some state that the learning curve expressed with a power law is an artefact of
averaging the data of multiple people from multiple series and that the learning curve of an individual can better be described with an exponential law. Yet, the use of an exponential law instead of a power law does not change the above described basic characteristics of the learning curve.

Learning in surgery
Surgical trainees enter the operating room (OR) with the intention of learning as much as possible through an experience that has been highly organized to provide the best available patient care. It is through this experience that the trainee is expected to learn the skills to become a respected member of the OR team. These skills range from the technical skills needed to safely perform surgical procedures on the living human body to the understanding of the unique roles and responsibilities of the different members of the OR team. However, while the OR is a learning environment characterized by a large variety and amount of cognitive triggers, the OR experience lacks educational structure. The lack of structure can lead to much of the learning of surgical skills being based on so-called ‘discovery learning’, a self-guided learning approach that is based on the concept that effective learning requires mental efforts from the learner. Although discovery learning has been supported by psychologists that believe learning requires active involvement from the learner, findings within the last decennia suggest that pure discovery learning is associated with several problems relevant to surgical training, such as an overload of new information, misinterpretation of information leading to wrong constructions and a high learning inefficiency.

A number of studies have demonstrated that surgical education is increasingly inhibited by environmental factors that manifest themselves on different organisational levels such as work hour restrictions, an increased focus towards patient outcomes of the public and government and more complex surgical cases. One of the most well-known changes that has caused a revolution in the way that surgery is performed, but also led to difficulties in surgical education, is the introduction of laparoscopic surgery.

Laparoscopic surgery
Extensive research has shown that laparoscopic surgery has health advantages for patients such as decreased post-operative pain, minimal blood loss and superior cosmetic results. It also has important socioeconomic advantages that benefit the community as a whole such as a shorter hospital admission time and a quicker reintroduction into society. It is therefore becoming the preferred surgical technique for an increasing number of surgical procedures. On the other hand, surgeons are confronted with a list of ergonomic challenges due to an alteration of the traditional work environment during laparoscopic surgery. First, the surgeon works with instruments that have a long shaft and are inserted through holes in the abdominal wall. As a consequence, there is an inversion and scaling of the movements of the instruments inside the abdomen, a decreased degrees of freedom of movement and diminished tactile feedback from the operative field. Second, the surgeon derives visual input from a screen in the operating theatre that displays images from an angled camera inside the abdomen, also called laparoscope. This leads to a diversion of the viewing perspective of the surgeon from the work field. Third, the surgeon has to translate the 2D images of the instruments and the intra-abdominal structures on the monitor to a mental 3D representation in order to perform surgery. Fourth, to optimize the viewing perspective, the assisting surgeon or scrub nurse can change the camera angle inside the abdomen according to the preference of the operating surgeon. Changing the camera angle in respect to the work field leads to a deviation of the viewing axis of the laparoscope from the work axis of the surgeon, thereby increasing the difficulty of accurately moving the instruments inside the abdomen.

All of these ergonomic challenges have a negative effect on the learning curve for laparoscopic procedures. So, although there are some well-established advantages to laparoscopic surgery, laparoscopic procedures are more difficult to learn and teach than open procedures. As a consequence, the introduction of laparoscopic surgery has led to debates about aptitude, training and assessment in the surgical scientific community.
Teaching laparoscopic surgery

The potential of the trainee
Evidence that supports the use of aptitude assessment can be found in research findings of occupations that place high technical demands on their workforce. In aviation, aptitude testing has been used for a long time to measure flying aptitude. Aptitude testing started during World War II, when the loss of financial resources, due to the high number of applicants not passing training criteria stimulated research about the relationship between psychometrics and flying performance. The resulting Army Air Force Qualifying Examination included a combination of psychometric tests. The introduction of aptitude assessment was successful as it decreased the financial expense of training by reducing the number of candidates needed to obtain 100 pilot training graduates from 397 to 155. Later research has shown that in a considerable portion of commercial and non-commercial aviation accidents errors in visual spatial perception play an important role. Moreover, the cumulative flying experience of pilots does not appear to influence the risk of spatial disorientation during flight. It is therefore believed that flying experience does not fully compensate for a low pilot aptitude.

In North American dental education, aptitude tests were introduced in the 1950s to assist dental schools in the selection of dental students. The initial selection assignment was the Chalk Carving test in which an applicant is instructed to carve a diagram of a geometrical design into a piece of chalk. Due to logistical issues this test was replaced by a paper and pencil visual-spatial ability test in 1972. Although in dental education the dropout rate has not been as dramatic as in the army air force, a number of study findings support the use of aptitude testing, as they have shown that the visual-spatial ability test scores can predict achievement in different levels of dental education.

Although technical aptitude has long been considered irrelevant or, at least, far less important than hard work in the field of surgery, laparoscopic surgery requires different skills than open surgery. It seems that the majority of surgical trainees overcome the visual-spatial and psychomotor difficulties of laparoscopic surgery during surgical training. Yet, recent research has raised concerns about individual differences before, during and after training that might be partly dependent on differences in aptitude.

Skills lab training
Nowadays, training of laparoscopic skills most often commences in a simulated minimal invasive surgery (MIS) environment. This environment involves a virtual reality (VR) simulator or a video trainer that creates a world in which the learners can safely adopt their sensor-motor system to the challenges of the MIS work environment. In VR simulators, the interface is connected to joysticks that exhibit the same ergonomic properties as laparoscopic instruments to enable manipulation and mobilisation of objects in the VR environment. A video trainer consists of a box with holes through which a laparoscopic camera and two real laparoscopic instruments are inserted. The images of the camera are presented on a monitor. The inside of the box functions as a playground that can only be touched with the tip of the laparoscopic instruments. Thus, in contrast to the VR simulator, the video trainer provides some tactile feedback that can be used as cognitive input.

It is generally accepted that simulator training in laparoscopic surgery leads to higher baseline abilities at the time of actual surgery on patients due to a higher degree of psychomotor adaptation to the ergonomic challenges imposed by the limitations of the work environment. However, the simulator computed metrics used as measurements of improvement and proficiency criteria are often chosen by testing all psychomotor metrics of a simulator in a group of novices and a group of expert laparoscopic surgeons and selecting those that show a statistical difference between the two groups. These metrics of psychomotor skills obviously have their limitations in measuring surgical skills, leading many authors to question the validity of the training content of simulators. The criticism on this deficit in the content validity of simulators has been persistent and appears to remain relevant in the evaluation of more sophisticated simulators that mimic full laparoscopic
procedures. As a consequence, the more complex levels of behaviour that exceed the basic sensor-motor patterns, still have to be learned through experience on patients in the OR, animal tissue or on human cadavers, all of which are costly, time absorbing and subject to medico-legal and ethical concerns. To increase the proportion of learning that can be achieved in in vitro training, the full range of intra-operative surgical skills that distinguish competent surgeons from novices during in vivo laparoscopy have to be identified.

**OR training**

Whether it be a Fundamentals of Laparoscopic Surgery training program on a video trainer, training on a VR simulator or training on human cadavers, preparatory skills training is followed by supervised OR training with real patients. During supervised surgical training in the OR, supervising surgeons aim to find a balance between creating the optimal learning experience and guarding the patient safety during the operation. The success of the dyadic relationship is determined by a variety of factors.

First, whether teachers teach and assess identically can hamper the learning process as it can be confusing and frustrating for a trainee to be trained by different clinical supervisors who differ in their opinion about important aspects of the operation. The differences in opinion can impede the achievement of competence, because each teacher will teach and assess in a different way. Uniform teaching and assessment criteria based on a consensus among involved supervising clinicians is therefore important for the quality of surgical training. However, training criteria based on consensus are currently absent in Dutch laparoscopic surgery training programs.

Second, as surgeons grow in their expertise, they tend to unconsciously perform the small tasks required to achieve surgical treatment of a patient in the OR. In order to transfer the necessary skills for safe and skilful surgery to an aspiring surgeon, the teaching surgeon has to step back from unconsciously competent to consciously competent. This can be compared to teaching someone how to drive. When teaching an inexperienced driver, an experienced driver is forced to become conscious of the individual smaller steps of driving a car and has to break down the complex behaviour into small digestible actions. As the cognitive steps are clearly formulated, novices will be able to more easily acquire the necessary skills to become competent in driving a car on his/her own. The same principle applies to learning a surgical procedure. Untangling the complex behaviour during surgical procedures into small cognitive steps is necessary for creating an effective teaching curriculum in surgery.

Third, the surgeon has the role of clinical teacher and patient safety protector in the OR, a dual responsibility or double bind that imposes a dilemma for the surgeon as a response to one of the two responsibilities can have negative implications for the other. Supervising surgeons utilize different methods to attain an optimal balance between patient safety and education during a mentor-apprentice training model. The instructional design is characterized by the teaching surgeon positioning himself as the `assistant surgeon’ while exercising safety control management by giving verbal guidance in the form of corrections or orders and physical guidance by temporarily taking over the instruments. By studying this teaching model we can understand how in many studies, the complication rate of teaching cases do not differ from cases operated on by expert surgeons. Finding the right balance between patient safety and education is a complex decision making process and is essential for the success in the teaching of surgical skills.
Assessment of surgical skills
The Dutch Health Agency has observed unusual complications in patients operated on during the introduction of laparoscopic surgery. The government and public have therefore urged for effective training and objective assessment of laparoscopic skills during specialist training programs. The majority of current surgeons were trained in a training model wherein a master surgeon decides, based on his/her own perception of the necessary skills and knowledge for surgery, whether a trainee showed sufficient improvement during surgical training. For this reason, more objective assessment methods have been developed in the last decennia. These surgical assessment methods, such as the Objective Surgical Assessment of Technical Skills (OSATS) and Global Operative Assessment of Laparoscopic Skills (GOALS), force clinical supervisors to quantify the quality of the observed skills on a specific set of domains relevant to the development of surgical competence. The OSATS has become an integral part of assessment of surgical skills during specialist training programs in the Netherlands. It can be used to monitor progression during a training program and identify strengths and weaknesses in trainees. However, it cannot be used for uniform step-wise procedure specific teaching and assessment, which is, as described above, essential for the learning process of surgical trainees. Also, the OSATS is not robust with the principles of safety control management exerted by the supervising surgeon during teaching in the OR as described previously. The last and most important disadvantage, a disadvantage that seems to be associated with all global rating scales, is the insufficient inter-rater reliability of the OSATS for high stakes examinations, such as certifications for independent practice of surgical treatment.

Thesis objective
The aim of this thesis is to optimize current selection, training and assessment methods in laparoscopic surgery.
Outline of thesis

This thesis is divided into 3 parts.

Part I: Aptitude

Chapter 2 describes the different forms of aptitude tests and their power in predicting laparoscopic skills in novice and in advanced surgeons. The results of the numerous studies that investigated visual-spatial ability, psychomotor ability, perceptual ability and simulator-based assessment of aptitude are aggregated and summary correlations with laparoscopic performance of groups of participants are calculated for each form of aptitude measurement to estimate the variability in laparoscopic skills that can be accounted for by aptitude and to investigate which factors influence the correlation between aptitude assessment results and laparoscopic skills.

Part II: Training

Chapter 3 evaluates a new method to identify on-the-job challenges in the operating room. The Pareto principle, also known as the ‘80-20 rule’, is used to evaluate the verbal corrections given by surgical supervisors during training in performing a laparoscopic cholecystectomy. By analyzing the aimed corrections in behaviour, the most prevalent novice behaviours in the OR are identified for the laparoscopic cholecystectomy. The discussion in this chapter also focuses on potential methods to train the identified behaviours outside the OR.

Chapter 4 focuses on the two operation setups for the laparoscopic cholecystectomy: the French and the American position. There is a lack of evidence that one should be preferred above the other in the training of trainees. We aimed to identify an ergonomic advantage for one of the two operation setups by comparing the posture of surgeons operating in the French and the American position.

Chapter 5 focuses on developing a set of fundamental procedural steps for the laparoscopic cholecystectomy and the laparoscopic appendectomy with the help of an expert panel of abdominal surgeons.

Part III: Assessment

Chapter 6 describes important aspects of study design for estimating the inter-rater reliability of surgical skills assessment. It also addresses the interpretation and quality evaluation of inter-rater reliability calculations.

Chapter 7 describes an evaluation of the validity and reliability of an alternative assessment method to the currently used OSATS, the Global Operative Assessment of Laparoscopic Skills (GOALS).

Chapter 8 focuses on the development of a new method for the evaluation of procedural specific laparoscopic skills, independence-scaled procedural assessment, and compares this method with the OSATS and GOALS in terms of validity, reliability and support for implementation for procedural assessment.

Chapter 9 provides a general discussion on the content of this thesis and topics for future research projects.
References


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PART I: APTITUDE