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**Author:** Spruit, E.N.
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Reflections, General Discussion and Recommendations

In the current project, our main focus was to test the effectiveness of different training interventions and their impact on skill acquisition and long-term retention of laparoscopic motor skills. In the literature, there is a substantial amount of prospective studies that investigate the influence of different trainee factors on the individual aptitude to acquire laparoscopic skills.

Training Interventions

In the third chapter, we listed several interventions which may be applied in laparoscopy training. Based on an extensive survey of the relevant literature, we submit several recommendations for optimal training design for procedural motor skills, and LS in particular.

1) Surgical training models need to be validated in terms of construct and predictive validity. An expert benchmark of performance needs to be established for the different training tasks in the simulator. The markers for performance can vary among the type of model that is used, but in general we advocate objective measures that are most crucial to surgical performance. This means that we value clearly defined metrics, completion times, accuracy and force feedback over path length and subjective rating scales. The expert benchmark serves as a training goal of proficiency for each specific motor skill for trainees. Although this benchmark is determined in terms of performance, the focus in designing training should be on learning.

2) Trainees should engage in adaptive training on a spaced practice schedule. This will allow for trainees to progress in the required motor skills at their individualized pace and for optimal allocation of cognitive resources for skill acquisition and long-term retention.

3) Segmented part-task training can be applied in complex training tasks to reduce the cognitive load and facilitate learning, although more research is needed to determine the validity of this learning strategy.

4) Dual-task training conditions should be implemented to measure the degree of automatization of motor skills, as well as to provide adequate integration of multiple tasks present in the criterion task. These immersive training conditions should closely resemble the realistic transfer setting of the OR.

5) Care should be taken that there is variability in task parameters during training, as this is associated with better long-term retention of skill.

6) Training sessions ought to be spaced in order to reduce mental fatigue during training and to increase consolidation, resulting in enhanced skill acquisition and retention.
8) Mental imagery can be utilized in surgical skill acquisition to reduce the amount of time and materials required for training.

9) The curriculum should capitalize on deliberate practice of skills that require further development. By continuing to engage executive control in learning after proficiency has been reached, trainees remain engaged in the process of continual improvement that will help them make the transition to expert level in the years following their training.

In addition to these points, which were discussed in detail in the above sections, a number of additional recommendations for medical training made by Wulf et al. (2010) deserve to be cited here. Wulf et al. recommended self-controlled practice, which corresponds with learner control (Wickens, Hutchins, Carolan & Cumming, 2011) in that trainees have an influence in deciding which task they practice on. Such a strategy is consistent with the aim to adapt the training to individual competence levels, but as indicated before, trainees are not necessarily good at deciding which skill is mastered and which requires additional training.

In addition, Wulf et al. (2010) argued in favor of observational practice by dyads, which is a cost-effective way of training in which two trainees can learn from each other in pairs. Providing feedback during training can have informational, as well as motivational effects on a trainee. We emphasize the importance of self-directed feedback during the acquisition of complex LS skills. Typically, minimal instructor feedback is needed during basic tasks of low difficulty, but trainees can benefit from self-directed feedback during more difficult tasks (Strandbygaard et al., 2013). Continual feedback may help reduce cognitive load during LS tasks, but this reduction in load does not necessarily reduce the intrinsic load of a task. If an instructor tells a trainee exactly what to do during a task this is more likely to take away from germane load, which makes performing the task too easy for the trainee. This type of continual feedback will make it less likely that a trainee is actively engaged in learning the task and can lead to inaccurate estimates of competence of a trained skill (Bjork, 1999).

Integration with Empirical Chapters

Into many of these interventions, empirical studies were conducted during this research project. The use of proficiency targets we did not assess with an individual study in the current dissertation, since this training principle has been researched thoroughly in the existing literature and is evidently beneficial for trainees. We did provide all trainees in our studies with existing proficiency targets for each task and developed the training from there. In the fifth chapter, we reaffirm that the use of visual force feedback to the trainee can be used effectively to train participants in bringing down the amount of force they
exert on the training tissues. This study is unique in this dissertation in that it utilizes additional different measures besides task completion times and accuracy scores. From the data in this study, we found that force parameters reflect a different construct than the often correlated completion times and instrument path length. This highlights the use of force as an important metric for safe tissue handling skills in laparoscopy training, next to the pre-existing metrics that signify efficiency.

In the sixth chapter, we explored the feasibility of a varied practice intervention. The results of this study revealed a negative effect for the group with more variability of practice. The pattern of results suggests this was mostly the result of using inverse viewing conditions on the laparoscopic rather than the effect of frequent interleaving of training tasks. In the seventh and eighth chapter we investigated the effects of spacing practice. These interventions showed the biggest benefit for skill acquisition and retention of laparoscopic skills out of all the empirical studies that were performed during this research project. From the second spacing study, we conclude that one week of spacing is beneficial over one day. This suggests that consolidation from mere spacing (and overnight sleep) plays a bigger role in facilitating learning than the alleviating of fatigue by rest.

Finally, there are a number of studies which did not add up to a full chapter, but the results of which will be briefly mentioned here. One study tested a part-task condition (which segmented training of intra-corporeal suturing in seven smaller sub-tasks) and a mental imagery condition against a control condition. The sub-tasks consisted of: (1) correct positioning of the needle in the instrument and correct orientation of the instrument into the laparoscopic simulator; (2) inserting the needle into the foam model with the right instrument, grabbing the other end of the needle with the left instrument completing the insertion and creating the correct length of the suture with the right instrument (while keeping vision on the needle) to start knot tying; (3) switching the needle from the left to the right instrument grabbing it by the tip and achieving correct orientation of the needle in the right instrument; (4) making two loops (throws) of suture around the left instrument by moving it in a circular motion around the end of the needle where the suture is attached; (5) grabbing the end of the suture with the left instrument, letting the loops slide off slowly by pulling the right instrument (which still holds the needle); (6) switching the needle over to the left instrument in the correct orientation, making one loop (throw), grabbing the end of the suture and completing the second knot; (7) switching the needle over to the right instrument in the correct orientation, making one loop (throw), grabbing the end of the suture with the left instrument and completing the third knot (see the online video appendix in the reference list to get a visual representation of the task). The part-task group practiced each of the sub-task separately and only performed that portion of the task during that part of the training. At the later stages of training, trainees performed the whole task together.
Participants in the mental imagery condition received a hidden internet link with the instructional video’s used during training and were instructed to watch these at home in between the weekly training sessions and to mentally rehearse themselves performing all the tasks successfully, at least ten times per week.

A minor non-significant trend was observed in favor of the part-task training condition at the end of training compared to the other two conditions, but no differences were found between the mental imagery condition and control condition. It is worth noting that simulator training in its own right is already a form of part-task training, namely fractionation. Most laparoscopic simulators only train motor and perceptual skills and the training tasks are not completely comparable to surgical procedures. It is important to realize that training on a simulator that integrates more facets (perceptual, knowledge, social, technical) of laparoscopic surgery is desirable before heading on to the training in the operating room. Simulators that integrate more facets are starting to emerge, but many improvements can still be made.

In another study, we tested a set of gaming principles during laparoscopic training in order to facilitate more coaching and interpersonal communication between trainees. The experimental group were instructed that their training group was a team and it was their goal to achieve the best performance as a group, rather than an individual. Trainees were also incentivized with a prize which would be awarded to the best performing group. Prizes were awarded randomly in a control group who received the traditional training. Results indicated no significant differences between the two groups in acquisition of laparoscopic skills, but did reveal a higher rate of proactive social behavior in the experimental group. I do recommend this intervention since the application of this principle requires very little investment and benefits interaction between trainees without compromising training efficiency.

**Predictors of Laparoscopic Skills**

In each of the empirical studies performed, we measured a variety of background variables of the trainees. These variables were primarily assessed to ensure comparability between the experimental and control groups, but had a secondary purpose in that their relationship with laparoscopic skill acquisition and retention could be assessed. Over the multiple studies performed, overall results can be briefly reported. We did not find any significant correlations between sex, age, academic year, openness to experience, extraversion, conscientiousness, agreeableness, growth mindset, goal orientation, proactive social behavior, gaming and sports activity. The lack of an effect of age may be due to range restriction (most trainees were between the age of 17 and 28, predominantly in their early twenties). Overall, musical activity was correlated with performance on the laparoscopic tasks. It is not clear whether this relationship is causal (practicing a musical
instrument improves laparoscopic skills) or shares an underlying construct that influences both proficiency with musical instruments and in laparoscopic skills.

**Recommendations**

This dissertation started with an analysis of laparoscopic surgery as a complex task performed by a surgeon in the operating room. This task entails many facets, one of which was the main focus of the remainder of this dissertation, namely the motor and partially perceptual aspects of training surgical residents in laparoscopy. The main focus for the current research project was laparoscopic motor skill training, but it is important to note that other facets are equally (or perhaps more) important when developing a curriculum for surgical residents. I suggest instructors to also explore the associated literature for these remaining facets. Also, I’d like to encourage researchers to design their future studies in different facets of laparoscopy training. Specifically, I’m referring to the other important skills a surgical resident ought to develop (i.e. surgical knowledge, perceptual skills, clinical decision making, mental endurance, social skills and technical skills, see chapter 2). This would especially be valuable on the topics where research is yet scarce in this relatively young field.

Based on the research in this dissertation I recommend instructors to design training with predetermined proficiency targets on a spaced schedule with intervals of a week instead of smaller time frames. Instructors may experiment with larger spacing intervals, but more research is needed to determine the effectiveness of more time in between training sessions.

I urge instructors to be cautious in increasing training variability in training novices, since laparoscopy is already an inherently complex task and can be overwhelming at the start of training. Fractionation of training of the different facets of laparoscopic surgery may be fine initially, but training focused on skill integration is desirable at a later stage. In examination, a dual-task setup can be used to assess the degree of automatization of the acquired skills. I encourage trainers to adopt force measures and visual force feedback as an additional metric in laparoscopy training to ensure trainees not only have fluent and efficient motor skills when they finish training, but also learn how to handle different tissues safely. Different outcome metrics of laparoscopic performance (completion times and exerted force) are not highly correlated and both efficiency and safe tissue handling are essential for being an excellent laparoscopic surgeon.