Surgical Skill: Trick or Trait?

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OBJECTIVE: Among other indispensible qualities, a competent surgeon needs to be technically skilled. With the advent of minimally invasive procedures, technical demands on surgeons also increase. Will it be possible for all individuals to meet these technical demands through motivated practice or is there a trait such as "aptitude" that determines ultimate surgical skill?

DESIGN: Baseline laparoscopic psychomotor aptitude (on a box trainer), visual-spatial aptitude (Schlauch figures test), and interest in surgery (10-point Likert scale) were measured in our study group. Afterward, study participants attended a 3-hour hands-on laparoscopy training, followed by 2 additional weeks of voluntary practice for those who were motivated to do so. After these 2 weeks, participants were retested using the laparoscopic box trainer.

SETTING: All research was performed in the Center for Surgical Technologies, Leuven.

PARTICIPANTS: A total of 68 fifth-year medical students without prior experience in laparoscopy from the University of Leuven.

RESULTS: Multiple additive regression analysis showed significant effect for psychomotor aptitude (26%), interest in surgery (9%), and voluntary practice (18%) on final box trainer performance. No correlation was found between aptitude and interest in surgery ($p = 0.27$). No correlation was found between aptitude and amount of voluntary practice. High-aptitude students more frequently applied for surgical disciplines in their final career choice (50% vs 18%, $p = 0.01$).

CONCLUSIONS: This study shows that aptitude and motivated practice equally influence final box trainer performance. Students with lower aptitude do not automatically train more. Although the interest in surgery was initially not related to psychomotor aptitude, eventually students with high aptitude apply more frequently for a surgical career. (J Surg 72:1247-1253.

KEY WORDS: surgical training, laparoscopy, aptitude, motivation, voluntary practice, surgical interest

COMPETENCY: Practice-Based Learning and Improvement

INTRODUCTION

In the new era of laparoscopy, robotic surgery, and other minimally invasive developments, surgeons are more than ever facing technical challenges. Where a steady hand, good anatomic knowledge, operative judgment, and stress coping were probably the most crucial skills in the earlier days of surgery, nowadays a whole set of technical tips and tricks needs to be mastered. In the laparoscopic field, surgeons encounter obstacles such as the fulcrum effect, the loss of depth perception, and limited haptic feedback.[1,2]

Many skill laboratories and training curricula have been developed to help surgeons to acquire the necessary skills in a safe environment. Abundant evidence shows that performance on laparoscopic procedures indeed increases after practice.[2,3] This is in concordance with the "skill acquisition view" of Ericsson[4,5] postulating that practice is of capital importance for expert performance in a domain. He claims that with sufficient training, all motivated people can reach the same expert level.

Reality is that even among practicing surgeons, great differences in skill exist.[6] The popular "talent view" assumes that such differences reflect limits of achievement determined by innate abilities.[7,8] Thus, quality of performance can increase as a function of practice, but only toward a fixed upper plateau reflecting these innate traits. Consequently, innate abilities (when appropriately measured) should predict the ultimate level of performance. In the

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surgical field, there is growing evidence that traits such as innate visual-spatial and psychomotor ability might indeed determine final surgical performance.[9-18]

Our research questions: What is the relative contribution of the variables, innate ability vs motivation and voluntary practice in the acquisition of basic laparoscopic skills? To what extent are these baseline variables related?

MATERIALS AND METHODS

Among medical students, with no or little laparoscopic experience, a wide range in aptitude and interest in surgery is to be expected. Therefore, the study was performed in 68 students in the fifth year of medical training at the University of Leuven, Belgium. None of the students had hands-on experience with laparoscopy. They completed baseline testing (interest in surgery and aptitude) and consequently attended a 3-hour training session on laparoscopic skills. Next, there was a noncompulsory possibility of voluntary practice during 2 weeks after which final evaluation took place. Informed consent was obtained from all students who participated in the study. Study setup is shown in the Figure. At 2 years after study completion, the final career choice of the study subjects for specialization into surgical or other disciplines was tracked down from their files.

Baseline Testing

Students had to indicate their *interest in surgery* using a 10-point Likert scale (1 = not interested and 10 = extremely interested). For *visual-spatial aptitude*, the Schlauch figures test was administered, requiring mental visualization and manipulation of objects in 3 dimensions.[10,17] The final test score, with a maximum of 21, was defined as visual-spatial aptitude. For the measurement of *psychomotor aptitude*, a composite score of the bean drop and running string exercise (southwestern exercises[11,18]) was used in this study. Each exercise was performed 3 times on a standard Karl Storz box trainer and scored using time and errors (10 penalty seconds was added per bean or string that was dropped during the exercise). Finally a composite score (average) of these 6 measurements was calculated and defined as psychomotor aptitude (seconds).

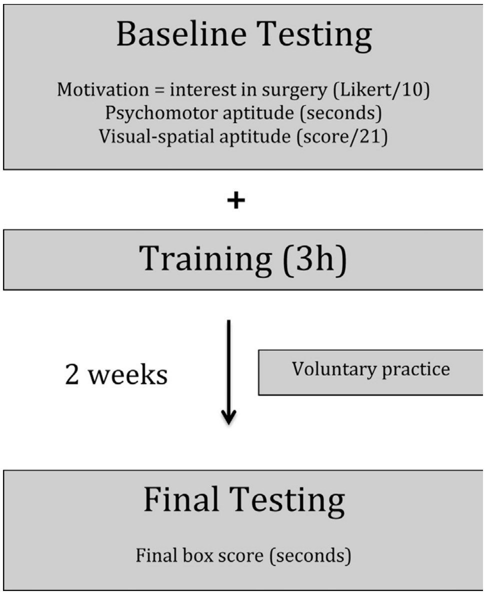

FIGURE. Study setup.

Training Session

After baseline testing, all students attended a 3-hour training session in basic laparoscopic skills. First, a theoretical introduction was given about the laparoscopic operating room installation and instruments. Afterward, students received hands-on training on several basic exercises. A total of 3 southwestern exercises (checkerboard, bean drop, and running string[19]) as well as 2 basic tasks (number 7 [cutting] and 8 [fulguration]) on the LapMentor virtual trainer (Simbionix USA Corp[20]) were performed. All these exercises were chosen because of their positive effect on operative performance.[19,20] Furthermore, the E3 bimanual coordination Laparoscopic Skills Testing and Training model exercise[21] was performed, and finally, a cystoscopy on an in vitro porcine bladder was added as real-life application. After video demonstration of the exercises, students performed independent practice supervised by a surgical research fellow. A strict time schedule was followed in order to allow every student to spend an equal amount of time performing each exercise.

Voluntary Practice

After the training session, we instructed the students to improve performance on the exercises of the training session (all but the porcine cystoscopy). For each exercise, the best scores of peers were accessible to serve as training goals.[22] Indirect feedback was readily available through the precisely defined error and time scores for each exercise as well as the written cognitive input and video demonstrations, the same as in the training session, which were permanently accessible through a specific website. We gave them the opportunity to practice during working hours (8 AM-7 PM) in the 2 weeks between the training session and the final evaluation. It was the student's own choice which and how often exercises were practiced. The number of exercises performed during these voluntary practice sessions was noted in a personal logbook and was used in all calculations as the amount of voluntary practice performed.

Final Performance

After 2 weeks, students took part in a second evaluation on the Karl Storz box trainer, as described earlier (= final box score). Before final evaluation, students were not informed about the exercises used for this evaluation.

Statistics

Data are shown as median (interquartile range). Squared Spearman correlations were used to identify relations between baseline variables. A multiple additive regression model was used to assess the effect of the predictor's aptitude, voluntary practice, and interest in surgery on final box trainer performance. Nonsignificant terms were not included in the final regression additive regression model. Partial correlations were calculated to assess the relative contribution of the variables on final performance. Students with high and low psychomotor aptitude were divided on the median. p Values lesser than 0.05 were considered significant.

RESULTS

All 68 students attended baseline testing, training session, and final performance testing. In total, 25 students (37%) performed voluntary practice. Median (interquartile range) and range (minimum-maximum) for all baseline variables as well as final performance score are shown in Table 1. Correlations between baseline variables are shown in Table 2. Visual-spatial aptitude showed significant correlation with psychomotor aptitude ($R^2 = 7.5\%$, $p = 0.02$). Interest in surgery correlated significantly with voluntary practice ($R^2 = 7.1\%$, $p = 0.03$).

The multiple additive regression model is shown in Table 3. Although simple Pearson correlation between visual-spatial aptitude and final box trainer score ($R^2 = 7.8\%$, $p = 0.02$) was significant, this variable did not show any predictive value in the multiple additive regression model ($p = 0.06$) and was therefore not included in the final model. The 3 predictors—psychomotor aptitude, interest in surgery, and voluntary practice—independently predicted final box trainer performance. The entire model showed a global predictive value (R^2) of 46%.

At 2 years after study completion, 50% of 34 high-aptitude students (score $\geq$ 104 s) applied for a surgical career, whereas this was only 18% for the 34 low-aptitude students (score $<$ 104 s). This was statistically significant ($p = 0.01$).

DISCUSSION

Over the past few years, surgeons are facing a technological revolution with the introduction of laparoscopy, robotic surgery, percutaneous techniques, etc. They have to be able to keep up with the elaborate set of technical skills that are now part of the job. According to the deliberate practice theory of Ericsson, all individuals should be able to succeed in this goal when engaging in sufficient deliberate practice.[4,5] Reality is that, even among practicing surgeons, great differences in skill exist.[6] This leads to the evident question whether it is possible to predict which individuals will become masters and to what extent this is related to aptitude or to motivation and practice.

In the Preclinical Acquisition of Basic Laparoscopic Skills, Which of the Variables, Aptitude vs Motivation and Practice, Predicts Best Which Individual Will Become an Expert?

In our study, psychomotor "aptitude" predicted roughly 25% (partial R^2) of final box trainer performance. This result confirms previous findings that psychomotor aptitude is an important determinant of laparoscopic skill[11,14-16]; in this study, it was measured 2 weeks later after voluntary practice. This does not necessarily mean individuals are born with this higher baseline skill level or that individuals are born gifted. In the 20 years that preceded this study, the students have had different exposures to video gaming,[23,24] billiard,[11] and music instrument playing,[25] all suggested predictors of baseline laparoscopic performance. Ericsson[4,5] explain that expertise is created over decades, so it might well be that an individual playing video games for the last 10 years has a significant "acquired" advantage over somebody who did not. Although visual-spatial aptitude has shown promising results in several surgical domains,[9,10,12,13] in our study, it showed no predictive value in the final additive regression model. There was a significant correlation between both types of aptitude, which does suggest that visual-spatial aptitude is reflected in baseline laparoscopic performance. Stefanidis et al.[11] found a similar correlation between initial performance on the southwestern exercises and the visual-spatial card rotation test.

TABLE 1. Median (IQR) and Range for all Baseline Variables and Final Performance Score

Variable	Median (IQR)	Range (Min-Max)
Interest in surgery (Likert/10)	6 (4.3)	1-10
Visual-spatial aptitude (score/21)	13 (4.3)	7-19
Psychomotor aptitude (seconds)	104 (39)	53-241
Voluntary practice (no. of exercises)	17 (17)*	7-47
Final box trainer score (seconds)	64 (21)	34-118

IQR, interquartile range.
*Data on the students that did perform voluntary practice (37%).

TABLE 2. Squared Spearman Correlations Between Baseline Variables

Variable 1	Variable 2	R^2 (%)	p Value
Visual-spatial aptitude	Interest in surgery	0.3	0.66
Visual-spatial aptitude	Voluntary practice	0.2	0.75
Visual-spatial aptitude	Psychomotor aptitude	**7.5**	**0.02**
Psychomotor aptitude	Voluntary practice	0.1	0.82
Psychomotor aptitude	Interest in surgery	1.9	0.27
Interest in surgery	Voluntary practice	**7.1**	**0.03**

Significant correlations ($p < 0.05$) are indicated in bold.

"Deliberate practice" in Ericsson's theory includes intrinsically motivated subjects who are instructed to improve some aspect of performance for a well-defined task while detailed immediate feedback is available and they have ample opportunities to practice.[4,5] In this study, we used the combination of "interest in surgery" assumed to reflect intrinsic motivation (doing something that is inherently pleasurable) and "amount of voluntary practice" as the best approximation of this concept. In the regression model, "deliberate practice," i.e., a combination of interest in surgery and voluntary practice, similarly predicted approximately 25% of final box trainer performance (partial R^2 of 9% and 17%). This indirectly supports data of Stefanidis et al.[11] who showed that students with lower aptitude had more learning to do but eventually reached the same expert performance. Wanzel et al.[9,13] and Kheener et al.[12] likewise showed that the influence of aptitude on performance outcome subsides by mere practice. However, it is interesting to note that effect of aptitude in this study was not leveled out after 3 hours of compulsory training and additional voluntary practice. So, even for these simple exercises, the amount of training needed to catch up might be considerable.

Is There a Correlation Between Practice and Innate Ability? Will Students Who Need More Practice Act to It?

There was no correlation between voluntary practice and innate ability, which means students with lower aptitude do not engage more frequently in voluntary practice. When the option of voluntary practice is introduced in surgical training programs, spontaneous participation is known to be very low.[25,26] Ericsson[4,5] similarly describe the phenomenon that many individuals reach a stable, mediocre level of performance instead of continuing the motivated and focused deliberate practice that could make them masters or experts in their domain. The proposed answer to this problem is supervised, proficiency-based training that ensures all individuals reach the required level of expertise.[27,28] Individuals starting with a lower psychomotor aptitude then need to perform additional training to reach these training goals.[11] Unfortunately, where proficiency-based training is pretty straightforward for basic laparoscopic exercises with clear outcomes such as time, this method is much more complex and subjective when it concerns procedural exercises[29] such as a laparoscopic gastric bypass.

Does Interest in Surgery Imply a Genuine Motivation to Participate in Voluntary Practice?

As expected, students with higher interest in surgery generally performed more voluntary practice ($R^2 = 7\%$, $p = 0.03$). However, this (rather low) relationship was not as straightforward as we expected. Both the parameters were independent predictors of final box trainer performance. This means that interest in surgery has an influence on final performance that is not only explained by the amount of voluntary practice. Probably, as Ericsson suggested, it can be explained by the effect on the quality of practice. He addressed this issue in his "deliberate practice theory," claiming motivation and focused attention constitute the most critical aspect of it.[4,5] Previous research by Koloszvari et al.[30] similarly showed that interest in a surgical career did significantly affect laparoscopic performance, with slower

TABLE 3. Multiple Additive Regression Analysis Showing the Results of the Significant Independent Predictors—Psychomotor Aptitude, Interest in Surgery, and Voluntary Practice on Final Box Trainer Performance. Partial R^2 = Correlation Between Predictor and Final Performance, Controlled for the Other Variables

Dependent Y = Final Box Score			
Independent Predictors	**Beta-Weights**	**Partial R^2 (%)**	**p Value**
Constant	75		
Psychomotor aptitude (seconds)	0.22	26	<0.001
Interest in surgery (Likert/10)	−1.73	9	0.01
Voluntary practice (no. of exercises)	−0.55	18	<0.001

rate of learning in subjects reporting low interest in a future surgical career. Maschuw et al.[31] likewise reported better performance for motivated subjects after training on a virtual simulator for a fixed period.

Are People With Higher Aptitude More Interested in Surgery?

Furthermore, interest in surgery did not show any correlation with aptitude. Apparently, the choice of becoming a surgeon does not originate from superior technical aptitude. Cope and Fenton-Lee[32] similarly found interns to have a varying inherent psychomotor ability, as judged by a virtual simulator that did not seem to have an influence on their career choice. On the contrary, Koloszvari et al.[30] found higher baseline scores for surgically interested subjects. In any case, ability or aptitude testing could be useful preclinically in positive career counseling: making students aware of their aptitude could encourage more skilled people to enter surgical disciplines.[32,33] At 2 years after study completion, a significantly higher percentage of high-aptitude students finally applied for a surgical career (50% vs 18%, $p = 0.01$). This indicates that along the way, during our training session or more realistically during surgical internship, students may become aware of their surgical aptitude and this does affect their final career choice. This finding supports the concept of early surgical exposure, leading to confrontation with one's aptitude and thus implicit positive (or negative) career counseling.

The study was prone to some limitations. Firstly, the study period was only 2 weeks, and final performance was measured as a single score instead of a learning curve. Therefore, we do not know whether a plateau of performance has been reached and how these students would evolve after abundant training. On the contrary, the exercises used were relatively simple, so significant learning should be possible within this time frame. Scott et al. described a training curriculum of all 5 southwestern exercises and showed significant improvement in performance after 5 hours of training.[23] The absence of learning curves also prevented us from identifying subjects without progression. Schijven and Jakimowicz[34] and Grantcharov[35] independently described 20% or 8.1% of subjects, respectively, who did not show progression of performance with training. They concluded that these subjects might form a subgroup that does not have the abilities to develop laparoscopic skills, in a predefined period of training. Furthermore, we used nonvalidated definitions of the baseline concepts. Previous psychomotor aptitude studies used a composite score of 5 southwestern exercises,[11,18] whereas, because of time restrictions, only 2 of 5 exercises were used in this study. On the contrary, the most important aspects of psychomotor ability, i.e., 2-handed video-eye-hand coordination and fine motor skill, are captured in these exercises.[19] We used "interest in surgery" as a measure for motivation instead of a validated motivation scale, mainly to simplify results. Given the significant results on final performance for 3 baseline parameters, we believe to have succeeded in our goal to mimic these theoretical concepts. Finally, concerning the results on final career choice, we accept the drawback of subgroup analysis and the possible risk of a type 1 error.

On the contrary, we believe that the results of this study are unique, as, to the best of our knowledge, this is the first time the question of aptitude is evaluated in combination with voluntary (instead of compulsory) practice and motivation or interest in surgery. This better mimics a real-life situation, revealing the complex interaction between these 3 parameters.

CONCLUSION

This study shows that psychomotor aptitude and motivated practice in medical students equally influence final box trainer performance. Students with lower aptitude do not automatically train more. Although the interest in surgery was initially not related to psychomotor aptitude, eventually students with high aptitude apply more frequently for a surgical career.

DISCLOSURES

Dr. Van Bruwaene, Mrs. Lissens, Mr. Lens, and Mr. Neyrinck had no conflicts of interest or financial ties to disclose. Dr. Schijven received the Dutch subsidiary "Pieken in de Delta" for enhancing patient safety through serious gaming and the Innovation subsidiary in augmented reality from the SURFnet/Kennisnet innovation program. These grants are unrelated to the research described in this article. Prof. Miserez and Dr. De Win received the OOI 2005/39 Grant for Educational Research, Development, and Implementation project from the Katholieke Universiteit Leuven. Part of the study was funded by this grant. The Center for Surgical Technologies Leuven received educational grants for training purposes by Johnson and Johnson medical, United States as well as Storz Medical. The LapMentor (Simbionix) virtual simulator was partially funded by Ethicon Inc. (Johnson and Johnson medical).

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