Perceptual Speed and Psychomotor Ability Predict Laparoscopic Skill Acquisition on a Simulator

Marleen Groenier, PhD, Klaas H. Groenier, PhD,† Heleen A.T. Miedema, MSc,* and Ivo A.M.J. Broeders, PhD*,‡*

*Department of Technical Medicine, University of Twente, Enschede, The Netherlands; †Department of General Practice, University of Groningen, University Medical Centre Groningen, Groningen, The Netherlands; and ‡Department of Surgery, Meander Medical Centre, Amersfoort, The Netherlands

OBJECTIVE: Performing minimally invasive surgery puts high demands on a surgeon's cognitive and psychomotor abilities. Assessment of these abilities can be used to predict a surgeon's learning curve, to create individualized training programs, and ultimately in selection programs for surgical training. The aim of this study was to examine the influence of cognitive and psychomotor ability on the training duration and learning rate.

DESIGN: A prospective quasiexperimental field study regarding the influence of cognitive and psychomotor ability, baseline measures of time to complete task, damage to tissue, and efficiency of movement, age, and gender on the number of sessions needed to reach a predefined performance level on a laparoscopy simulator. The same variables were investigated as predictors of the learning rate.

SETTING: The study was performed at the Experimental Center for Technical Medicine at the University of Twente, The Netherlands.

PARTICIPANTS: In all, 98 novices from the Master program of Technical Medicine followed a proficiency-based basic laparoscopic skills training.

RESULTS: Perceptual speed (PS) predicted training duration (hazard ratio = 1.578; 95% CI = 1.084, 2.300; p = 0.017). Cognitive ($b = -0.721$, p = 0.014) and psychomotor ability ($b = 0.182$, p = 0.009) predicted the learning rate of time to complete the task. Also, the learning rate for participants with higher levels of PS was lower ($b = 0.167$, p = 0.036). Psychomotor ability also predicted the learning rate for damage to tissue ($b = 0.194$, p = 0.015) and efficiency of movement ($b = 0.229$, p = 0.004). Participants with better psychomotor ability outperformed other participants across all sessions on all outcome measures.

CONCLUSIONS: PS predicted training duration in a basic laparoscopic skills training and the learning rate for the time to complete the task. Psychomotor ability predicted the learning rate for laparoscopic skill acquisition in terms of time to complete task, damage to tissue, and efficiency of movements. These results indicate early automation of basic laparoscopic skill. Careful selection of the cognitive abilities tests is advised for use in training programs and to identify individuals who need more training. (J Surg Ed 72:1224-1232. © 2015 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: laparoscopy, aptitude, learning curve, psychomotor performance

COMPETENCY: Practice-Based Learning and Improvement

INTRODUCTION

Recent developments have changed the way residents learn to perform surgery.[1] Traditionally, learning took place in the operating room (OR) but teaching time in the OR is now limited.[2] Resident and staff working hours have been reduced and advanced OR technology has changed training conditions.[1] These changes result in different operating strategies for the surgical team as well as different learning opportunities for the residents. Although the OR continues to be the most important for learning surgical skills, technical skills training for minimally invasive surgery (MIS) has increasingly moved to simulation centers. In these skills laboratories, residents can practice basic

Correspondence: Inquiries to Marleen Groenier, PhD, Faculty of Science and Technology, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands.; e-mail: m.groenier@utwente.nl

  1931-7204/$30.00 http://dx.doi.org/10.1016/j.jsurg.2015.07.006

technical skills in a safe environment on simulators. Previous studies showed that innate abilities, such as spatial awareness and short-term memory, were related to duration of training with these MIS simulators.[3-5] The current study further investigated this relationship among cognitive aptitude, psychomotor ability, the learning curve for the performance of MIS, and duration of training. In the future, training programs might be tailored to the specific abilities of individual trainees, ensuring efficient and effective means to educate future surgeons (cf. Ritter et al.[6]).

When performing MIS procedures, surgeons have to learn to adapt to ergonomic, perceptual, and psychomotor limitations,[7] resulting in a steep learning curve and high complication rates during the acquisition phase.[8] A surgeon's cognitive abilities, such as visuospatial ability (VSA) and perceptual ability, are related to the learning curve for the performance of MIS.[5,9,10] In general, the term "learning curve" refers to improvement of performance with increasing experience until a certain level of performance is achieved. Learning curves for different outcomes have been reported regarding MIS, such as patient outcome or the duration of a procedure. Higher ability has been associated with shorter training times[11-13] as well as a higher learning rate.[5,9,10] However, a review by Maan et al.[14] showed that results are mixed and depend on the type of cognitive ability measured and minimally invasive task performed. Also, cognitive ability is not a strong predictor by itself and Gallagher et al.[15] argue that the role of psychomotor ability should be investigated in combination with cognitive ability.

Psychomotor ability, i.e., the ability to control and coordinate movement, is associated with the duration of training[6,12] and positioning of objects in a virtual-reality laparoscopic task.[16] However, in most studies the effects of cognitive and psychomotor ability on MIS performance were tested separately. An exception is the study by Ritter et al.,[6] which showed that a combination of perceptual, visuospatial, and psychomotor abilities better predicted duration of training than each of these abilities did alone. Research on the relationships among cognitive ability, psychomotor ability, and instructional methods enables proficiency-based programs with automated, individualized feedback. Ultimately, it helps provide insight into who would struggle during training and who would be competent in actual clinical practice. In the future, cutoff scores for cognitive ability and psychomotor ability measured on a simulator could be identified.

In the current study this relationship among cognitive aptitude, psychomotor ability, training duration, and the learning rate is examined further. Previous research suggests that cognitive and psychomotor abilities influence the learning curve for the performance of MIS skill acquisition, measured by the duration of training[5,6] or the learning rate given a certain amount of training time (e.g., a fixed number of training sessions).[5,6,9,10] Trainees with better cognitive or psychomotor ability generally outperform trainees with poorer cognitive or psychomotor ability, although the relationship seems to depend on the type of MIS task, type of innate ability, and how skill acquisition is measured.[14]

We examined 2 aspects of skill acquisition: training duration and the learning curve for performance of MIS. Trainees' performance on a virtual-reality simulator is tracked during a 2-month proficiency-based training. Individual learning curves are modeled to examine the influence of cognitive and psychomotor ability over time. We expect that both the cognitive abilities (VSA, spatial memory [SM], perceptual speed [PS], and reasoning) and psychomotor ability uniquely contribute to the duration of training as well as to the prediction of individual learning curves for the performance of MIS, cf.[6]

MATERIALS AND METHODS

Participants

In all, 98 students from 2 cohorts (2011 and 2012) of the Technical Medicine program at the University of Twente participated in this study, 46 men and 52 women. Results from the 2011 cohort were also analyzed in a previous study.[5] Mean age of the 2 cohorts together was 22.7 years (standard deviation [SD] = 1.3, *range* = 20-26) and students were inexperienced in any kind of laparoscopic technique. In all, 9 students (9%) indicated they were left handed. All reported normal or corrected to normal vision. Participation was a required part of the curriculum. The aim of the training program was to make students aware of the importance of good hand-eye coordination in MIS. Students did not have to pass the training program and because of time constraints in the curriculum attended 6 sessions at most. An informed consent form was signed by all participants.

Materials

Cognitive Ability Tests

In all, 4 tests were chosen to represent VSA: the Mental rotation test,[17] the Paper folding test, the Surface development test (both from the Kit of factor-referenced cognitive tests[18]), and the Rotating shapes test (constructed from a stimuli set of random 2-dimensional nonsense shapes, cf. Cooper[19]). The Corsi block tapping test[20] was used as a measure of SM. The 2 tests, the Number comparison test and the Identical pictures test (both from the Kit of factor-referenced cognitive tests,[18]), were supposed to measure PS. The Raven advanced progressive matrices test[21] and a verbal reasoning test from the Groninger intelligence test (GIT)[22] were used to represent the reasoning (R) construct.