Review Article

A narrative review of psychomotor abilities in medical sciences: Definition, categorization, tests, and training

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Extensive research in the past decades has evidenced differences in the psychomotor ability of individuals resulting from varying levels of experience, age, gender, response precision, compatibility, performance, and ability. Many studies have called for the need to identify psychomotor ability and appropriate tests that can assess it. This review article surveys the definition, categorization, and tests of psychomotor ability as well as training based on psychomotor ability in medical sciences. We searched the literature with no time limit, using the ProQuest, PubMed, and Eric databases, as well as the Google Scholar search engine. The keywords for the search involved psychomotor, psychomotor performance, assessment, psychomotor ability, motor learning, education, training, psychomotor ability testing, and psychomotor skills. Other relevant papers found through hand searching and snowballing were also included in the review. The EndNote X8 was employed as a reference manager tool. Only abstracts of the papers whose full texts were accessible were reviewed after repetitious papers were excluded. The documents were categorized into five groups: definition of psychomotor skills and ability, psychomotor ability components, psychomotor ability tests, identification of psychomotor ability (task analysis), and training. This review article revealed that there is not a single definition for psychomotor ability and its components. However, it can be said that motor abilities are the foundation for the rapid acquisition of skills and according to the neuroplasticity process are learned through training and practice. Given psychomotor abilities vary among individuals, training courses should also provide different levels of psychomotor training for learners. The literature introduces psychomotor tests as a selection tool, a predictor of future professional behavior, and a means to evaluate progress in performance, academic guidance (ability-oriented medical specialty), and curriculum implementation tailored to the needs of learners of varying graduate disciplines. The tests should be profession-specific because each profession entails its peculiar characteristics and abilities. On the other hand, the major problem in studying and analyzing underlying psychomotor skills and abilities is that the components are being investigated by researchers from varying, and usually unrelated, scientific fields. Therefore, it is necessary to have a holistic view through close interaction between the researchers of different sciences to better understand this area.

Key words: Aptitude, education, motor skills, psychomotor performance

How to cite this article: Changiz T, Amouzeshi Z, Najimi A, Adibi P. A narrative review of psychomotor abilities in medical sciences: Definition, categorization, tests, and training. J Res Med Sci 2021;26:69.

INTRODUCTION

Developing psychomotor skills constitutes the primary learning outcome in almost all procedure-oriented professions.[1] Psychomotor skills involve using the psychomotor ability in doing various activities. Psychomotor ability is defined as the relative innate potential of an individual to acquire psychomotor skills upon practice. By definition, the psychomotor ability exists in an individual from birth and remains virtually unchanged throughout life. It is not substantially affected by training or other interventions.[2] However, neuroscience studies and the results from the neuroplasticity process suggest that psychomotor ability may change upon training and practice at all ages.[3,4]

The significance of psychomotor ability is evident in the following equation:

Access this article online

Quick Response Code:

Website: www.jmsjournal.net

DOI: 10.4103/jrms.JRMS_965_19

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Submitted: 20-Jan-2020; **Revised:** 31-Aug-2020; **Accepted:** 23-Mar-2021; **Published:** 30-Sep-2021

Psychomotor ability × Amount of practice = Proficiency in motor skills

Taken together, an increased practice can compensate for one's lower level of psychomotor ability and help the individual approach the desired or required proficiency level. However, if an individual's psychomotor ability is below a certain threshold, it would be virtually impossible to acquire the skills related to that ability. On the contrary, those with above-average ability can reach the highest level in the respective profession.[2]

The more rigorous climate in some professions demands proficiency in critical skills so that weakness in a skill may be associated with irreversible consequences, making the rapid acquisition of skills doubly important.[5] On the other hand, it is worth evaluating an attribute that the learner possesses at the very outset enables him or her to learn skills more quickly.[6] Therefore, it is desirable to test the psychomotor ability before one enters disciplines that require the respective abilities, such as surgery and dentistry.[5] In the Royal College of Surgeons in Ireland, the technical skills and fundamental abilities (including psychomotor skills, visuospatial ability, and depth perception) of all the shortlisted candidates are formally tested for higher surgical training. Reports on each candidate's performance are submitted to the interview committee. Besides, a database is maintained to assess the correlation of test results with the future surgical performance of the admitted candidates. It is believed that the selection for a surgery course should fit the attributes that are significant for safe and efficient surgery.[7]

When the purpose of the test is to assess a person's potential fit with a particular profession, a psychomotor test may be used for career guidance. Such tests need to comply with the requirements of the respective profession[8] because any given profession has its own characteristics and demands. In open surgery, for example, the most critical attributes that a surgeon should possess are hand–eye coordination and finger dexterity.[9] In medical ultrasound imaging, psychomotor skills (visuomotor and visuospatial) are central.[10] Core abilities (e.g., psychomotor skills, visuospatial ability, and depth perception) are vital for catheter-based interventions, natural orifice transluminal endoscopic surgery, robotic surgery, and other procedural interventions.[7] Laparoscopic surgery requires both surgical and psychomotor skills (e.g., camera navigation, hands–eyes coordination, and bimanual coordination).[9,11]

A psychomotor test is useful for monitoring learners' progress and maintaining standards.[8] Research throughout the past years has revealed differences in the psychomotor ability of individuals due to dissimilar levels of experience, age, gender, response precision, and compatibility.[7] Given that individuals may have varying degrees of psychomotor ability, training courses need to provide varying degrees of psychomotor training for learners.[2] Learning curves need to be drawn to ensure that a sufficient level of psychomotor skills is attained when designing educational and assessment programs.[12] Measuring the learning curve has potential benefits for patient safety and professional education.[13] It has applications for training and adopting new procedures and devices. The learning curve theory is based on the principle that the time required to do an activity decreases as the activity is repeated. A learning curve indicates changes in one's proficiency upon reiterating a specific skill.[14] Organizational factors (facilities and equipment), the surgical team (experience and collaboration), the complexity of the case, and characteristics of the surgeon (experience, natural abilities, motivation, etc.,) can affect one's learning curve in a particular procedure.[13,14]

Given the uncertainty and differences in competency standards, it would be significant to determine which learners need more and which require less training to attain proficiency. Alongside this, it is very contributory to assess the core abilities of learners.[15] In procedure-based medical interventions, these abilities should be evaluated in volunteers before they are introduced into the training course.[7] To sum, psychomotor abilities are the foundation for skill acquisition. Varying health professionals employ psychomotor skills as part of their professional performance. Besides, clinical teachers need to be informed of interventions that can be used to enhance the learning of these skills. Hence, this review article aimed to survey the definition, categorization, and tests of psychomotor ability as well as training based on psychomotor ability in medical sciences.

This review was designed to address the following questions:

- What is the difference between psychomotor skill and psychomotor ability?
- What are the components of psychomotor ability? How can these components be identified?
- What are the standard tests for measuring psychomotor ability in medical sciences?
- How can learners be taught based on psychomotor ability?

METHODS

We searched the literature with no time limit, using the ProQuest, PubMed, and Eric databases, as well as the Google Scholar search engine. The keywords for the search involved psychomotor, psychomotor performance, assessment, psychomotor ability, motor learning, education, training, psychomotor ability testing, and psychomotor

skills. Moreover, other relevant papers found through hand searching and snowballing were included in the review. The EndNote X8 was employed as a reference manager tool. Only abstracts of the papers whose full texts were available were reviewed after repetitious papers were excluded. Documents were categorized into five groups: definition of psychomotor skills and ability, psychomotor ability components, psychomotor ability tests, identification of psychomotor ability (task analysis), and training.

The eligibility criteria for inclusion of papers in this review were as follows:

- Paper format: Journal article, book or book section, and thesis
- Paper language: English and Persian
- Paper subject: Psychomotor education and psychomotor ability/skills in medical sciences.

To exclude nonrelevant papers, we considered the following items:

- Paper format: Anything other than journal article, book or book section, and thesis (e.g., letter to the editor, conference abstract, etc.,)
- Paper subject: Psychomotor education and psychomotor ability/skills in nonadult populations and patients.

RESULTS

Definition of psychomotor skills

Various terms are used to refer to psychomotor skills such as motor skills, technical skills, and manual skills. Psychomotor skills can be defined as skills that coordinate sensory information and muscular response when doing a given action. These skills are involved in controlling muscles through brain signals and motor nerve pathways and thereby trigger voluntary movements. The term psychomotor skill is sometimes confused with the term psychomotor ability.[16] Any skill that can express one's competence in a given activity can be improved through practice. One may require many skills, but each skill is based on a combination of relatively few fundamental abilities.[17] The psychomotor skill involves the use of the psychomotor ability to perform various activities.[2] It refers to one's ability to perform, learn, or adapt to situations that require fine and complex motor activities. This process depends on the body's sensory information about the position and movement of body organs. Kinesthetic information is derived mainly from body movements whether generated by the individual or an external force.[6]

Definition of psychomotor ability

This section deals with various definitions of psychomotor ability. Psychomotor ability refers to the process of a muscular action based directly on a mental process. It does not need to be limited to a specific activity. Psychomotor ability is the relative intrinsic potential of an individual to acquire psychomotor skills upon practice. By definition, the psychomotor ability prevails from birth and remains virtually unchanged throughout one's life. It is not substantially affected by training or other interventions.[2] Ability is an intrinsic capability that lies at the heart of every skill and is not modified by practice and experience.[16] Motor ability involves an individual's characteristics or capacities when performing motor skills, with the latter being intrinsic or acquired and stable over a long period.[18] Nevertheless, according to neuroscience studies and the neuroplasticity process, the psychomotor ability may change after training and practice at all ages.[3,4] The motor ability provides the information required for movement, interaction, and control of the body and the environment.[6] Motor abilities are the foundation for the rapid acquisition of skills, which are learned through practice and are based on innate abilities. Any individual has all the abilities, but different individuals have strengths and weaknesses in their abilities. Abilities are the underlying and limiting contributors to one's performance when doing a given activity.[17]

The term ability typically describes the human capacity to do something or to act physically or mentally, while a skill describes the level of learned proficiency to perform an activity that requires one or several abilities.[19] Psychomotor abilities may be characterized as abilities that require one to have the ability to synchronize sensorial data and strong motor coordination such that s/he can play out a decided errand.[20]

Although there is no consensus on the definition of psychomotor ability, Fowler quoting Ackerman (1988) describes this ability as: "The psychomotor domain represents an amalgamation of a family of related but independently identifiable sub-abilities. A general psychomotor ability represents individual differences predominantly in the speed of responses to test items with little or no cognitive processing demands."[21]

Individuals who have high levels of critical abilities for a particular task and spend many hours practicing it will usually achieve the highest levels of performance. In sum, the skill level that individuals ultimately achieve depends on the abilities associated with the task and the quantity and quality of their practice. In this case, research over the years has revealed that there are sharp differences in the psychomotor ability of individuals based on the variables of age, gender, dominant hand, and response precision.[22]

Categorization of psychomotor abilities

Psychomotor ability is discussed in terms of fine and gross motor functioning. However, several other factors affect this

ability, including power/force, manual dexterity, balance, movement precision, and spatial perception.[2]

Quoting from Malpass, Kaufman proposes that psychomotor functioning has three basic components: force, speed, and precision. Citing from McCarron, moreover, Kaufman enumerates four areas of motor functioning in which lies the balance of the body, including muscle power, persistent control, kinesthetic integration, and bimanual dexterity.[2]

Several factor analysis studies have been conducted to assess fundamental abilities and motor skills. Fleishman and Reilly (1992) have listed 52 human abilities in four domains: cognitive, psychomotor, physical, and perceptual sensory.[23] The psychomotor domain is often described along with three components, including perceptual-motor behavior, fine motor skills, and gross physical tasks.[24]

Psychomotor abilities, based on Fleischman's studies, include control precision, multi-limb coordination, response orientation, rate control, reaction time, arm–hand steadiness, manual dexterity, finger dexterity, wrist–finger speed, and aiming.[23,25,26] Fleishman's list, of course, is not a complete list of all the abilities associated with utilizing skills.Quoting from Edwards, Magill (2007), for example, pointed out that Fleischman's primary analysis, although extensive, does not include a wide range of skills to demonstrate critical motor abilities. It is because static balance, dynamic balance, visual acuity, visual tracking, and hand–eye or hand–foot coordination are not mentioned.[26]

The motor abilities developed by Keele *et al*. (2003) include movement speed (similar to Fleischman's speed of limb movement), movement timing, perceptual timing, and force control. Although Keele's observations are attractive and require further research, Fleischman's system remains the accepted standard and is widely used in development, industrial, ergonomic, therapeutic, educational, and physical environments.[26] It is essential to know that neither Fleischman nor Keele examined the performance of whole-body coordinated movements such as those involved in many activities of daily living. Until the motor skills are systematically studied, one can only speculate how long the final list of ability components will be.[22]

Craig presented another set of motor skill-related abilities including hand–arm steadiness, body orientation, dynamic strength, finger dexterity, the flexibility of movement, manual dexterity, multi-limb coordination, rate control, and static strength.[27]

Table 1 lists the motor abilities according to the literature review.

The following points should be noted concerning an individual's abilities.

First, one needs to understand that people have varying ability patterns, and thus, educational materials should be developed after these patterns are identified. Second, it should be recognized that the ability pattern of each individual helps him/her to outperform in certain tasks and perform less satisfactorily in other tasks. Third and last, it should be remembered that the pattern of abilities of each individual is just one of the factors involved in the performance. A useful analogy to conceptualize the role of abilities in motor performance is the "toolbox." When one is born, s/he inherits a toolbox of abilities. Individuals use

Table 1: Motor abilities according to the literature review

Motor abilities	Description
Control precision	Ability to make highly controlled movement adjustments, particularly when large muscle groups are involved
Multi-limb coordination	Ability to coordinate the movement of several limbs simultaneously
Rate control	Ability to produce continuous anticipatory movement adjustments in response to changes in the speed of a continuously moving target or object
Arm-hand steadiness	Ability to make precise arm and hand positioning movements where strength and speed are not required
Finger dexterity	Ability to manipulate small objects
Manual dexterity	Ability to manipulate relatively large objects with the hands and arms
Reaction time	The speed with which an individual can respond, using a prescribed movement, to a stimulus when it appears
Response orientation	Ability to make quick choices among numerous alternative actions often measured as choice reaction time
Wrist-finger speed	Ability to rapidly move the wrist and fingers with little or no accuracy demands
Aiming	A highly restricted type of ability that needs the making of accurate hand movements to targets under speeded conditions
Hand-foot coordination	Ability to coordinate control of foot movement with hand movement
Hand-eye coordination	Ability to coordinate control of eye movement with hand movement
Speed of limb movement	Ability to move arms or legs rapidly but without a reaction-time stimulus to reduce movement time
Balance-visual cues	Ability to maintain total body balance when visual cues are available
Static strength	Ability to use muscle force to lift, push, pull or carry objects
Flexibility of movement	Ability to apply whole-body movement in completing a task by bending, stretching, twisting, or reaching

these abilities to perform an almost unlimited number of tasks that they have to face throughout their lives. Every ability fulfills a specific purpose in a similar way that each tool is designed to serve a specific function. Any motor skill or task requires a specific set of abilities, and individuals use different combinations of their abilities for different tasks.[22]

Assessment of psychomotor ability

Psychomotor tests have been proposed in the literature as a selection tool, a predictor of future professional behavior, and a means for performance progress evaluation, academic guidance (ability-oriented medical specialty), and curriculum implementation tailored to the needs of learners of different graduate disciplines.[7,8,28,29]

Selection involves predicting whether the selected person will perform the occupation-specific tasks better than other tasks. This prediction also presumes that the person selected will outperform others who are not selected for the occupation. Choosing the right person for each profession will save time and cost, and the person him/herself will be more satisfied with the profession.[30,31]

Predicting one's chance of success in a motor skill depends on the identification and accurate measurement of the fundamental abilities to perform that skill. This skill is called the target skill. The first step is to perform a task analysis for the target skill. This analysis should identify the abilities that appear to underlie the successful implementation of the skill in question. The next step is to test the abilities identified in the task analysis using a series of tests on a large sample. Finally, the scores of the ability tests are compared with the scores on the performance of the target skill.[32]

Cuschieri and Francis maintain that while selection should be based on the identification of the required abilities, the abilities needed in the case of skilled surgical practice are still unclear. Unfortunately, most of the research published assumes that the selected psychomotor tests measure what is supposed to be relevant abilities in surgery. Most of the available aptitude tests measure abilities that do not echo the skills needed by a surgeon. Longitudinal studies are needed to approve of such tests regarding the predictive value for a competent surgical outcome. The problem of identifying the components of psychomotor ability required for surgical practice is considered a significant concern in testing a candidate for selection and admission in surgical training programs.[8]

Selection can be considered a two-way process in which not only the employer/specialty/institution selects the individual but also the individual selects the employer/specialty/institution. Thus, when the purpose of a test is to assess the potential fit between an individual and a particular profession, the psychomotor test may be used for career guidance. Tests are also useful to monitor a learner's overall progress and to maintain standards. There has been extensive research on psychomotor tests as a means of selection in dentistry. Psychomotor tests have been suggested as a means to select surgical assistants, assuming that these tests can predict proficiency in surgical skills. These types of tests must be in line with the respective profession. In the meantime, substantial research is still needed to determine the appropriate psychomotor tests that can be used to select students of medical sciences.[8]

There may be people who aim to learn a specific specialty but whose psychomotor ability is so weak that the time and resources devoted to guiding them to master the specialty during the course would not be economical. These candidates should be oriented to other disciplines during the selection process. Candidates with low levels of ability require extensive monitoring and training, but those with high ability need little training and may learn advanced skills quickly.[2]

According to the reports and facts stated above, it is time to evaluate the psychomotor abilities of candidates before admission to the training course in medical practice interventions. People with perseverance, intelligence, and commitment do not necessarily have the abilities needed to become proficient. They may not be aware of it until they reach the end of the course. This is an unpleasant event that could be prevented if their aptitudes were evaluated during their undergraduate study and if they were oriented to another medical specialty.[7]

Although the use of psychomotor tests is still controversial, Stefanidis *et al*. state that such tests seem to be more useful in predicting educational needs than selecting candidates. Specifically, the psychomotor test used in the proficiency-based laparoscopic skills training may allow educators to quantify the candidate's initial abilities and execute the curriculum based on each individual's needs.[28]

Gallagher *et al*. also state that surgery has undergone extensive changes, and surgeons and those involved in medical procedures need different skills and characteristics than before. The selection for surgery should reflect the skills and qualities that are important for surgery. It would no more suffice to reject these tests on the ground that they are not validated for surgery. Many of the tests of fundamental abilities have been, in effect, validated for surgery. Other professions, industries, and occupations in which the output plays a vital role have validated tests. It is time for surgery to address the selection of basic skills, characteristics, and abilities that predict future performance.[7]

Psychometric test data can be of high predictive value for identifying individuals who are capable of learning motor skills rapidly. The basic principles related to the psychometrics of a good test are validity and reliability. Moreover, an ideal measurement tool needs to possess each of the following characteristics: feasibility, comprehensiveness, flexibility, timeliness, accountability, relevance to the examiner and the examinee, cost-effectiveness (in terms of time and cost), availability, and history of administration.[33,34] Table 2 lists the tests related to the psychomotor domain used in medical sciences.[6,8,35-39] Attempts have been made, as far as possible, to note standard tests.

Identifying psychomotor abilities (task analysis)

Magill maintains that predicting one's chance of success in a motor skill depends on the identification and accurate measurement of the fundamental abilities to perform that skill.[32] According to the skill acquisition theory, three major abilities are required in different phases of skill acquisition (i.e., the cognitive phase, associative phase, and autonomous phase). In the cognitive phase, cognitive ability is needed to understand the procedures required for a specific task. In the associative phase, perceptual speed ability helps identify the most effective way to fulfill the task. Finally, in the autonomous phase, a learner's psychomotor ability dominates the learner's performance, with a reduced reliance upon cognitive ability. Skill acquisition theory maintains that the different phases of skill acquisition are influenced differently by the three innate abilities.[40,41] The results of Kaufman (1987) review study "Teaching surgeons to operate – Principles of psychomotor skills training" showed that although the ultimate success of the surgeon is dependent on the adequate use of psychomotor skills, the evaluation of the abilities and training of these skills are not yet systematized. The selection of a surgery candidate must be at least partially based on his/her intrinsic abilities, and his/her training should begin at a proportionate level. The procedures utilized by the learner in the future must be analyzed to determine the associated skills. These skills should be trained in a specific manner, for example, the learners can be trained initially in safe environments such as the laboratory settings, subsequently evaluated, and accordingly guided to a higher level and more advanced work.[2]

Task analysis is required to determine the psychomotor skills required to perform a specific task (which varies across disciplines). It is obligatory if the course aims to bring people to appropriate psychomotor levels. The results of task analyses are useful for guiding professional training. To do an appropriate task analysis, one needs to behaviorally analyze the role played by experts of the field in question, that is, the specific behaviors they present. Once desirable behaviors have been detected and described, these behaviors can be broken down into subcomponents for which behavioral objectives can be written.[2]

Van de Loo, as quoted by Wanzel *et al*., tried to provide a comprehensive list of the most critical aspects of surgery through comprehensive job and role analysis. He presented a list of 16 criteria, grouped into five dimensions, which could be used to predict the future performance of volunteers to surgical training. These five dimensions were intelligence (verbal, spatial, and numeric), operative skill (manual dexterity, psychomotor ability, attention, and concentration), stability *and* organization (stress tolerance, judgment, and organizational ability), work attitude (motivation, accuracy, carefulness, and energy),

Table 2: Tests related to the psychomotor domain used in medical sciences

Ability	Test
Manual dexterity	CSPDT Manual dexterity loop test The MRMT
Visuospatial ability	Space relations test MSRT Revised minnesota paper form-board test PicSOr Matrix reasoning Rey figure Map planning Cards rotation Cube comparison
Fine motor response	Tremor Purdue pegboard Finger tap Reaction time Grooved pegboard
Speed and precision	MRMT
Eye-hand coordination	Crawford small parts dexterity test part 1 (Psychological Corporation Ltd, London, England) Gibson spiral maze test (Hodder and Stoughton, London, England)

MSRT=Minnesota spatial relations test; MRMT=Minnesota Rate of Manipulation Test; CSPDT=Crawford Small Parts Dexterity Test

and cooperation (sociability, independence, self-criticism, empathy). However, the authors did not present any data on the future performance of the residents to determine the predictive validity of the system.[34]

Procedural task analysis is performed using multisource, multi-method task analysis. The steps to perform a procedural task analysis are as follows:

1. Identify the task to be analyzed
2. Identify the criterion that indicates task completion
3. Organize the successive components and steps that lead to task completion. Several methods have been proposed for organizing procedural task analysis, including:

A. Write down the necessary/obligatory steps to perform that task. Necessary steps are those that, if not performed or if performed incorrectly, inhibit the attainment of the ultimate goal
B. Observe and/or videotape the person performing the task. The doer must meet the accepted standards and be competent in the task at hand
C. Consult an expert on the task in question or use resources that indicate how the task is performed

4. Review the steps recorded in step 3 and ask about the process of task completion. This step helps identify invisible cognitive knowledge that is responsible for the behavior of the specialist
5. If more than one specialist is involved, review the findings and identify the common steps and decision points collected from steps 3 and 4
6. Identify the shortest and easiest way to complete the route
7. Identify factors that may require further or more complicated steps
8. Select the steps and conditions that best match the goals
9. Enlist the steps and decision points useful for the goal
10. Confirm the task analysis in collaboration with other specialists.[42,43]

Finally, experts can build on the task analysis approach to determine which motor components to emphasize when training.

Training

Since psychomotor abilities vary among individuals, training courses should also provide different levels of psychomotor training for learners. Each person should have adequate practice based on their level of psychomotor ability to achieve the required proficiency. It is evident that as the course concludes, learners will finish with different levels of proficiency in the psychomotor skill, depending on their psychomotor ability and practice.[2] In this regard, Stefanidis *et al*. conducted a study entitled "Psychomotor testing predicts the rate of skill acquisition for proficiency-based laparoscopic skills training." The results showed that the psychomotor test is of greater importance in predicting educational needs than selecting candidates. Specifically, for proficiency-based laparoscopic simulator training, psychomotor testing may allow instructors to quantify baseline abilities and adapt the curriculum to learners' needs.[28] Another study entitled "Perceptual, visuospatial, and psychomotor abilities correlate with duration of training required on a virtual-reality flexible endoscopy simulator" was conducted by Ritter *et al*. According to the results, the best role currently envisaged for testing learners' ability is to identify those who need more training to acquire proficiency. This results in a more efficient assignment of time and resources.[15] Another study in this area showed that the results of ability testing are strongly correlated with the time required to achieve mastery in minimally invasive surgery and endoscopy.[7] On the other hand, contemporary cognitive and motor learning texts can help teach and learn complex task-based skills.[44] It has been shown that providing a proper training program based on motor learning-related parameters can enhance the acquisition of effective skills.[16]

Until it reaches proficiency, motor learning can be recorded and displayed in the form of a learning curve. Understanding the nature of motor learning allows us to have proper planning for teaching.[45]

The learning curve is also used to train and adopt new procedures and devices.[14] The learning curve theory is based on the principle that the time required to execute an activity decreases as the activity is repeated. In fact, a learning curve depicts changes in one's proficiency upon reiterating a specific skill. The curve has three components: the starting point, the slope, and the plateau. The starting point suggests that each individual possesses his/her own experience and background that integrate and lead to his/her baseline proficiency for doing a particular procedure. The slope refers to the speed at which a person learns something and varies depending on the procedure, the person performing the procedure, and the number of times the procedure has been performed. The slope turns into a plateau when the incremental change in the desired variable is not significant. This is usually the case when one has sufficient experience in doing the task.[14]

Some caution should be taken when analyzing a learning curve. First, the term learning curve is a misnomer. A more precise description of this concept is the performance curve because learning cannot be measured directly but must be deduced from changes in performance. Second, performance curves are obtained by calculating the scores of some subjects in a trial. Thus, the curve may not accurately reflect the differences between individuals at a given trial

period or the difference in one's performance during the trial period. Moreover, stagnation in performance does not mean stagnation in learning.[34]

Standardization of variables, methods, and statistical analysis is required to draw this curve. Confounding variables such as the participant's prior experience, case complexity, procedure difficulty, and extent of supervision, among others, should be controlled. Besides, professional performance and proficiency must be precisely defined.[13]

It is worthwhile to mention that learning in the clinical setting does not follow one single track or line. Training is currently being refined so that it is implemented in a step-by-step process, based on simulation, to achieve different levels of proficiency and guided progress.[14] When the learning curve with the simulator reaches the plateau, it is time to start the procedure with the real patient. Learners have different learning curves for different activities, and the timing and number of repetitions to attain proficiency may vary among them.[12] In this new age of education, the efficient use of time and educational resources is of paramount importance.[15]

CONCLUSION

A review of the literature revealed that there is not a single definition of psychomotor ability and its components. However, it can be said that motor abilities are the foundation for the rapid acquisition of skills and according to the neuroplasticity process are learned through training and practice. Given psychomotor abilities vary among individuals, training courses should also provide different levels of psychomotor training for learners. Many studies point to the need to identify psychomotor abilities and to develop/administer appropriate tests to evaluate them. Psychomotor tests have been proposed in the literature as a selection tool, a predictor of future professional behavior, and a means for performance progress evaluation, academic guidance (ability-oriented medical specialty), and curriculum implementation tailored to the needs of learners of different graduate disciplines. On the other hand, the major problem in studying and analyzing the underlying psychomotor skills and abilities is that the components are being investigated by researchers from varying, and usually unrelated, scientific fields. Therefore, to better understand and study this area, it is necessary to have a holistic view through close interaction between the researchers of different sciences. Moreover, instructional designers and managers are advised to use psychomotor ability tests (valid and reliable tests) to select, train, and evaluate learners.

Our study has some important strengths. Our search had no time limit and was fortified by a manual search of the references of the relevant review papers. Besides, all studies were included regardless of the study design. Despite these strengths, the current study suffers from two important limitations. First, all the reviewed papers were in English and Persian, which may reflect a publication bias. Second, the quality of the papers was not assessed. Hence, there is a need for further research to remove these limitations.

Acknowledgments

The authors wish to thank the Isfahan Medical Education Research Center and the National Agency for Strategic Research in Medical Education, Tehran, Iran, for the financial support of this study.

Financial support and sponsorship

This study is a product of the project registered by Isfahan Medical Education Research Center, No. 398061, and the National Agency for Strategic Research in Medical Education, Tehran, Iran, Grant No. 981096.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Thoirs K, Coffee J. Developing the clinical psychomotor skills of musculoskeletal sonography using a multimedia DVD: A pilot study. Australas J Educ Technol 2012;28:703-18.
2. Kaufman HH, Wiegand RL, Tunick RH. Teaching surgeons to operate – principles of psychomotor skills training. Acta Neurochir (Wien) 1987;87:1-7.
3. Chang Y. Reorganization and plastic changes of the human brain associated with skill learning and expertise. Front Hum Neurosci 2014;8:35.
4. Shumway-Cook A, Woollacott MH. Motor Control: Translating Research into Clinical Practice. Philadelphia, PA: Lippincott Williams and Wilkins; 2007.
5. Whetstone TS. Enhancing psychomotor skill development through the use of mental practice. J Ind Teach Educ 1995;32:5-31.
6. Nugent E. The Evaluation of Fundamental Ability in Acquiring Minimally Invasive Surgical Skill Sets [Thesis]. Dublin: Royal College of Surgeons in Ireland; 2012.
7. Gallagher AG, Leonard G, Traynor OJ. Role and feasibility of psychomotor and dexterity testing in selection for surgical training. ANZ J Surg 2009;79:108-13.
8. Cuschieri GH, Francis NK. Psychomotor ability testing and human reliability analysis (HRA) in surgical practice. Minim Invasive Ther Allied Technol 2001;10:181-95.
9. Molinas CR, Binda MM, Sisa CM, Campo R. A randomized control trial to evaluate the importance of pre-training basic laparoscopic psychomotor skills upon the learning curve of laparoscopic intra-corporeal knot tying. Gynecol Surg 2017;14:29.
10. Nicholls D, Sweet L, Hyett J. Psychomotor skills in medical ultrasound imaging: An analysis of the core skill set. J Ultrasound Med 2014;33:1349-52.
11. Campo R, Reising C, Van Belle Y, Nassif J, O'Donovan P, Molinas CR. A valid model for testing and training laparoscopic

psychomotor skills. Gynecol Surg 2010;7:133-41.
12. Grantcharov TP, Bardram L, Funch-Jensen P, Rosenberg J. Learning curves and impact of previous operative experience on performance on a virtual reality simulator to test laparoscopic surgical skills. Am J Surg 2003;185:146-9.
13. Khan N, Abboudi H, Khan MS, Dasgupta P, Ahmed K. Measuring the surgical 'learning curve': Methods, variables and competency. BJU Int 2014;113:504-8.
14. Harrysson IJ, Cook J, Sirimanna P, Feldman LS, Darzi A, Aggarwal R. Systematic review of learning curves for minimally invasive abdominal surgery: A review of the methodology of data collection, depiction of outcomes, and statistical analysis. Ann Surg 2014;260:37-45.
15. Ritter EM, McClusky DA 3rd, Gallagher AG, Enochsson L, Smith CD. Perceptual, visuospatial, and psychomotor abilities correlate with duration of training required on a virtual-reality flexible endoscopy simulator. Am J Surg 2006;192:379-84.
16. Suksudaj N. What Factors Influence Learning of Psychomotor Skills by Dental Students? [Thesis]. University of Adelaide; 2010.
17. Dashfield AK, Smith JE. Correlating fibreoptic nasotracheal endoscopy performance and psychomotor aptitude. Br J Anaesth 1998;81:687-91.
18. Ibrahim H. Assessing General Motor Ability and Tests for Talent Identification of Malaysian Adoloescents. [Thesis]. University of Western Australia; 2009.
19. Schwibbe A, Kothe C, Hampe W, Konradt U. Acquisition of dental skills in preclinical technique courses: Influence of spatial and manual abilities. Adv Health Sci Educ Theory Pract 2016;21:841-57.
20. Khan S, Inamdar MN, Munaga S, Khare N, Farooq MU. Development of psychomotor skills in dentistry based on motor learning principles: A review. World 2020;11:248.
21. Fowler KM. Gender Differences in Mirror-Tracing Task Performance [Thesis]. Georgia Institute of Technology; 2011.
22. Schmidt RA, Wrisberg CA. Motor Learning and Performance: A Problem-Based Learning Approach. Champaign, Illinois: Human Kinetics; 2000.
23. Fleishman EA, Reilly ME. Handbook of human abilities: Definitions, measurements, and job task requirements. Palo Alto, CA: Consulting Psychologists Press; 1992.
24. Doran RL, Dietrich MC. Psychomotor abilities of science and nonscience high school students. J Res Sci Teach 1980;17:495-502.
25. Schmidt R, Lee T. Motor Learning and Performance, 5E with Web Study Guide: From Principles to Application . Champaign: Human Kinetics; 2013.
26. Edwards WH. Motor Learning and Control: From Theory to Practice. Wadsworth, Cengage Learning: Yolanda Cossio; 2010.
27. Craig M. Analysing Learning Needs. Aldershot: Gower; 1994.
28. Stefanidis D, Korndorffer JR Jr., Black FW, Dunne JB, Sierra R, Touchard CL, *et al*. Psychomotor testing predicts rate of skill acquisition for proficiency-based laparoscopic skills training. Surgery 2006;140:252-62.
29. Mitchell PB, Ostby S, Mara KC, Cohen SL, Chou B, Green IC. Career interest and psychomotor aptitude among medical students. J Surg Educ 2019;76:1526-33.
30. Waez Mousavi S. Abilities, individual differences and talent identification. Quarterly Olympic 2000;8:3-20.
31. Moglia A, Morelli L, Ferrari V, Ferrari M, Mosca F, Cuschieri A. Distribution of innate psychomotor skills recognized as important for surgical specialization in unconditioned medical undergraduates. Surg Endosc 2018;32:4087-95.
32. Magill R, Anderson D. Motor Learning and Control. 11th edition. New York: McGraw-Hill Publishing; 2016.
33. Yancosek KE, Howell D. A narrative review of dexterity assessments. J Hand Ther 2009;22:258-70.
34. Wanzel KR, Ward M, Reznick RK. Teaching the surgical craft: From selection to certification. Curr Probl Surg 2002;39:583-659.
35. da Costa Neves T, Garcia PP. Use of manual dexterity tests in dental education. J Adv Med Med Res 2018;27:1-7.
36. Gutierrez JC, Holladay SD, Arzi B, Clarkson C, Larsen R, Srivastava S. Improvement of spatial and non-verbal general reasoning abilities in female veterinary medical students over the first 64 weeks of an integrated curriculum. Front Vet Sci 2019;6:141.
37. Langlois J, Bellemare C, Toulouse J, Wells GA. Spatial abilities training in the field of technical skills in health care: A systematic review. Heliyon 2020;6:e03280.
38. Harrington CM, Dicker P, Traynor O, Kavanagh DO. Visuospatial abilities and fine motor experiences influence acquisition and maintenance of fundamentals of laparoscopic surgery (FLS) task performance. Surg Endosc 2018;32:4639-48.
39. Walker MA, MacCormick MR, Kilkenny JJ, Phillips J, Singh A, Zur Linden A. Visuospatial skills are better predictors than dexterity for basic ultrasonographic and fluoroscopic skills in veterinary students. Vet Radiol Ultrasound 2019;60:81-92.
40. Suksudaj N, Townsend GC, Kaidonis J, Lekkas D, Winning TA. Acquiring psychomotor skills in operative dentistry: Do innate ability and motivation matter? Eur J Dent Educ 2012;16:e187-94.
41. Shahriari-Rad A, Cox M, Woolford M. Clinical skills acquisition: Rethinking assessment using a virtual haptic simulator. Technol Knowl Learn 2017;22:185-97.
42. Yuen HK, D'Amico M. Deriving directions through procedural task analysis. Occup Ther Health Care 1998;11:17-25.
43. Dabbagh N. Procedural Task Analysis. Available from: http://cehdclass.gmu.edu/ndabbagh/Resources/IDKB/task_analysis.htm. [Last accessed on 2019 Aug 24].
44. Nicholls D, Sweet L, Muller A, Hyett J. Teaching psychomotor skills in the twenty-first century: Revisiting and reviewing instructional approaches through the lens of contemporary literature. Med Teach 2016;38:1056-63.
45. Ben-Gal G, Katorza L, Weiss EI, Ziv A. Testing motor learning curves among dental students. J Dent Educ 2017;81:1171-8.