Theory on Psychomotor Learning Applied to Arthroscopy

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"I hear and I forget. I see, I remember. I do, I understand." – Confucius

Take-Home Messages

- Learning to use arthroscopic instruments involves minimization of predicted and actual sensory information by tuning the internal models in our brain that represent the tasks at hand.
- As all individuals demonstrate differences in innate arthroscopic skills, the training period should vary in order to allow all trainees to achieve a preset competency level.
- Exposure to many different conditions in a training program facilitates skills learning.
- A perfect teacher is not the one who has the best ability to perform a specific motor skill but the one who has the ability to transfer a skill to a student.
- Developing "ideal" training programs for basic part task arthroscopic skills is needed to complement current residency curricula

3.1 Definitions

Sensorimotor relates to activity involving both sensory and motor pathways of the nerves (Oxford English Dictionary 2014).

(*Psycho*)*motor skill* is the potential to produce voluntary muscular movements after practice (Kaufman et al. 1987; Oxford English Dictionary 2014).

Psychomotor learning is an interaction between cognitive functions and physical activities with the emphasis on learning coordinated activity involving the arms, hands, fingers, and feet.

Efference copy is an internal copy of an outflowing, movement-producing signal generated by our human motor system (Kawato 1999; Wolpert and Miall 1996).

Internal model is a postulated neural process that simulates the response of the motor system in order to estimate the outcome of a motor command (Kawato 1999; Wolpert and Miall 1996).

3.2 Introduction

This chapter is highly interesting as it brings together theories from different fields – i.e. neuroscience, education, and arthroscopy – which combination gives insights in human performance capabilities when interacting with the environment and more specifically effectively training arthroscopic skills, the title of this book.

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Section A describes the state of the art on sensorimotor learning from a neuroscience perspective, whereas Section B discusses psychomotor skills in arthroscopic training through the science of learning.

3.3 Section A: Sensorimotor Learning from Neuroscientific Perspective

The range and complexity of the tasks involved in arthroscopy are impressive but even more so is the capacity of humans to learn the variety of precise and delicate motor skills needed to successfully perform these operative procedures (Kaufman et al. 1987). Arthroscopic instruments introduce changes in the relationship between the movements of the surgeons' hand and the tip of the instrument. The use of arthroscopic instruments challenges the operators' sensorimotor abilities, by requesting efficient gathering of the often limited and distorted sensory information and by requesting the implementation of adaptive mechanisms to perform instrument handling. Mastery of instrument handling implies that one is able to account for complex transformations, as is, for example, needed to cope with the disturbed eye-hand coordination (Miller 1985) and the uncertainties about task-relevant information when planning the movements.

When we use novel tools in everyday life, we are exposed to a new mechanical environment. The tools initially perturb our movements, but after practice, we are again able to process a certain input (the sensory information provided by our sensor organs – eyes, proprioception) to obtain the desired output (the movement of the tip of the instrument). Learning of surgical skills can be thought of as the process of mastering and adapting such sensorimotor transformations. Depending on the complexity of the transformations, this may take several hundred movements. This is reflected in the prolonged learning curves for the minimally invasive techniques, in comparison to the time needed to acquire the skills for open surgery (Atesok et al. 2012; Megali et al. 2005).

In the past decade, there have been substantial advances in our understanding of how we learn (psycho)motor skills, with models emerging from computational approaches to movement science. The following is a discussion of the main concepts for our understanding of learning surgical motor skills:

Internal models
Sensory weighting
Structural and parametric learning

These concepts will be applied to understand and explain the, often limited, transfer of learning from the training situation to the real performance in the operating room.

3.3.1 Internal Models

It is generally believed that the process of learning skilled control relies on the acquisition of models of both our own body and the instruments we interact with (Davidson and Wolpert 2003; Flanagan et al. 2003). Learning to control a new instrument (i.e., act in a novel environment) produces an "internal model" that represents the sensorimotor transformations involved in the use of the instrument. Two main classes of internal models are being distinguished: forward models and inverse models. Here, we describe how these two fundamental concepts of motor control are related to learning to handle arthroscopic instruments.

Forward internal models describe the causal relationship between our interactions with the instrument and the environment and the sensory feedback that will result from these interactions (Wolpert and Miall 1996).

In particular, they allow us to predict the sensory consequences of our actions on the basis of a copy of the motor command (i.e., efference copy) that is send to our motor system (Fig. 3.1). These predictions are essential for acquiring a training signal when learning a new task. This is elucidated with one aspect of performing an arthroscopic procedure: the scaling of visual

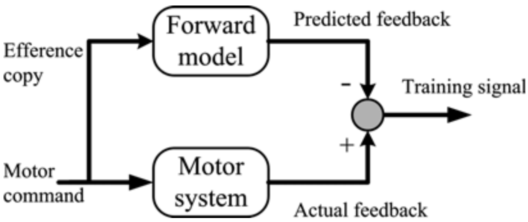

Fig. 3.1 Forward models are necessary for learning. A copy of the motor command is used to predict the sensory feedback. The prediction is compared to the actual feedback. A discrepancy in the sensory signals can be used for training

motion of the instruments seen via the two-dimensional monitor. The arthroscopic image is a zoomed-in two-dimensional projection of the surgical area, for which the exact zoomed-in scale factor is initially unknown to the trainee. As a consequence, the predicted visual motion of the instrument tip is likely to be underestimated: one moves too far. This difference between the predicted and the actual sensory information results in an error that can be used as a training signal to update the internal model (Fig. 3.1). In a subsequent repetition of this aspect, the error is likely to be smaller by generating an adapted motor command, which is sent to the involved muscles.

The second group of internal models that are relevant for understanding motor learning are known as inverse models. These models perform the opposite transformation in that they obtain the required motor command from the desired sensory consequences. Thus, when the task is to reach a visual location as seen on the monitor, one needs to compute the required hand movement in order to achieve this desired state. In the above-presented example, where the actual visual motion on the monitor screen was larger than intended, the thus generated error signal can also be used to update the inverse model and by that induce learning.

In summary, learning to use arthroscopic instruments involves both building up inverse models to control the instrument and forward models for predicting the consequences of this control. Discrepancies between predicted and actual sensory information generate an error signal that is a prerequisite for learning.

3.3.2 Sensory Weighting

The accuracy of the error signals generated with help of forward models not only depends on the accuracy of the predicted feedback but also on the accuracy of our estimate of the actual sensory information. The signals obtained from our sensors are disturbed by internal noise (i.e., in the neural transmission). However, when we have various sources of information available, then these can be optimally combined to achieve estimates that reduce the effects of noise (van Beers 2009). For instance, when moving the hand to a visual target, the location of the target and the location of the hand need to be to be determined. Both visual information and proprioceptive information contribute to estimations of the positions of the target and the hand. When information is available in both modalities, we combine these sources of information into one coherent idea of where objects are relative to ourselves.

This integration process also needs to take into account the disturbances in sensory information inflicted by external objects, such as the surgical instruments and the operative environment. In the case of arthroscopic procedures, the sensory information is often limited and distorted. Altered 30° viewing angle of the arthroscope makes that the visual and proprioceptive modalities are no longer aligned. Friction and reaction forces of the manipulated tissue often disturb the forces experienced at the handle of the instruments. Especially in the inexperienced trainees, this induces movement inaccuracy and variability.

The ability of humans to compensate for such disturbances is a well-studied phenomenon. In a wide range of tasks, it has been found that humans are still able to perform well by optimally combining sensory cues. For instance, it has been shown that the optimal use of unaligned sensory information can limit movement errors in the absence of vision (Smeets et al. 2006). These studies show that when we have knowledge about the reliability of our sensory information, we can combine different modalities together in a statistically optimal manner. Depending on the reliability of the information, different weights are assigned to the sensory signals when they are combined. Therefore, one important aspect of training arthroscopic skills may be sufficient exposure to the variable conditions that can be encountered. This enables the trainee to come to an estimate of the reliability of the sensory information that is available in the procedures. The variable conditions include different handling instruments form different companies, anatomic variations of human joints, variation in pathologies (e.g., meniscal tears), and different disturbance conditions (e.g., bleedings). An advantage of offering many variable conditions is that trainees remain motivated as they need to deal with new situations in subsequent training sessions.

The idea arises that the crucial difficulties in arthroscopic skills are much more related to a lack of experience with the large variety of disturbing sensations as opposed to a lack of experience with instrument-tissue interaction per se. This is supported by a study of Bholat and coworkers (1999) that shows that, without vision, both expert surgeons and novices are able to correctly identify object properties when using minimally invasive instruments. In this study, the movements of the instruments were not constrained so that no other external objects could affect the sensations of the subjects. Therefore, the substantial performance differences between experts and novices in arthroscopy presumably only arise, because experts are better able to discard the disturbing sensations due to their larger experience with various instruments and the compact intra-articular operative environments. As all individuals demonstrate differences in innate arthroscopic skills, the training period should vary in order to allow all trainees to achieve a preset competency level (Alvand et al. 2011; Kaufman et al. 1987).

3.3.3 Structural and Parametric Learning

Once we have learned a motor skill, such as moving arthroscopic instruments under highly zoomed-in viewing conditions, we can rapidly generalize to other surgical situations in which the field of view is scaled and movements are visually amplified, even though the scaling factor may differ. Such fast learning can presumably be accomplished by making small adjustments to the parameters of an existing internal model. This parametric learning implies that the model is already available and that only the proper parameters need to be adapted. Such adaptive learning has been reported in a large variety of motor tasks (Shadmehr et al. 2010).

One difficulty with learning to control a new instrument is that the physical properties of the instrument are initially unknown and need to be characterized first in the process of building up an internal model. An important part of this learning process is identifying the relevant inputs and outputs of the system and the transformations that define the relationship between them. Through experience with many comparable instruments, one might discover the general form of the transformations for a certain type of instrument (Braun et al. 2010). For instance, the consequence of operating through small incisions in the skin is that the movement of the hand is opposite to the desired motion of the effective part of the instrument (fulcrum effect). Such complex transformations are in essence what is learned in structural learning, whereas subsequent parametric learning would involve selecting the proper parameters for the currently used instrument (i.e., the scaling of the movements).

Evidence for structural learning comes from a study of Braun and coworkers (2009). In a series of experiments, they exposed human subjects to rotary visuomotor transformations in different virtual reality environments. The parameters of these transformations (i.e., the direction and angle of rotation) were varied randomly over many trials, but the structure of the transformation (i.e., the presence of a rotation) was always the same. Because subjects showed faster learning of such transformations after random training, they must have learned much more than the average mapping as one would expect for simple parametric learning.

Enhancement of structural learning may also be achieved by means of providing additional information about the interactions of the instruments with the environment and therefore increasing the transparency of the transformations.

For instance, previous research has shown that providing information about the orientation of the tip of the instrument improves performance in tasks performed with a minimally invasive simulator (Wentink et al. 2002). Horeman and coworkers (2012) showed that continuous visual information about exerted forces reduced the magnitude of forces used in manipulating minimally invasive instruments (see also Chap. 9). However, retention of learning with such substituted feedback is generally low.

Sülzenbrück and Heuer (2012) demonstrate that visual feedback that enhances mechanical transparency can have opposite effects on learning. It is likely that the visual feedback reduces the need to build up an accurate internal model of the instrument interactions as evidenced by the lack of improvement once the visual feedback is removed. Alternatively, substituted sensory feedback, like visual information that represents exerted forces (e.g., cognitive representations), may require additional transformations to update internal models relevant for force control. In the study of Horeman and coworkers (2012), the visual information needs to be transformed into an error signal that is suitable to train the models of the dynamics of the task. Possibly, it is more beneficial to provide error signals within the sensory modality that is relevant for the task.

In summary, training of arthroscopic skills benefits most from approaches that induce learning of the general structure of the task, the characteristics of the transformations imposed by the arthroscopic instruments. Structural learning is mostly facilitated by exposure to a variety of tasks that share this common structure. Substituted feedback enhances the transparency of the transformations and can support performance but may be less efficient for building up new internal models.

3.3.4 Transfer of Learning

In the above, we have discussed how structural learning could provide a mechanism for transfer of learning between tasks with the same task structure. Building up experience in one or more tasks often enables one to subsequently learn related tasks more rapidly. "Transfer of learning" has been demonstrated for various motor tasks (Braun et al. 2009; Seidler 2007). Unfortunately, there is still insufficient evidence for transfer of skills from surgical training programs to in vivo performance in the operating room (Modi et al. 2010; Slade Shantz et al. 2014). In surgical training often simulators, e.g., computer-controlled virtual environments, are employed as they allow precise control of the task parameters and assessment of specific performance measurements (Chap. 5). In general, these simulators mimic only part of a surgical procedure. So far, results suggest that simulator training only improves performance in the same task in the same simulator (Strom et al. 2004).

The lack of transfer can partly be explained by our ability to control a large variety of instruments with different physical characteristics. When we use different instruments, the context of our movement changes in a discrete manner. For dexterous control of the instruments, we must select the appropriate internal model on the basis of contextual cues (Fig. 3.2). However, a perfect match is rarely found, because the instrument properties may fluctuate over time (e.g., due to wear, friction), and the exact environmental conditions (e.g., the patient) may never have been encountered.

Therefore, just as we need to combine sensory information to optimally estimate our current state, we need to derive models from combinations of previously experienced situations. The central idea is that when we encounter novel situations, with unknown dynamics, we weigh the outputs of several internal models selected on the basis of sensory information, for appropriate performance (Fig. 3.2).

Crucial in the above-proposed scheme is that skilled manipulation in untrained situations requires previous exposure to many comparable contexts with various dynamics (Kording and Wolpert 2004; Wolpert and Ghahramani 2000). In contrast, an often-adopted solution in surgical training simulators is to create conditions in which the training context mimics the real

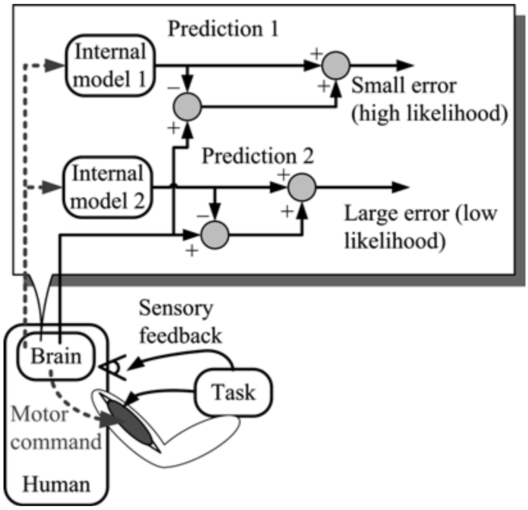

Fig. 3.2 The internal model is chosen that is most likely to predict the smallest estimation error

performance context as closely as possible and, more importantly, always with the same physical properties. The drawback of this approach is reflected in the lack of transfer of learning from one simulator to another. Albeit similar, the properties of the simulated may slightly differ so that a less effective internal model is selected.

The idea emerges that the broad repertoire of motor skills needed in the operating room can be more effectively learned when being trained in much more variable environmental conditions using a diversity of instruments. From a pragmatic perspective, such an approach also reduces the need to recreate real situations in the training setting which is probably also more cost-effective. The validity of this perspective for training of arthroscopy is illustrated by studies that compare the performance of expert surgeons and trainees on novel surgical trainers. Although expert surgeons generally display better performance than novices, the performance of experts improves with practice, as well as that of novices (Chap. 7) (Pedowitz et al. 2002; Tuijthof et al. 2011). Presumably, the learning curves of the experts reflect further optimization in the weighting process based on the sensory information that is currently experienced in this novel situation.

3.4 Section B: Psychomotor Learning from Educational Perspective

Learning and teaching have a very old history. Written records showed that ancestors of formal education were seen in Egypt around 500 B.C (Tokuhama-Espinosa 2010). Through the human history, educators tried to develop better ways of teaching. In 1956, Benjamin Bloom and a group of educational psychologists developed a classification of educational objectives known as "Bloom's Taxonomy" (Bloom et al. 1956).

Taxonomy divides educational objectives into three domains: cognitive (Fig. 3.3a), affective (Fig. 3.3b), and psychomotor. Within the domains, learning at the higher levels is dependent on having attained prerequisite knowledge and skills at lower levels. Bloom's Taxonomy guides educators to focus on all three domains, creating a holistic form of education.

Benjamin Bloom has completed his work on cognitive and affective domains, but never completed the psychomotor domain. Dave was the first to suggested simple form of the psychomotor domain in 1970 (Dave 1970) and underlined the significant role of "imitation" in psychomotor learning (Fig. 3.3c). In the 1990s, Anderson and coworkers updated the taxonomy to reflect today's educational systems (Fig. 3.3d) (Anderson et al. 2001). Examples of psychomotor skills learning in daily life include driving a car, throwing a ball, and playing a musical instrument.

As indicated in Section A, the psychomotor domain of learning is not explained by pure knowledge or experience (Rovai et al. 2009) but focuses on sensorimotor skill development involving parameters such as speed, accuracy, and grace of movement and dexterity (Anderson et al. 2001; Rovai et al. 2009). Initially, these manual tasks can be simple such as throwing a ball but can become complicated such as arthroscopic surgery. As they increase in complexity, the amount of overall skills needed to execute the task also increases. That is why psychomotor learning cannot be isolated from the cognitive domain. One should have sufficient

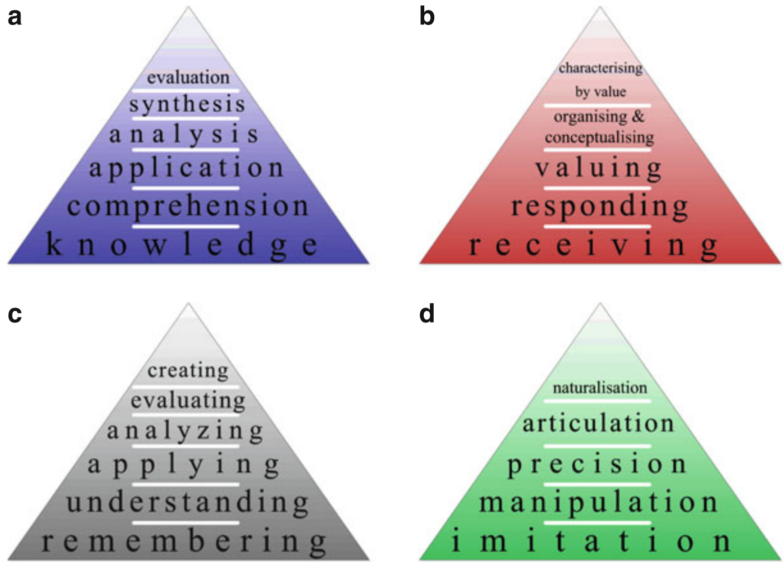

Fig. 3.3 (**a**) Levels of cognitive domain of Taxonomy in the 1950s (Bloom et al. 1956). (**b**) Levels of affective domain of Taxonomy in the 1950s (Bloom et al. 1956). (**c**) Levels of psychomotor domain of Taxonomy in the 1970s (Dave 1970). (**d**) Levels of Taxonomy updated by Anderson and coworkers in the 1990s (Anderson et al. 2001)

theoretical information about the skill that is going to be trained but also know what type of learning style in order to design an “ideal” training program to learn arthroscopic skills. In the remainder, learning styles, psychomotor acquisition models, feedback, and other elements are discussed that need to be taken into account when designing such an “ideal” training program.

3.4.1 Learning Styles

Individuals have different ways of learning. In adult learners, three types of learning styles are defined: visual, auditory and kinesthetic learners, which make up around 65, 30, and 5 % of the population, respectively (Dankelman et al. 2005). Visual learners need slide presentations, pictures, flow charts, videos, and handouts. In society, they will tend to be the most effective in written communication and symbol manipulation (Dankelman et al. 2005). Dialogues, discussions, and debates are the main tools for auditory learners, who may be sophisticated speakers. Kinesthetic learners learn effectively through touch, movement, and space; they learn skills by imitation and practice. They benefit highly from games and hands-on training sessions. A quick way to determine what learning style you have is to follow this link to the VARK-Learn questionnaire (www.vark-learn.com) (Kim et al. 2013). Training techniques and teaching programs should be designed such to accommodate the three learning styles (Windsor et al. 2008).

Learning styles of adults are also related with intelligence of the individuals. Gardner developed multiple intelligence theory to define a relation with the learning styles of individuals (Gardner 2011). According to his theory, intelligence of trainees is classified into nine categories (Table 3.1). Each person has these intelligences; however, their ratios vary from one to another. Ratios of these intelligences in a person can also change over time, because of environmental factors. This is a major obstacle in front of when trying to design an “ideal” arthroscopic teaching program.

To accommodate the learning style of individuals in respect to their intelligences, a pre-course evaluation would be useful. MIDAS stands for Multiple Intelligences Developmental Assessment Scale (www.miresearch.org) that is a self-administered questionnaire to define the learning styles of individuals before starting a

Table 3.1 Details of the Gardner's multiple intelligences (Gardner 2011)

Multiple intelligence type	Incorporated into subject matter	Way of demonstrating understanding
Linguistic	Books, stories, speeches, author visits	Writing stories, scripts, storytelling
Logical	Exercises, drills, problem solving	Calculating, theorizing, demonstrating, computer programming
Musical	Tapes, CDs, concert going	Performing, singing, playing, composing
Visual-spatial	Posters, art work, slides, charts, graphs, videos, museum visits	Drawing, illustrating, collage making, photography
Bodily kinesthetic	Movies, animations, exercises, physicalizing concepts	Dance recital, athletic performance or composition
Interpersonal	Teams, group work, specialist roles	Debates, panels, group work
Intrapersonal	Reflection time, meditation exercises	Journals, diaries, habits, personal growth
Naturalist	Aquariums, pets, farm, nature walks, museum visits	Collecting, classifying, caring for animals and nature
Existential	Working on causes, charity work	Community service

training program (Shearer 1998). By using MIDAS, trainees' primary, secondary, and tertiary intelligences can be identified prior to a course; in the long run, this can be helpful to design specific training programs, perhaps even per learning style. In a previous study among surgeons, it was shown that trainees with a primary "bodily kinesthetic" intelligence were the best performers in laparoscopic tasks (Windsor et al. 2008). Thus, knowing once learning style is a prerequisite for both trainee and teacher to achieve an optimal learning experience.

3.4.2 Psychomotor Learning Education Models

Fitts and Posner proposed a three-stage model of learning psychomotor skill (Fitts and Posner 1967):

Cognitive Stage

In the cognitive stage, tasks are well defined, and appropriate consecutive actions are listed needed to accomplish the task goals. This stage usually interacts with the knowledge of the trainee. In other words, one must have enough theoretical information to complete the cognitive stage. Characteristic of this stage is that the trainee must think about the execution of each action before doing so, which results in slow and intermittent actions.

Associative Stage

Once the cognitive stage is accomplished, the trainee can focus on the details of the actions to achieve task completion. In this transient associative stage, the required actions are split into simple sensorimotor skills, and smooth transition between these skills is exercised. This results in a decrease of the time consumed for thinking about the action, but actions are not fluent yet.

Autonomic Stage

The final stage is the autonomous stage, in which the trainee can perform the necessary sensorimotor skills fluently and completes predefined task goals in an optimal or efficient manner. Thus, the trainee does not need to spend time to think about the action and demonstrate a fluent skill.

A characteristic feature of this three-stage model is that the initial stages have a rapid progression whereas slowly progress to the autonomic stage. Simpson described more detailed stages of psychomotor learning connected to teaching strategies (Simpson 1972). This psychomotor learning model consists of (1) perception, (2) ability to perform a specific task by the guidance of a supervisor, (3) ability to perform a specific task without supervision, (4) ability to perform a complex pattern of simple tasks, (5) ability to respond to new situations by altering the action plan, and (6) ability to develop new action plans. This model represents the transformation of a rookie to a pro, as can also be seen in the

Global Rating Scales scoring forms (Appendices 13A-E). According to Van Merriënboer and coworkers, one should be careful not to assume that learning of a complex task is the sum of part tasks, because it also includes the ability to coordinate and integrate those parts (Merrienboer et al. 2002). This latter is basically already applied in the residency curricula of arthroscopy, as training in the operating room requires this form of integration, which is reflected in the holistic type of performance monitoring (Chap. 14). However, part task training is especially needed, when certain actions need to be automated. This is where basic skills training in simulated environments can play a central role in increasing learning efficiency of psychomotor skills.

3.4.3 Preconditions for a Training Program of Basic Arthroscopic Skills

In today's surgical education, most of the endoscopic skills are practiced on real patients. Studies showed that a surgeon may need 15–100 cases to reach proficiency which may take quite a time on clinical setup (American Board of Internal Medicine 1991; Eversbusch and Grantcharov 2004; Hawes et al. 1986; Hoppe et al. 2014; O'Neill et al. 2002). The difficulty of teaching in a clinical setup as it resembles the highest level of task complexity forced medical educators to seek different and effective training tools. Until recently, the abovementioned basic skills training has not been given a lot of attention. That is why it will have the focus in the remainder of this section. Several important preconditions are discussed that need to be taken into account when design the "ideal" basic training program.

In other fields that require psychomotor skills training such as sports and playing a music instruments, the abovementioned theories have been used to design different educational programs. The general approach has been to divide a complex task into basic pat tasks. For example, when training basketball players, basic skills such as dribbling and passing are thought before full court playing. In archery, one must exercise inspiration techniques and hand-eye coordination before shooting. Another program involving this kind of stepped skill teaching has been successfully used in music students (Neiman 1989).

3.4.4 Define Basic Skills

Nowadays, information on the science of learning and education gradually is being applied in residency training. To use or adapt previous studies and knowledge about psychomotor learning to arthroscopic training, a first crucial step would be the unambiguous definition of the basic skills that is needed for the arthroscopic tasks. In the current literature, basic skills are not standardized; many others can be added. In a different study, Suksudaj and coworkers tested different psychomotor skills and showed that tracing is an important basic skill among dental students, which is correlated with performances (Suksudaj et al. 2012). Neequaye and coworkers showed basic components of endovascular surgical procedures (Neequaye et al. 2007). Chapter 2 presents data that can be used to fulfill this precondition for arthroscopy as well. When defining such basic skills, one must consider the basic components of endoscopic surgery. The main differences between endoscopic surgeries and open surgeries are loss of binocularity, loss of tactile feedback, the *fulcrum effect* of portals (as mentioned in Section A), and the need for triangulation. Two-dimensional monitors are used in endoscopic surgeries, and this leads to the loss of binocularity. Loss of binocularity means that you lose substantial part of your depth perception. Tactile feedback is a very important cue in open surgery as surgeons use it to discriminate between normal and pathologic tissues. During endoscopic surgeries, tactile feedback is substantially decreased because of the instruments such as probes that act as interface between the hand of the surgeon and the tissue. This implies that surgeons need to rely more on the visual impression behavior of tissue when probing. A characteristic of experienced endoscopic surgeons is their ability of anticipation to this new environment to cope with the lost or disturbed cues.

The last important difference, the *fulcrum effect*, is caused by the portal dependency in endoscopic surgeries (Gallagher et al. 2009). This reverse relation causes a visual proprioceptive conflict for the surgeon's brain (Gallagher et al. 2005). As this effect is so different from interactions with our environment in daily lives, this conflict consumes a significant time for the surgeon to adapt. Bilateralism and triangulation are helpful to overcome the fulcrum effect.

The abovementioned basic skills can be exercised in training simulators as presented in Chaps. 3, 4, and 5. So the training means are available, the next step would to design validated exercises to train them and to extend the arthroscopic curriculum with these exercises to improve the residents' performances and achieve efficient learning.

3.5 Example of a Basic Skill Course

Karahan and coworkers are among the first to propose such a basic skills training program, which has been validated. The program consists of a 2-day course consisting of six modules (Unalan et al. 2010):

1. Interactive presentations about arthroscopic technology and basic knee pathologies.
2. Video presentations of basic arthroscopic procedures.
3. Basic motor skill exercises such as triangulation; depth are shown in (Chap. 6, Fig. 6.1).
4. Triangulation exercises on dry knee joint models or virtual reality simulators.
5. Wet lab exercises on a cow knee (Chap. 5), which is mainly designed to mimic a real arthroscopic procedure.
6. The knot station, in which all participants can train surgical knot tying again on a very basic model.

In their studies, Karahan and coworkers and Unalan and coworkers showed that experienced surgeons outperform the novices in reaction time and double-arm coordination time when executing the basic skills exercises of Module 3 (Karahan et al. 2009; Unalan et al. 2010). This is in line with the theory that assumes that skill can be explained as the ability to perform a specific task with less energy and time (Straub and Terrace 1981).

3.6 Additional Points of Attention

When designing a basic skill training program, other elements of psychomotor learning should also be considered. Training time or the number of training sets in order to achieve proficiency on a skill can vary from one surgeon to another. For example, Eversbusch and Grantcharov concluded that ten repetitions on a gastrointestinal simulator would be enough to acquire basic skills (Eversbusch and Grantcharov 2004). In a different study, Unalan and coworkers as well as Verdaasdonk and corworkers used ten repetitions on basic motor skill training instruments to achieve the plateau in the learning curve (Unalan et al. 2010; Verdaasdonk et al. 2007). An average number of repetitions on a specific training instrument should be defined before organizing a training program.

Another important element is the loss of a gained skill. Gallagher and coworkers showed that 2 weeks of no use will cause loss of recently acquired skills (Gallagher et al. 2012), whereas Gomoll and coworkers showed that continued training indeed maintained skill proficiency over a period of 3 years (Gomoll et al. 2008). Any training program should be followed by a practicing session within weeks in order to reinforce the skill acquisition.

Feedback is another important point in psychomotor learning. Closed-loop theory points out that feedbacks are important in skill acquisition. Trainees receiving verbal feedback while performing a task do better than the ones who do not receive that (Adams 1971). This finding is supported in various other studies in which structured feedback was compared with no additional feedback during endoscopic surgery by decreased errors and improved learning curves of the feedback groups (Boyle et al. 2011; Harewood et al. 2008; O'Connor et al. 2008; Triano et al. 2006). Live feedback during skill teaching may provide a better learning environment. Consequently, arthroscopic training programs should include interactive sessions with real-time feedback mechanisms.

3.7 Discussion

Although the precise nature of the mechanisms involved in learning arthroscopic techniques are at this point still largely unknown, the hypothetical constructs discussed in the current chapter provide a framework for our thinking about training programs for arthroscopic surgeons. The importance of such a methodical approach is obvious when one considers the variations in the acquisition of surgical skills among residents (Alvand et al. 2011). Prior to a course or training program, trainees can be assessed on their initial skills levels with instruments for dexterity tests and on their learning style with online questionnaires. Both tests can be done within minute and provide the teachers valuable information to adapt to the trainee's levels and enhance transfer of knowledge and experience.

Skills training programs should focus on facilitating the buildup of internal models of the arthroscopic instruments and the environment they interact with – which are the human joints. The approach of using training tools, such as instruments virtual reality training simulators, will be useful to automate certain surgical actions. However, the current absence of sufficient clinical variation in these simulators makes them insufficient to mimic actual procedures. Experiencing task variation will enhance learning of the structure of the task as opposed to merely learning one set of parameter values that only applies for a specific training condition. Therefore, it is of much more importance to ensure that the variability in training tools and tasks captures the subtle but high variability of sensory information that is encountered in the real procedures. This is, for example, the case in the presented 2-day basic arthroscopy course.

A well-designed adult teaching program should cover all these needs; one should not forget that competent teachers are equally important to complete an "ideal" teaching program. A perfect teacher is not the one who has the best ability to perform a specific motor skill but the one who has the ability to transfer that skill to a student.

In conclusion, including psychomotor learning theory into our daily training grounds, teaching skills will be more efficient and effective. As much as it seems as if it is "other people's ball field," theory on learning is for us orthopedic surgeons a primary concern and should be applied on a day-to-day basis. Only then we will become true teachers.

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