**12 Principles concerning Motor Learning**

* Table structure: Short Summary of the Evidence - Reference - PNF Relation.

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| **Summary of the evidence for ML principles** | **Scientific Reference** | **PNF Relation** |
| **1. „Emotion / Motivation“**Encreasing Motivation is probably one of the most important things for enhancing Motor Learning.Therapists might facilitate Patients Motivation through:* + - Meaningful Goal-Setting
		- Observational Practice
		- External Focus of attention
		- Positive Feedback after successfull Motor Attempts
		- Self controlled practice
 | Wulf G, Shea C, Lewthwaite R. Motor Learning and Performance: A Review of Influential Factors. Medical Education 2010: 44: 75–84 | **•**Therapists „Positive Approach“ implies positive Experience after motor attempts as well as meaningful goal-setting.•As „Add-On-Aspects“ for visual stimulation we recommend observational practice as well as working with external focus of attention before and during facilitation and for self controlled practice.(eg. Using objects, recognizable goals etc.)•Self controlled practice can be provided after facilitation, when the patient repeats enhanced activities. Individuals should be able to choose those exercises out of a PNF-program which are most important or meaningful for them. |
| **2. „Repetition and Variabilty in Practice“*** Volitional motor sequences will ultimately have to be practiced thousands of times in order to store a new motor program that is relatively fast, automatic, co-ordinated, effortless, functional and generalizable
* Cognitive operations such as problem solving activities subserve the learning of motor skills
 | Bach-y-Rita P, Balliet R. Recovery from stroke. In: Duncan PW, Badke MB, eds. Stroke Rehabilitation:The Recovery of Motor Control. Chicago, Ill; Year Book Medical Publishers Inc; 1987:79-107. Cauraugh J H, Kim S B. Stroke motor recovery: active neuromuscular stimulation and repetitive practice schedules. J Neurol Neurosurg Psychiatry 2003;74:1562–1566 | „Homework“ such as self controlled repetitions of PNF-enhanced Activities are most important to adduce the amount of repetitions needed to realy learn a new skill.Problem solving activities take place during variable task-practice: important is to „shape“ the difficulty of the request adequately.Example for repetition without repetition: Stanceleg activity in halfkneeling, halfstanding, gait, at stairs. Same muscle chain with different influence of gravity, thus high impact on coordination |
| **3. „Stages of Motor Learning“**Fitts and Posner (1967) describe 3 stages of Motor Learning:* + - Cognitive Stage
		- Associative Stage
		- Automatic stage
 | Fitts PM, Posner MI, Human Performance. Belmont, CA: Brooks-Cole 1967 | The earlier the stage of Motor Learning, the more attention and PNF-Facilitation is needed. In later stages patients should train task oriented with therapists Hands off. |
| **4. „Shaping“*** Shaping is a technique that grades the difficulty level of a task just above a patients activity level (Sterr and Saunders, 2006)
 | -Taub E, et al. An operant approach to rehab medicine, overcoming learned nonuse by shaping. Journal of experimental analysis of behaviour. 1994 (61) 281-293-Wulf G, Shea C, Lewthwaite R. Motor Learning and Performance: A Review of Influential Factors. Medical Education 2010: 44: 75–84 | Working with PNF it is important to grade the difficulty of the task / the complexity of the motor pattern constantly to patients actual activity level. |
| **5. “Practice conditions “*** + Massed versus distributed practice
	+ Constant versus variable practice
	+ Random versus blocked practice
	+ Whole versus part practice
	+ Mental practice: combined with physical practice shows superior results compared to either of these interventions seperately.
	+ Guidance versus discovery learning

In general all the mentioned practice conditions come to one result: Guidance, blocked-order, constant excercise, part-task training and massed training are effective in a short-term time mask, but have less retention effect compared to distributed, variable, random, whole-task, discovery practice conditions.Transfer/retention: is best when the training situation is as close to the real daily life situation as possible | -Schmidt & Lee, 2005 see PNF text book-Winstein CJ, Knowledge of results and motor learning - Implications for physical therapy. Physical Therapy 1991 (71) 140-149.-Krakauer JW. Motor learning: its relevance to stroke recovery and neurorehabilitation. Current Opinion in Neurology 2006, 19:84–90 | Following the principles of ML as part of the philosophy, PNF treatment approaches do cover the needed practice conditions according to the patients needs. From facilitation to participation.Depending on the capacity of the patient, guidance, blocked- order or part task etc. practice is suitable to begin with for low level patients. Such as with cognitive, strenght, coordination problems, to facilitate motor control at all. Whereas advanced patients may be trained in distributed, random, discovery etc. practice conditions.  |
| **6. „Intrinsic vs. Extrinsic focus of attention“**• Leading the patients focus on external goals enhances Motor Learning more than focusing on internal sensation of the movement | Wulf G, Höss M, Prinz W. instructions for motor learning differential effect for internal versus external focus of attention. Journal of motor behavior 1998 (30) 2 | The therapeutic consequence out of this research is integrated in our Basic principles by using the * visual Stimulus (giving a goal in space, demonstrating the movement, watching a movement video…) and
* verbal stimulus („step on this chair, reach for this object…“)
 |
| **7. „Feedback“*** It is suggested not to give feedback at any trial , rather than let the patient evaluate his/her performance on his/her own.
* This has an impact on further brain areas responsible for problem solving strategies as a kind of self-controlled practice!
* Thus the development of error detection capabilities needed at the time of retention and transfer gets promoted.
 | CJ Winstein. Knowledge of Results and Motor Learning-Implications for Physical Therapy., 1991; Physical Therapy V 71 | Knowledge of Results is covered for example by the technique ReplicationKnowledge of Performance is covered for example by the technique Rhythmic InitiationWith these 2 “hands-off” techniques therapist and patient is able to verify and examine once own outcome of practicing |
| **8. „Active Participation“**Transfer from perception to action (PAT) is well documented, for instance in the form of observational learning. **Action-perception transfer (APT)** is compatible with several learning theories and has been predicted within the framework of common coding of perceptual and motor events. Experiments by the authors provide evidence that transfer between perception and action is bi-directional. Transfer from perception to action and, more importantly, from action to perception was found. | Hecht H, Prinz W, Vogt S. Motor Learning enhances perceptual judgment. a case for action-perception transfer. Psychological research 2001(65) 3-14 | PNF provides both, perception for action (PAT) through the application of the Basic principles (sensory input) and action for perception (APT) by facilitating motor activity in different gravitysituation and goal oriented ADL context. PNF is an active treatment concept; „….. active participation is a necessity for the development of best strenght, coordination and endurance“ Knott M, Voss D. Komplexbewegungen Fischer Verlag 1970 |

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| **9 . „Rhythmic Cueing“*** External Rhythm causes tripping ("priming") and synchronization of muscle activity
* An external clock is specified during a movement sequence to be practiced, or movement beginning and end are marked with the rhythm ("rhythmic cueing").
 | -Thaut MH et al. Rhythmic auditory stimulation improves gait more than NDT / Bobath Training in near-ambulatory patients early poststroke: a single-blind, randomized trial. Neurorhabil Neural Repair. 2007 Sep-Oct; 21(5): 455-9-Whitall J, et al. Bilateral arm Training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke. Stroke 2000; 31:2390-2395-Wittwer JE et al. Rhythmic auditory cueing to improve walking in patients with neurological conditions other than Parkinson's disease--what is the evidence? DisabilRehabil.2013 Jan;35(2):164-76 | We have some techniques which are characterized through rhythmic movements with additional rhythmic (verbal) cueing, such as:Rhythmic InitiationDynamic Reversals(Rhythmic Stabilisation and stabilizing Reversals)As a basic principle PNF Pattern or activities are typically facilitated with verbal/auditory stimulis, this can be done rhythmically to enhance priming and synchronization of muscle activity |
| **10. „Cognition as a premise for learning“*** Pre-practice instruction by verbal stimulus should also include theoretical components how to perform a movement.
* This can be close to mental practice approach.

Asking the patient to recall the movement components cognitively | -Roy S., Park NW 2010; Dissociation the memory systems mediating complex tool knowledge and skill. Neuropsychologia 48-J Stanley, JW Krakauer, 2013 Motor Skill depends on knowledge of facts -Malouin F, Jackson PL, Richards CL, 2013;Towards the integration of mental practice in rehabilitation programs. A critical review. Front Hum Neurosci. 2013 | Verbal stimuli, especially the preperation command matches this information. Recall of a movement is a goal with Rhythm. Initiation and ReplicationCreating an active pause we may ask the patient to imagine what was exerciesed before. Just few components, only the main ones of the exercise, should be mentally practised.Example sit to stand: main components are position of feet, upright leaning forward with “nose over toes”, push off |
| **11. „Action Observation“*** Nearly the same motor neurons are activated in three different conditions: Observation, Imagination or Execution of a movement.
 | -Ertelt D. et al. (2007). Action observation has a positive impact on rehabilitation of motor deficits after stroke. Neuroimage 2007; 36 (Suppl 2) T164-173.-Filimon F, Nelson JD, Hagler DJ, Sereno MI, 2007, Human cortical representations for reaching: mirror neurons for execution, observation, and imagery.Neuroimage.2007 Oct 1;37(4):1315-28.Epub 2007 Jun 18-Grezes J, Decety J, 2001, Functional anatomy of execution, mental simulation, observation, and verb generation of actions: a meta-analysis. Hum Brain Mapp.2001 Jan;12(1):1-19 | A meaningful pre-practice instruction is to show the movement to the patient several times while the patient should attentionally watch it before PNF Training.In group therapy give time to watch other participants.A video about the target movement sequence can be a homeprogram or is useful for low level patients. |
| **12.“ Task oriented practice/approach“**A task oriented approach to intervention focuses on: * Resolving or prevention of impairments
* Developing effectiv task/activity-specific strategies
* Adapting goaloriented tasks to changing enviromental conditions, thus maximizing participation and minimizing disablement
 | -Shumway-Cook and Woollacott, 2012, see PNF text books-Mulder T, A process- oriented model of human motor behaviour: toward a theory-based rehabilitation approach. Physical Therapy 1991 (2) 82-89.-Newell KM, Vaillancourt DE. Dimensional change in motor learning. Human Movement Science 2001 (20) 695-715 | The **patient** defines his/her **wish** in solving an impaired ADL task. This is the **ultimative guideline for a PNF intervention**. The goal of therapy should be recognizable/understandable for the patient. PNF therapy takes place in a most possible real ADL context. Using the ICF based IPNFA eval form, first interest is given to the patients wish, which ranges mostly on activity level, seldom on participation level, almost never at bodystructure-function level. PNF provides therapeutic tools to intervene at all levels of the ICF.Example: Hold Relax to mobilze hip extension, one leg standing to facilitate hipextensors, highstep to improve exaggerted hip motion and endurance, in specific context like hurdling |