Motor Control and Motor Learning: Incorporating the Fundamentals into Clinical Practice

Recorded September 18, 2019

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PhysicalTherapy.com Course #3538

- [Kalista] Well it is my pleasure to welcome back one of our wonderful presenters Dr. Jill Seale today. Dr. Seale has been a licensed physical therapist for over 23 years. She received her board certification in the area of neurologic physical therapy from the American Physical Therapy Board of Clinical Specialties in 2004, and her recertification in 2014. She has practiced almost exclusively in the field of brain injury and stroke rehabilitation. She has a variety of teaching experiences in physical therapy academia as well as in the healthcare community at large. She is currently faculty in the DBT program at South College, and she has also served as core faculty in the neurological physical therapy residency program and guest lectures at Baylor College of Medicine Masters of Orthotics and Prosthetics program. Teaches at several online and onsite continuing education programs. Dr. Seale has taught and presented in the areas of nuerologic pathology, rehabilitation, gait, orthotics, mentoring and research, and is currently involved in clinical research and stroke rehabilitation, orthotic management, and gait analysis, and rehabilitation. We're so pleased to have you back with us today Dr. Seale. At this time, I'm gonna turn the microphone over to you.

- [Jill] Thank Kalista, and thanks everybody for joining us this afternoon or this morning for those of you who maybe are out on pacific time. I'm happy to be with you guys and happy to talk with you about a topic that I enjoy speaking about and that I really enjoy putting into my clinical practice. I hope that you find some things to put into your clinical practice today as well. The title there is incorporating the fundamentals of motor control and motor learning. We're starting with sort of revisiting the classics of motor learning and motor control. Then we'll have a second part where we'll learn a little bit more about more contemporary topics in motor learning. I find that this content often times is things most of learned about in school, and promptly forgot. Or just maybe there needs to be a little dusting off of this content and some thoughts about some new ways to put this into practice. That's what I hope to accomplish today. I need to go over the learning outcomes with you, so after this course participants will be able to outline at least one historical and one current motor control, motor learning

theories and models. Identify at least two supporting or contradictory evidence for a given motor control and motor learning model. Identify at least three differences in the motor learning approach to other past and current treatment approaches. Identify at least four principles necessary for effective motor learning in persons with neurological injury. With a focus on how the manipulation of practice and feedback maximize positive neuroplastic change and recovery. Identify at least three evidence based models, which integrate principles of motor learning. List at least five treatment strategies that incorporate practice and feedback in order to enhance motor learning and outcomes. That's our road map for today, so let's jump in because as you can see we have a lot of content to cover.

We'll start with a little bit of a historical perspective and we'll begin with motor control theories. I think it's important to go back and understand what has occurred through time in terms of our understanding of motor control. This is a quote from Perry back in the 90s. There's no one theory that's universal in the explanation of movement control. We select pieces which are evidence based and clinically relevant. Apply them in a systematic fashion and share with colleagues. I think what you're gonna see as we go through this is we have supportive evidence for many of the theories, and we have some evidence that calls into question some of the theories. I think what you're gonna see is that, what you're gonna start to unpack is that motor control can occur in a variety of ways.

We'll talk about what kind of determines, who's in control of movement, or what's in control of movement. In terms of motor control theories, these are just descriptions of really unobservable structures and processes, and the relationships to what we can observe. Which is movements and skill. It's really trying to understand the model of how movement is achieved. What we're gonna do is we're gonna look at different treatment approaches and how those are driven based on what type of model of motor control. The basic question when we start thinking about motor control, is who's in

control. What part of my system, what part of my body? Whether it's the nervous system, the musculoskeletal system, all the parts together. Who's in control? Who's driving the bus, we should title this. When we look back at the earliest theories you have the reflex theory which was back in the late 1800s and 1900s. This really tried to explain movement by saying reflexes were in control. That movements were really explained by combinations of these individual reflexes. We just put several reflexes together and that's how we got a movement. Movement was the sum of reflexes. One key aspect of this was that sensation was necessary. In order to stimulate that reflex to occur, you had to have sensation.

This was one of the earliest theories. Certainly we can see this if we think about the withdrawal reflex kind of being the classic. If I'm walking along and I start to step on a tack, or something hot. Long before that sensory information gets to the top of my brain and I'm aware of it. I have already moved my foot off of that danger. That's the withdrawal reflex. Sensory information comes in from the periphery. It goes up just to the level of my spinal cord, has a couple synapses. Then sends out an almost instantaneous motor response that says flex your knee, flex your hip, get your foot off of that danger. Happens completely and almost instantaneously and complete subcortically.

Meaning I don't have to think about that, I don't have to process that in the upper regions of my cortex. Movements like that help to reinforce this idea of the reflex theory. There's also reciprocal inhibition that says if I'm reaching forward to get a cup. My triceps are most active and that movement sends another signal to my biceps, that tells my biceps to relax. So my triceps are work easily. Reciprocal inhibition. The existence of those kinds of monosynaptic and polysynaptic reflexes help to reinforce this idea of the reflex theory of movement. Also when they looked at animals who had been disconnected from their upper cortex, or disconnected from their cortex. In that fact that they could still move. Explain that movement is really reflexive. However,

there's some contradictory evidence. For example, we can turn off our reflexes if we want to for the right motivation, and under the right conditions. I always joke that my reflexes are gonna keep me from stepping all the day down on that tack. If you offer me the right money to step on it, I might step on it. That means that I could inhibit those reflexes. The other thing that we've seen time and time again is that sensory is not needed for movement. A person can still move, can still relearn how to move without sensation. However, movement is not normal. You certainly wouldn't want that person being your brain surgeon if they don't have normal sensation, but they will have movement. All of that serves to contradict this reflex theory. Then they moved on to what was called the hierarchical theory. Some people refer to it as the top down. It was this idea that higher centers of the brain were really the control center, or the super computer, and that everything filtered down from there.

That the higher centers could activate the reflexes, but the reflexes were under the control of the higher centers. Then when the higher centers got damaged, that's when you saw those reflexes run amuck. In terms of supporting evidence, was that idea that I just said. If I have damage to my brain, if I have some damage to my cortex. Then you see this submergence of these reflexes that have maybe been "integrated." That was supportive evidence there was this hierarchical theory. Mobility in humans progresses in sort of a step wise process. You have these reflexes initially, then they again "get integrated," and we have more higher order control of movements. We're suggesting again this takeover of the higher centers. That's kind of what explains motor development, or some people believe that explains motor development in kiddos. That they start out with very reflexive movement and they progress to more refined, much more controlled by the cortex kinds of movement. Again, there's some contradictory evidence to that. We can take a cat, an animal, and completely disconnect them from their higher centers, and they still move. Suggesting that nobody has to order the reflexes to work. The reflexes just start to work. We also know that when we suppress reflexes, let's say we have a patient who is exhibiting some abnormal reflexes after a

brain injury of some sort. Suppressing those reflexes doesn't equate to normal movement. I can do things to suppress those reflexes, but doesn't necessarily make their movement normal. There's also this question whether some reflexes are really integrated, or if they're just a product of peripheral constraint. I'll explain this to you. There's a stepping reflex in babies. I know nothing about pediatrics, so don't ask me the actual milestone, what month this occurs in. Little babies have a stepping reflex. If I stand them on a surface, they'll move their feet as if they're stepping. At some age, that gets "integrated."

The reason why I'm saying quote, end quote. If you can see me sitting here, you'd see I'm doing air quotes. There's a question whether that's really integration that occurs. It gets integrated at a certain age. However, if you take that same child and the reflex has been integrated, and you put them in some water up to about their waist. That stepping reflex returns. Suggesting that it's not really an integration of reflexes, it's that the baby got a little too heavy. Their fat added on faster that their muscular development. We can picture that, right. All babies go through that super chunky phase. That super chunky phase, they have a lot more fat than they have muscle that have development. Maybe it was that the system was constraining them from being able to step. Maybe the fact that they got heavier then they could manage, they couldn't step. When we put them in a system that takes away part of their body weight, that stepping reflex recurs. Is that really a reflex then?

Again, these things sort of call into question a little bit the validity of the hierarchical theory. Then came the motor programming theory. This said that there was this central pattern for movement, or this central motor program for movement. This certainly can explain how movements can occur in absence of sensory feedback. It rules out this need of the higher centers, but we have these motor programs that are representing these generalized movements that we have some place that stores these rules for generalized movements. Supporting evidence here. It could be these locomotive

patterns that we see in those animal models where they've been spinalized. Even in humans we see that can develop a walking pattern, even after they've had a significant spinal cord injury. The idea of central pattern generators, that certainly supports this idea. That there's this motor programming. There's handwriting examples that have been given. From way back in the 60s. What this says essentially is if you write you name. You can try this, write your name. Make your signature with your dominant hand, and then make your signature with your left hand. You could even put the pen in your mouth and make your signature. What you would see, even though certainly it's messy with your non-dominant hand. The pattern of the signature is the same. If a handwriting specialist looked at it they would know it was the same person because of the way the loops are made, and the way the curls are made, and that kind of stuff. Again, suggesting that we have this hard wiring of patterns for movements. To a certain degree this is pretty accepted in some instances.

However, the question became how do we control so many degrees of freedom with all the joints that we have in our body? We have something like 222 degrees of freedom. How do we control that? How do we have enough motor programs for all of that movement potential? It doesn't really give us much flexibility for fine tuning our movements, and changing our movements, and adapting our movements. How do we adjust to different environmental and contextual factors? Where do we store all this, and what's the cognitive requirement in the storage system where we would put all of this information? That becomes a question. What's probably the more accepted sort of compromise about this theory is that for certain movements we do have stored patterns that we rely on. Movements that we do often. We probably do store a generalized pattern for those kinds of movements. That's one of the ways in which we move. Again, there's some contradictory evidence for us just accepting this as the whole way that we control movement. Then came the systems theory. The goal here was to look at the whole system, the whole person. Not just the neural components of the person and how they contributed to movement. It looked at it more as a

mechanical system. The whole body as a mechanical system and you have all these various parts. The idea here is that you have this control of integrated movement that's distributed across these many interactive and cooperative systems, all these storage systems that we've been talking about. All these levels of the work that's going on, integrate together, and work together. That there wasn't any sort of prescription of movement from the top down necessarily. This theory really didn't have much in the way of limitations. It's really been the broadest, most applicable approach we've talked about thus far. Criticisms of it, it doesn't really talk about how we interact with the environment, but neither do most of the other theories. This just merged into what became known as the dynamic action, or the dynamic systems theory.

It was really just a progression of the systems theory. It says that motor tasks are problems to be solved and solutions to them are movement strategies that are generated by the system. It's based on the principle of self organization. This is really important. What this means essentially is that movement is not prescribed by some one particular part of my nervous system. I as a person, I'm going to organize my movement as best I can, with what I have available to me. If I have weakness, or if I have tightness, or if I have hypertonicity, or I have visual impairment or whatever. I'm going to organize and I'm going to execute that movement with whatever I have available to the best of my ability. I'm putting all these individual parts together to act collectively in this ordered way.

Again, there's no need for instructions from a higher center, or this prescription of movement. That's really these interacting elements that come together, or merge together to form movement. I've created this from a classic representation of how this works. This says that we have three key elements. The organism, or the person, the individual is that one circle. The environment and the task, and that movement merges from that overlap of all three of those. Meaning that the task contributes to the movement, the environment contributes to the movement, and the organism

contributes to the movement. How they do, depends on the limitations of each one of those. This idea that movement is not really prescribed, but movement emerges based on the constraints on the systems. I'll give you an example here, if this is seeming a little nebulous to you. If you think about the person, you might have a patient who has a plantar flexion contracture, or plantar flexion tightness. This is an example I always like to give. The task that we're working on is walking. They're going to change their walking pattern based on that plantar flexion contracture. They're going to likely have a extensor thrust in the stance phase because they're trying to get that heel on the ground. The only way to get that heel on the ground is to push the knee back behind the gravity line. They may have to then flex forward because of that compensation. Because they're keeping their knee in a lot of extension and not allowing their weight to come forward, they'll probably have a swing phase that's maybe stiff. Even though there's not anything wrong with keeping them from flexing their knee and their hip, but because of the altered mechanics in stance.

Because of that plantar flexion contracture, they may alter the way that they carry out swing. They may have difficulty with swing because of that plantar flexion contracture. They may have to circumduct, or hip hike, or any or all of those kinds of things. They're gonna be able to walk. The movement is gonna happen, but it's gonna be altered based on the constraints. Likewise, we could think of, give you one more example, the environment. All the time we see patients in our clinic. We've been working with them and we say, "Oh wow, they're really doing good at whatever task." Let's say dressing. They're really doing great with this dressing task. Maybe you score them as Mod I. Then they go into their home and they're trying to get dressed, but things are different. The mirror that they need to look into is different, or there's children running around screaming and hollering, and the TV is on in the environment is different. The environment then can create some constraints on the ability for that skill, or that movement of dressing to occur. The movement pattern may be altered. It may have less quality. They may suddenly have more stiffness or something because of that

change in the environment, that's impacting they're ability to have that movement. Hopefully those couple of examples help that to make sense. There's quite a lot of supporting evidence for the dynamic action theory as we talked about the normal development of gait, and how maybe those stepping behaviors aren't necessarily integrated. They're more of a constraint on the system. The idea that we have these transitions between movement patterns where we don't necessarily have to have that prescriptive movement. That we change our movement patterns based on the conditions where we are, where we're working within. The idea that we have some variability prior to the emergence of a more stable pattern. You've probably seen this in your patients. They're looking pretty good with whatever skill we're working on, and they're getting better and better.

Then they hit this period of instability. Things don't look so good. If they just keep working on it and they don't give up, they'll shift to a higher level. A better motor performance, but they have this period of instability before then they move forward to that period of more stability and improved movement. There's really no limitations or any sort of contradictory evidence in terms of the dynamic action theory. Again, it does down play the role of the nervous system that's not necessarily a limitation. There's one more theory that doesn't get mentioned often and this is the ecological theory. This really focuses in on how motor systems interact with the environment during goal directed behaviors. This theory really focuses in on perceptions.

That it's about our perception as the mover, and our perceptions guide the actions. That motor control evolves so organisms could cope within the environment, and with a changing environment. Which is kind of interesting idea to think about. They suggest that we should first focus on how actions are geared to the environment. Again, they feel like sensation is not really key, but it's about the movers' perception. This is sort of an interesting theory for us to think about. I do think we would be better served, and better serve our patients if we took a little bit more account into the environment and

the environments impact on movement. In terms of limitations, it's not very widely studied. Again, less focus on the nervous system. Not that that's a bad thing, but not a lot of information on that. It's something that's been put out there, but not really widely studied. When we ask which theory is best, or is there a theory that's right. I think the most widely accepted theory would be the dynamic action theory, or the dynamic systems theory. Again, when you look at that, it really does combine all of the other theories that have come before it. What it says is there's just no one way in which movement occurs. Movement occurs depending on the demand for the movement, and the constraints within the system. For something that demands immediate movement, I'm not going to go up to my highest centers and ask around for information. I'm going to have more of a reflexive movement. Again, within the constraints on the system. For something that requires more skilled, precise movement, I am going to have to tap into my higher centers of my nervous systems to get information there.

Again, we're driven by demand and more the outcome is really the result of the constraints on the system. When we think about the person, the task, and the environment. If we move forward from motor control, we move to talking about motor learning. Remember motor control was about who's in control of movement. Motor learning then is about how do we get movement, how do we acquire movement? Or in the case of most of us when we're thinking about our patients, how do we reacquire movement after it's been lost because of injury? How do we modify movement, when we need to modify movement? Some key things are summarized about motor learning in that last bullet point. Processes associated with practice or experience leading to permanent changes in skills. I'll go ahead and skip to the next slide too, because I think I covered this and I don't wanna speak ahead here. Processes meaning it's something that takes time. It's a process, it's not a one and done sort of thing. It results from experience or practice. The patient, the person. I shouldn't just say patient, the learner has to have some experience. There has to be some practice. Again, not a one and

done kind of phenomenon. We can't directly measure motor learning, but we infer it from behavior. When I look at my outcomes measures related to walking, relating to balance. Related to other functions like dressing, or any sort of motor tasks that we look at. When I look at those outcome measures and I see improvement, I sort of can infer motor learning. It's not always the case that motor learning has occurred, but we can't directly measure it. We try to infer it based on the behaviors that we see from the patient. It should produce a relatively permanent change in behavior, although we certainly can unlearn things that we've learned. We'll talk a little bit more about that later. Again, coming back to this schematic that motor learning is going to emerge from the interaction of these three parts again. It's going to emerge what the person, the individual brings to the movement.

What the demands that the environment places on it, and the degree of difficulty of the task. All of those sort of mix together to lead us to what the movement pattern is going to be. I didn't jump over, sorry I thought I jumped over a slide there, my bad. It's really important here to think about that motor learning is not performance, it's retention. Let's stop for a moment and think about this. Often times as a therapist in the clinic, I'm seeing my patient here for three days. Let me get my pointer here. I'm seeing my patient over three days. Let's say we're working on transfers or something. Over the three days we're practicing. Every day, transfers.

The only thing we're practicing in our therapy session we'll say. I'm practicing transfers and the patient's getting better. Some days they're a little bit more flat. Some days their progress is really steep, but they're getting better. I'm measuring every day as we practice. That would be, I'm measuring their performance. Hopefully everybody can imagine that. Now let's say their performance here, they're at a supervision level. They started off at a Max Assist down here somewhere, and now they're at a supervision level. Do I say that the person has learned the skill of transfers, or not? Well the only way to know if they've learned is to have break in practice. For example, in this little

schematic I've given you some break in time. Let's say it's a couple days or something. There's some break in time where we're not practicing transfers in therapy. Then I reassess their transfers at this point. Whatever this time point is. If they're ability to perform that transfer here is about the same as it was when we stopped practicing. If they're still at a supervision level, then they have had some learning occur. They have better learned how to do transfers. However, if when we did this retest after some break in practice. They're back down here at a Max or Mod Assist level. That would indicate to us that learning in fact had not occurred. Or had not fully occurred. Hopefully everybody can understand that. Here's the problem, most the time as a therapist, I'm documenting performance. I'm taking that documented performance and I'm saying, "Oh yes, they're better in their transfers. They're better in their walking." Their whatever, whatever. I'm sort of implying that this improvement in performance, is the same thing as improvement in retention, and it's not.

We need to better at assessing a person's retention. Remembering that it can't be right at the end of having just practice that skill. We have to have some period of time there, where we're not practicing that all the time. In order to assess that they've really retained it. This is a problem in the therapy world. Often times the only thing we're really looking at, and the only thing we're really documenting is their retention. Is their performance, I apologize. What we need to figure out is how can we better attend to and document retention. Now, in addition to documenting for retention, I'll suggest here and we'll come back to it as we more forward today. There are things that we do, during our practice time with the patient that can either promote better retention. Or can actually interfere with retention, and diminish the patients capacity for retention. What we do in this practice time here. Where we're seeing changes in their performance. We can actually effect in a positive way, or a negative way, whether or not they actually retain that skill. Those are gonna be some of the things that we continue talking about as we go forward. We're gonna more forward now and talk about motor learning theories. We've talked just a little bit defined motor learning and

those kinds of things. The reason why I put this picture in here is because people can do amazing things. I watch these skateboarders. Do you guys ever go and watch it on TV, some of those skateboard contests and stuff? They're just insane. I look at these, mostly kids. I look at these kids and I'm just like, "Wow, we have an amazing capacity for movement that somebody learned how to do these sorts of things." Then I think about my patients. I work mostly with patients with neurological injuries like stroke and traumatic brain injury, and sometimes spinal cord injury. I think, if our nervous systems have a capacity to learn how to do what this guys doing in this picture. How is it that we're aren't getting our nervous systems to relearn basic movements necessary for return to life functions? That's a question I keep asking myself. If we have the capacity to learn these great things. We probably have better capacity to relearn after injury then we're sometimes tapping into. That's kind of a driving factor for me to keep thinking about.

What is it that I need to do to capitalize on what are these innate features that our nervous system has for motor learning. If we move through and talk a little bit about some theories that are out there related to motor learning. If you read text, you'll read a lot about Schmidt. Schmidt, back in the 1970s tried to address the question of how motor programs were learned. He talked about things like the open loop control, and the generalized motor program. There was this idea that generalized rules can be applied to a variety of context and that we don't necessarily need sensory feedback. We don't need to have this feedback loop. We could have this open loop. Essentially I think of it as we're making adjustments on the fly. We don't have to first make an error, and then come back and try again. We can actually make adjustments in the movement to not necessarily make the error in the first place. Again, a lot of it's centered around this idea of motor programs. That motor programs are these generalized rules for specifics types of movements, or what they refer to as schema. Again, this is the equivalent to what we talked about in the theories of motor control. Where we talked about motor programming. Schmidt also predicted that variability of

practice improved motor learning. This is really important, we're already getting ahead of ourselves a little bit to talk about. How do we construct practice to best improve motor learning? Schmidt said there needed to be variability of practice. Again, this doesn't account for all the ways that we acquire movement, but this was fairly widely accepted. It centered around this idea of generalized motor programs for creating these spatial and temporal patterns. That we need to carry out more of our movements that we're doing consistently and often. They looked that after making a movement, there are four things that are available for storage in the short term memory. There's the initial movement conditions.

What were things like before I actually made the movement? The parameters that were used in the generalized motor program. The outcome of the movement, or what is often times referred to as the knowledge of results. Meaning just simply the outcome of the movement, what was the result? Was it hit the target, or didn't hit the target? Then the sensory consequences of the movement. They talked about that, so we utilized these two schemas. We used this recall schema that relies more on the motor aspects of that, and this recognition schema. That incorporates the sensory information from those four pieces that we have available. They talked about this open versus closed loop system as both being ways in which movement occurs. It's not that there's one right or one wrong.

Each is really can be crucial for successful performance. Originally, what most people thought was that movement occurred via this close loop system. Meaning that identified some goal. I had some sensory input. I executed, I made an error. I adjusted my instructions. I got input from the environment and I started over the process again. That sort of insinuates that I have to make a mistake, I have to make an error before I can learn, and I have to have rely a lot on the sensory input as well. Versus this open loop system said that I can learn without necessarily having all of that sensory input and I don't necessarily have to make an error. I can execute and have an output that

occurs correctly by changing what's going on in this execution box. That this execution box isn't fixed, but I can make some adjustments on the fly essentially. Certainly when we're learning something new, completely novel and we're successful at it, that sort of insinuates that we have gone along these open loop processes. Versus if it's something I'm learning and I have to make quite a few mistakes and keep readjusting. I think about a golf swing, or a tennis swing. Rarely ever do we get that right off the bat. Then maybe are utilizing more of a closed loop system, but both being really crucial to movement. Then likewise there's an ecological theory that goes along with these theories of motor learning. Again, it just takes into account the use of the environment. I like some of the ways that they describe motor learning here. They say that we are searching for optimal strategies to solve a task, given the task constraints. This goes very well along with the dynamic action theory of motor control.

Says that motor learning is a task that increases coordination between perception and action. Again, that there's this hinge around our ability to perceive and whether or not we have correct perception about something in order to get a correct action. The other thing that I really like is that it talks about this exploration of the perceptual and motor workspace. We'll talk in a minute about the importance of trial and error. Our patients can only experience that trial and error learning when we let them explore their workspace. When we let have some exploration of movement.

Again, talking about that importance of perception involved in movement. Certainly we can see this when we have patients with perceptual difficulties. If you think about somebody who has some perceptual issues. They have apraxia, they have neglect, some type of spatial issue. Those all equate to disruption of movement. We can kinda see that in our patients that have those. It's also important to talk about the stages of motor learning. There's a couple that I utilize a lot in my practice and that are well talked about in the literature. The first one being the Fitts and Posner Three-Stage Model of motor learning. This looks at motor learning occurring in three stages. The

cognitive stage, the associative stage, and the autonomous stage. In the cognitive stage, this is when a person is just learning a new skill or a new movement. They're just sort of acquiring knowledge. They're trying to understand the dynamics of the task, and there's a lot of trial and error. They're making a lot of mistakes. Performance looks pretty rough here. In the associative stage, they're refining the skill. They've acquired the basic knowledge, and now they're layering on more refinement, more subtleties. They look better, there's less variability in how they're doing it. They're more consistent. Then we progress to the autonomous stage where we have automaticity of the skill. Where we're able to do something without thinking about it. What's key in motor learning is not just that we can do a skill effectively, but that we can do it without thinking about it in a variety of context, and circumstances, and environments? Can we do it without thinking about it in a variety of environments, contexts, circumstances? In this autonomous stage, the person's able to do this with a very low degree of attention. Think about walking for you guys. I'm guessing today at some point you were walking while texting, or talking on the phone. Maybe you were drinking a cup of coffee and you were maybe looking at your environment.

Maybe you were looking for street signs, or maybe you were looking at the birds in the trees or something. You had cognitive things, you had your visual attention was somewhere else besides walking. You had a lot of things going on, you were paying a low degree of attention to walking. You're definitely in that autonomous stage of walking. Do our patients get to this autonomous stage of walking? We think about it. Our patients are early on after a stroke, after a spinal cord injury. When they might have new issues with some neurodegenerative disease, and they're trying to reacquire movement. They have to pay a lot of attention to it. They're really focused on the motor task. As they progress in these stages and become more autonomous, they're giving a much lower degree of attention. However, what I will say is sometimes we don't allow our patients to get to this autonomous stage. What's necessary for the patient to get autonomous? Well, we have to challenge them to do so. We have to give them some

other things to do so they have less attention that they can place on the motor task. Maybe we introduce dual tasking to them. Maybe we give them less assist and let them learn some self management strategies. The other thing that we can't do, is that we can't keep emphasizing to our patients to think about their motor task. Maybe in this early stage, in the cognitive stage. Maybe I do have my patient think. I may actually instruct them or cue them, think about the movement. I can't continue to tell them to think about their movement if where I want them to get is to the autonomous stage. In the autonomous stage, they can't be thinking about their movement. They just have to be doing it automatically. I think we can work harder as therapists at how do we get our patient to that autonomous stage of learning? I think there's some ways that we sort of block them from getting there, or don't make that occur as often as we should. Another theory of motor learning that I think is really important is Bernstein's Three-Stage Model. This is all about degrees of freedom. Hopefully degrees of freedom isn't a new term for you. If it is, or if it's something you're like I kinda heard about this in school. I don't really remember.

Degrees of freedom has to do with all of the movement options that we have. If you think about at the shoulder. We have flexion, extension, ab/ad-duction, external and internal rotation. That's six degrees of freedom. I did look it up one time and I really honestly think it's 222 degrees of freedom we have in the whole body. I also tend to use 222 as my go to number for when I'm trying to be exaggerating about how hot it is here in Texas. It's 222 degrees. I could be wrong about the number of degrees in freedom in our bodies. If you think about it, we have a lot of degrees of freedom. Think about all the various joints that we have, with two arms, two legs, the trunk. All the movement that we have available at the spine. We have a lot of degrees of freedom. Think about when a baby is learning how to walk, or how to move, how to stand. They're struggling. You can just see all the degrees of freedom that they can't control. It's all the wobbly bobbly parts. What do they do to try to be able to walk or stand? They try to decrease their degrees of freedom automatically. The baby pushes up with

their hands on the floor and they don't let go of the floor until they can catch hold of something else. Then they're standing holding on to the table, or the chair, or mommy's leg, or whatever. They're just naturally decreasing their degrees of freedom. So that they can master the skill of coming to standing, or starting to walk. Really no kiddo stands up and starts walking automatically. They all cruise on the furniture. They walk while holding on to stuff. That's just our innate ability to decrease degrees of freedom. What this theory suggest is that in order to help somebody with motor learning, we can control some of the degrees of freedom.

Or limit some of the degrees of freedom. In order to progress them to where they master all of them, or master as many of them as they can. This idea when somebody's in the novice stage of learning, we simplify the movement by decreasing the degrees of freedom. Then as they advance, we gradually release some of them back. Making sure that they can manage those. They can't really get to the expert stage until we release back all the degrees of freedom. Take a moment and just think about to yourself what are some ways that this could be useful, or that you've used this idea in your clinical practice. Some of you may already do this, but maybe you're not thinking about it. What ways can you see this happening in clinical practice? When I give somebody an assistive device, I decrease their degrees of freedom.

When I put some type of orthosis on the upper extremity, on the lower extremity. I decrease their degrees of freedom. When I choose to work on upper extremity tasks in a seated position, or a supine position to help them better control the upper extremity. I'm decreasing the degrees of freedom. If I have my patient work in kneeling and half kneeling. I'm decreasing the degrees of freedom, helping them focus in on more the trunk and the hips by taking away their need to control the knee, and the ankle, and the foot. Hopefully that makes sense to you. I think this is a critical way that we can help our patients relearn movement if we think about this in a very structured way. I'm going to decrease degrees of freedom initially. I have to remember to give them back though,

so that they can remaster that movement. Then Gentille's Two-Stage Model just says where in the first stage where the patient's developing an understanding of the dynamics of the task. They have to understand the movement that they're wanting to do. We'll talk about some ways in which we help our patients understand that movement. Once they do that, then they can progress towards refining that movement. Being able to do that movement and then being able to diversify that movement, and adapt that movement, and change that movement. Which is important. Can they do a basic movement, but then can they adapt that based on the conditions at hand. Then the last thing we learn to phases of learning has to do with neuroplasticity really. This is literature that's come from a number of sources, but Jeffrey Klein the first one there who's done a lot of work in neuroplasticity. They talk about the two phases of learning.

The fast phase is when the patient initially has these fast improvements. We all see these in our patient where we're training something and they're just having a lot of rapid improvement. It occurs in a single session, or a few sessions. Again, remembering that that's really performance changes right, if we go back to that schematic earlier. That's performance changes. Then the person changes gears into the slow phase. This is where, just like it sounds, improvements are more slow. They're more of an evolutionary process. Taking some time. They're making more moderate gains, instead of rapid big gains. Then progressing that over multiple sessions, not within the same session. If you look at the fourth bullet point here. This is when you see an increase in number of synapses. What does that mean? That means this is when, the slow phase is when you're actually having neuroplasticity occur. You're seeing neuroplastic changes in response to the intervention. This means the slow phase is really important. This is where the permanent changes happen. What happens to our patients when they hit the slow phase? Probably all of you there are saying, "Well we discharged them because we think they've plateaued, or the patient gets depressed and loses motivation for continuing." Those are all possibles. This is really important to talk to our patients about. Progress is slowing down, that does not mean that no

progress is happening. It's just that more things are cooking under the radar, so to speak. Then you're gonna see that improvement, but we have to keep going. We have to keep going, we have to keep doing the good stuff that we're doing. This is a slow down now, not a stop. We have to do a better job of being able to demonstrate this and also making sure that we're giving the right interventions to keep the patient progressing. So that we can demonstrate this in our outcomes. Important to educate our patients about the fast phase versus the slow phase. We'll talk a little bit now about motor learning approach versus some other past and current treatment approaches. How does this motor learning approach stand up to other ways that we might approach rehab in our patients with neurological injury. I'll tell you that most of the research.

There's very little research that A, says this is a motor learning approach. Or that B, compares it to many other approaches. Most all of it's done with patients with strokes. If you're wondering why the literature that I'm gonna show you, I think all of it, that's just where it's all been. I'm not just trying to be biased toward stroke. This was studied back in 2006, that looked at the motor relearning program. If you look at the literature, all the stuff that we've just been talking about in terms of motor learning. The literature, it often times shows up as the motor relearning program, or the movement science based relearning program.

There's various names that they use. Again, which you can imagine is a problem in research when we can't really define what it is we're doing consistently across practice and across research. That's a problem. Like much of what we see in the research related to our patients with neurological injuries. In this study, this was just looking at comparing the motor relearning program to conventional therapy. As we know, defining conventional therapy's also a challenge. So you can picture that there's some problems with this study already, right. You can see the outcomes there that they used. Pretty traditional things, Berg, TUG, FIM, community integration questionnaire which is

a little bit questionable what that was. What this found was when you compared the motor relearning program with people getting "conventional therapy." Those in the motor relearning group showed better results in all but the TUG. Sort of a positive for motor relearning compared to whatever was defined as conventional. Which is again, hard to do. There have been several studies that have looked at NDT/Bobath and compared those to the motor relearning program. Again, in the studies you'll see both of those words used, NDT and Bobath. Again, we're assuming they all kinda mean the same thing. Back in 2000 there was this double blind study with 61 subjects. For neuro, that's pretty good to have 61 subjects, and to be double blind. You can see their outcomes there were measures of spasticity, volitional movement and ADLs. Looked at length of stay and use of assistive devices. In the group that got the motor relearning program, there was a shorter length of stay, improved spasticity, and volitional movement. No change in ADL. Again, more in favor of the motor relearning program.

That same group in 2010 kinda moved that study forward, and they did a randomized control trial of patients with acute stroke. They found that there was significantly improved function and quality of arm and hand movement with the motor relearning program group compared to those who got NDT. The results supported that the task oriented exercises related to motor relearning promoted movement quality. This is big because what a lot of the people, especially in the earlier days of NDT and Bobath said is that motor relearning is just about doing the task over and over, it's not really about the quality of the movement, and NDT was more about quality. That was sometimes a sort of dividing line that you would hear between the two camps. In this study actually suggested that the motor relearning program promoted movement quality, and did so more successfully than NDT. In this study in 2001, again kinda going back in time a little bit. It's quite a dated study now I guess, but I really liked this study. It's a simple little observational study, and they looked at people getting Bobath/NDT. They looked at people who were getting what they called the movement science-based approach. Which was again, the motor relearning approach. They just compared what they saw in

terms of the therapists that were delivering of these two approaches to stroke rehab. What they saw in the group that was practicing in the Bobath approach, or the NDT approach. They saw that it included more physiotherapy equipment, had more social conversation, and more often required the assistance of another person. There were a lot of manual strategies that were favored. Meaning there was a lot of physical handling. There was a lot of manual cuing that was done. In the movement science-based approach, there was more detailed feedback, more use of everyday common functional objects, and there was training that was specific to a goal. In other words, when you observed that therapy session, you could very easily see what the movement goal was the patient was working on. In contrast to not being able to see that as clearly in the Bobath treatment sessions. In this group, more of a cognitive strategy was favored.

Meaning more of a learning strategy. I think when you see this, this resonates with me. I have done lots of Bobath stuff. I did training as a new therapist, and I certainly utilized some NDT skills in my treatment sessions today. When I think about when that's your only focus, versus having more of a motor learning focus. I can really see this. I can see that often times some of the interventions that I created with my patients. Although I had a function in mind, it wasn't quite obvious what the function was in the treatment. Or it didn't feel functional to the patient, or it didn't use common every day objects.

Maybe it involved some tools that I created for the patient to be able to do, but it didn't so much involve common every day objects. I always like to use this study because I think it's really interesting. I think it really paints a clear and unique picture about the differences in more of a neurophysiological facilitatory versus inhibitory kinds of approaches. Compared with more a motor relearning approach. Then most recently and this study just came out this year and I find this just really interesting. It was comparing folks who had gotten more of a motor relearning program versus NDT, and the prevention of post stroke apathy. That was their outcome, really interestingly

enough. We know that folks who've had a stroke are much more prone to apathy, along with depression and other things like that. Apathy is often times a big component. This was a fairly large, randomized controlled trial. They found that there was significantly less apathy or severity of the apathy in participants receiving the motor relearning, compared with Bobath. At each time point that they assessed them. Those receiving Bobath, you can see 1.629 times more likely to develop post stroke apathy after 12 months. Their conclusion was that this was people with acute stroke. The acute stroke rehab should focus more on motor relearning program. That this was significantly more effective in preventing the new onset of apathy in these patients. They did measure them across time, at multiple time points. There was a fairly large study, that had almost 250 people in each comparison groups. A fairly large study. Interesting new study, interesting outcome measures. If you were to go and look at the literature and say I'm gonna do a lit search for motor relearning.

One of the problems with what does this look like as an interventionist? There's not really good catchy sort of phrase. We don't have a PNF, or an NDT, or letters that symbolize what this approach means. In the literature, the things that you're looking for are studies that look at things like specific skills training, task specific training. Intensive mobility training, repetitive task specific practice training. Those are more of the labels that tend to mean or insinuate that this is gonna be more of a motor relearning approach. That's certainly not an exhaustive literature review, but those are most of the studies that are out there that compare anything related to motor relearning approach to some other type of intervention. As you can see, that's relatively thin. Not unusual in neuro rehab unfortunately. Let's move forward and lets talk about why we would even incorporate this idea of motor learning. I'll just go ahead and tell you the reasons why, is it's related to neuroplasticity. If what we're wanting to do is to create a situation to maximize the neuroplastic change in our patients with some type of neurological injury. It's definitely gonna be strongly connected to motor learning, and the opportunities that we provide for motor learning. Let's look at a couple slides on

that. What we know is that plasticity is learning dependent. You see this in animal models and human models. You see this in folks that have normal nervous systems versus impaired nervous systems after some type of injury. For you and I, who are "normal," I try to never say that I'm normal, but if I were to go out on a limb and say that I am normal. As a normal person, if I were to want to take up playing the cello. I really love the cello. I can't play anything, let's just make that clear. I can barely play the radio. I can't play any musical instrument, but I would love to learn how to play the cello. If you were to map my brain right now, and look at all the areas in my brain that correspond to those finger movements that my left hand would have to do in order to do the fingering on the fret of the cello, the neck of the cello. If you were to map that area of my nervous system right now, you would see what areas of my cortex activate when I move those fingers on my left hand. If I learned to play the cello. I took lessons, I went faithfully.

Not when I was a kid and I did piano, but I went faithfully, and I really practiced. I practiced everyday for a meaningful amount of time. I practiced progressively harder pieces and really learned how to play the cello. Then you remapped my nervous system, remapped my brain at least. What you would see is that the areas of the cortex that relate to those fingers on my left hand. Now when I move those fingers, you have a lot more areas of cortex that light up. Another words, I had to go in and do a real estate grab. I had to create more synapses.

I had to create more areas of activation. I maybe even had to have new neurons develop related to that movement, because I had a demand for better movement of my left hand to be able to do that skill. This has been demonstrated over and over in normal things. Anytime we have a learning experience, we have some reorganization of our cortex. We increase the number of synapses we have. We increase our utilization of neurotransmitters. We maybe have more of certain neurotransmitters that's expressed. That indicates that these plastic changes are related to learning. They are learning

dependent. I've given you a few bullet points here that kind of summarize that. That we have to have a task specific learning. That's the important stimulant for neuroplastic change, as well as remediation of maladaptive patterns. Again, this was looked at in patients with stroke. What does that last part mean? Remediation of maladaptive patterns means essentially compensation. When a patient is allowed to compensate, they have neuroplasticity that occurs, but in a maladaptive way. In other words, they strengthen a unimpaired side of their cortex, as opposed to strengthening their impaired side of their cortex. We have to have this motor learning, this task specific motor learning to bring about neuroplastic change, as well as to undo that maladaptive change that's occurred. Again, most of this research is gonna say it's done within stroke, but I think it's pretty widely accepted that this applies across most or all neurological injuries.

We know that the brain continuously remodels to encode new experiences and cause behavior change. That new experience of me practicing daily the cello, that would result in a behavior change of me mastering playing the cello, because I've had these neuroplastic changes that occur. It needs the skill learning that leads to the rewiring of the motor cortex. That being the key feature there that we want to capitalize on. I'll give you an example from the animal model literature, about this idea of skilled learning. In a group of animals that they were doing some research about stroke. They had two groups of animals. Both groups got some type of stroke that impacted the upper extremity. Pretty consistent across all the animals in the study. They were divided into two groups. One group did a skilled intervention, while one group did an unskilled intervention. They did mapping of the brain after the stroke. They did mapping of the brain after the interventions. The group that did the non-skilled intervention, their food was put out for them in a way that they really didn't have to use their affected hand in order to get it. They could use more of a gross grasp. I always tell people, this wasn't how it worked. I picture the monkeys laying in front of a trough. Then they're able to use their affected hand and kinda shove it in their mouth. Don't really have to do any

fine dextrous movements, no big movements, not control much in the way of degrees of freedom. The group that did a skilled intervention. I think about it being in the bottom of a puzzle box and they have to be able to use their digits and manipulate both their fingers, and their wrists, and their forearm. Kinda their whole arm. They have to do some more intricate movements in order to be able to get their food. The other thing is, they're gonna make many mistakes before they actually succeed and get the food. They're gonna drop the food pellet a bunch of times before they actually get it to their mouth and have success.

Where as the non-skilled group, they were instantly able to be successful in getting the food to their mouth. Which group had the most neuroplastic change occur? It was the group that did the skilled intervention. When they remapped their cortex, there was much more territory that lit up, that was activated when they were doing those movements of their affected upper extremity. Their lesion size had gotten smaller. When they looked at the mapping of the group that did the non-skilled intervention. Their lesion size had expanded and they had diminished areas of the cortex that activated when they did their affected side upper extremity movement.

Again, that just gives you some of this framework for this idea of learning dependent plasticity. In this next bullet point, this talks about motor learning and the recovery of function. Again, what are the connections there? Learning being our best hope for brain remodeling. Learning is what actually causes that reorganization that we want to have happen. We're striving to create in our therapy sessions. The brain that's injured, that brain that has some type of injury, some type of disease process, that can change how the brain responds to learning. Some of our patients who have impaired cognition, may be more difficult for them to have motor learning occur. In this last study that's cited there, by De Beaumont. It talks about that there was impaired learning after multiple concussions. When they looked at a group of kiddos that had had multiple concussions related to sports, they had impaired learning capacity. They also had a

decrease in synaptic plasticity. The idea that those two concepts being related. If I have learning that's occurring, I'm gonna have better synaptic activity. If I have learning that's not occurring, or that's impaired, I may have a decrease in synaptic plasticity. Again, just showing that relationship between the two. What we're looking forward to happen in our patients is a recovery process, not just developing compensatory strategies. An actual return to those functional movements that they had, using those parts that were affected, as opposed to substituting other parts that were not effected. In order to achieve that, we have to create a situation for relearning. The brain relies on the same neurobiological processes it used to initially learn the movement. It relies on those same processes to relearn it after injury. What does that mean? That means again, I said this earlier I think. If you think about a baby. Baby learns to rollover, and sit up, and stand up, and walk.

They're using certain neurobiological processes. Your patient who's had a stroke, who's had a spinal cord injury, who has MS, whatever it is they have. Even a more musculoskeletal injury, they use the same neurobiological processes to relearn and to reacquire that skill, as they did as a baby learning it the first time. Why is that important to think about? Well, think about how movement develops in a baby. There's a paper and I've gotta look this title up, because I know I misquote it. There's a paper on motor development in children and it's called something along the lines of 'Millions of Steps and Thousands of Falls.' That's probably not the exact title, don't write that down. What that's about is a baby develops walking by taking a lot of steps. Many, many, many, many, many steps. They make a lot of errors, they fall down a lot. That's how walking develops in a baby. It gives us an idea there, if thinking about we're relying on the same processes. Gives us an idea about how we reacquire movement after an injury. That should give you some scaffolding to think about what's gonna be different, about how we need to approach our patients to help them actually relearn the skill. It's motor learning, not motor activity that leads to this neuroplastic change. It's not about just doing a bunch of activity. If its activity that I can easily do, that's probably not

going to lead to neuroplastic changes, because there's no learning that I have to acquire. I wanna look for things that require motor learning. This is a paper that I often times cite, it's now getting kinda old. It's from back in 2001, but I like what it talks about. This is a paper by Beth Fisher and Kathy Sullivan. They talked about this activity dependent plasticity and how do we get it. What are the key ingredients? How do we drive it? They said that the task has to be sufficiently complex. It has to be something that can't be mastered easily on the first try. Along with that, it has to have difficulty and intensity. Think about the degree of difficulty that we're giving them. Are we giving them something that's too easy? Again, that they can easily master. That's probably not getting at the degree of difficulty and intensity.

Are we giving them something that is intensive? Is it requiring a good deal of effort? Is their heart rate going up? Is there sweat happening? These are the kind of things we wanna look at for intensity. It needs to be task specific. We've always known that task specificity was important for motor learning. What we know is that when we do things more intensely, we actually have to have less task specificity. Just throwing that out there. In some of the most recent research in 2016 and 2017 looking at locomotive training. Intensive locomotive training and patients with stroke. It's seen that when you intensely practice walking, then things like balance and transfers improve without having practiced those.

Meaning, we need less of a degree of task specificity when we hit that intensity mark really well. Then the last thing that they talked about which we often times skip over, is that we need a rich sensory experience. Meaning that for our patients, we need to try to utilize sensory input. Give more sensory input, because again, sensory and motor are linked. I can improve motor output by improving the use of sensory information. Providing our patients with a little bit more of a rich sensory experience then we often do might be key there. My question to you right now that I want you to take just a second to reflect on while I'm talking is are you promoting or preventing motor

learning? Do you think in your practice the things that you do daily with your patients. Do you think that you're promoting motor learning? You're promoting them to have those necessary experiences and processes that results in a relatively permanent change that leads to automaticity? Being able to do things effectively without thinking about them, in a variety of contexts and circumstances. Is that what you're doing? Or, could you potentially be doing something to prevent it? I hope you're all puzzling about that. I hope you are actually thinking about that, and reflecting on that. I'm gonna tell you that I think in our practice, we do a lot of things that prevent motor learning. I think we stand in the way sometimes of our patients' motor learning. We'll talk about how in the remainder of the time. We know that there are some principles related to motor learning. The familiar factors of motor learning have to do with practice and feedback. That's kind of the things that I learned about in school way back in 1993 and 94/95. Those are the things that I learned about, was practice and feedback. When we get to part two of this series on motor learning and motor control, we'll talk about more of the more contemporary less familiar factors of motor learning.

We'll make some hints at those today. Practice being what's seen is one of the most critical factors in retraining motor skills. That amount of practice. Then feedback. How are we providing feedback? Is the patient utilizing intrinsic or extrinsic feedback? We'll talk about those in detail and remind you what knowledge of results and knowledge of performance means. In terms of practice, which has been seen as really important. Performance improvement is dependent upon the amounts of practice. Certainly there are other factors other than just the amount of practice that are critical here. What are those? It's really about how we structure practice, in addition to the amounts of practice. We do need this large number trials. We need more opportunities to establish these relationships amongst the various types of information associated with each movement. We need to create connections, correlations, relationships between these. We need to enhance the stability of recall and recognition. Mentioned those earlier when we talked about Schmidt's schemas related to theories of motor learning. We

need to give them many opportunities to recognize movement patterns, to recall movement patterns. To put those into execution. This requires more instances of retrieval of those motor programs. We need to practice over and over. Lots of instances of retrieval. It's just like if you were going back to school, would learn information on anatomy. It's really not about reading it over and over, it's about forcing yourself to have many opportunities to retrieve. That means creating a question, and having an opportunity to answer that question. It's not really about the exposure to it, it's about the retrieval that we have to do. This can help automatize the activation of those patterns for future use.

The amount of practice being really critical. The need for variability of practice, which we already alluded to. Schmidt talk about this way back, that there needs to be this variability of practice. Variable practice relies on higher order motor areas, Constant practice depends more heavily on just the primary motor cortex. We want to be activating more areas of the nervous system. In order to do that we need some variability of practice. This doesn't mean they have to be widely variable. It doesn't mean that I have to be doing 15 different things in a session. It could be variability within the same generalized motor pattern. Just not doing exactly the same every time. This doesn't work well for everyone.

The last bullet point there, the study my Dick et al. This was looked at variable practice in a group of patients with Alzheimer's or with some time of dementia. Variable practice didn't work well for them, and that makes sense. The cognitive impairment sort of limited their ability to manage the variability of practice, but that was with significant cognitive impairment. Even our patients with mild cognitive impairment can typically do well with some variability in their practice. In terms of practice conditions, some things you probably learned about in school. Massed versus distributed, constant versus variable, random versus blocked, whole versus part, transfer, mental practice, guidance versus discovery learning. We'll hit on all of those quickly, but I think we'll

cover them sufficiently. Massed versus distributed is a little bit challenging to wrap your mind around. I gave you the exact words here of what it means. Massed means that the amount of practice time in a trial is greater than the amount of rest between the trials. The amount the time I'm shooting free throws, each block of it that I do. That amount of time is greater than the amount of rest where I'm not shooting free throws. Doesn't mean like rest, like I'm laying down or sitting down. Just means where I'm not doing that actual practice. Versus distributed means that the amount of rest between the trials. The amount of time between my trials of shooting free throws is gonna be greater than the amount of time I'm actually shooting the free throws. Again, that just means that there's more of a spread out practice in distributed, then there is in massed. There's really not a significant difference in the literature about one of these being better or the other, in terms of retention. Pretty equal. You can probably think of some instances where one might be better than the other.

I typically do start with more massed practices, but I often times try to move to distributed. I feel like that introduces some degree of variability there. When you look at constant practice versus variable practice. We've already said variable practice increases motor learning, it improves the ability to adapt and generalize. Which is certainly what we want. It seems to be most useful when learning tasks, are performed in variable conditions. We definitely wanna be hitting on something that's variable versus constant. Random versus blocked. This just means something that's predictable versus unpredictable. Blocked practice is when I'm practicing in a way that the sequence that I'm doing is predictable. I'm repeating the same sequence of practice over and over again, versus random. There is no predictability about the sequence of activities how I'm practicing them. Blocked practice is gonna improve my performance in the moment, but random practice is gonna be better for retention and transfers. That means in terms of me and therapy. I want to try to progress my patient to that random practice, or utilize random practice more than I utilize blocked. That makes sense because random practice, that's introducing some variability. Random

practice causes what's called contextual interference. This just means that it increases the degree of difficulty. It makes learning more effective. How do we improve learning? We have to have that degree of challenge, that degree of difficulty. Again, I may not start off with random because I want the learner first to understand and master the dynamics of the task. I want to move to that random practice as quickly as possible. Whole versus part. This is something we utilize a lot in neuro. We'll break down something into it's component parts, and we'll have the patient practice their component parts. This can be helpful, especially in something that's complex. This could certainly be helpful. Here's what the literature says about his. It says some skills don't really break apart easily. Walking is really a continuous activity, not really easy to break down in component parts. Some skills easily break down into parts. We can certainly see practicing them in parts making sense. Things like transfers, that kinda has step one, step two, step three, step four, that we can take the patient through. Essentially the literature suggests that we don't utilize whole versus part unless we really need to.

We only break down things into parts when it makes sense to break down into parts. Here's the bottom line. If you do part practice, you need to make sure that before your time with that patient is up, you've come back to the whole practice. Don't ever finish just practicing the parts. Always put it back together in the whole. Otherwise you sort of wasted that time that you spent in the part practice. Transfer, we've already mentioned. Transfer just means that what I'm learning in one practice is going to trickle down to other similar skills. We want to maximize that ability for transfer. We want to make things intense as possible, so that we get as much transferred down to other skills as possible. Making our treatment most effective, most efficient. Mental practice is another good practice condition that I think we often times overlook. There's certainly more that could be said about this and I have to time to say. I've given you some good sources there, but essentially mental practice is a cognitive rehearsal. What we know, and this is just so cool to me. Let's say you look at a person doing

sit-to-stand, and you look at their brain imaging while they're doing that. You see what areas of the brain light up while they're doing sit-to-stand. Then you have the person mentally rehearse sit-to-stand. What you'll see in that imaging is that the same areas of the cortex, same area of the nervous system is activated while they're mentally rehearsing. The same areas are gonna be activated that were active when they physically practiced. If our goal is to get more therapy in the day, more therapy that's outside of therapy. More therapy that doesn't require me doing one on one, this could be a great way to enhance their learning very efficiently.

Make sort of maximum use of our time. Now this has to be combined with task specific practice. Just not sitting and thinking about it all day, not helpful. When they have mental rehearsal before or after task practice. This has been found to be very beneficial in motor learning and improving all kinds of motor tasks. I've given you some references there, if you wanna look further in that. The other thing that's been researched. I feel like it's been researched quite a bit, but not talked about enough is the power of observation. It's a very viable method for practicing complex skills is by observing someone else doing them. If I have an opportunity to sit and observe someone else model a particular skill.

Or even watching a video of somebody doing that. I combine that again with my own task specific practice. This very much increases training efficiency. Again, if we're thinking about how do we get more therapy outside just our one on one time with the patient? How do we help them learn faster, more efficiently? Combining with some type of observation can be excellent. There's even literature that looked at combining the two of them. Very recently in the last two, three years, there's been studies that have looked at what happens when we combine the two of them? Essentially, there's increased activity in the motor regions with both of these by themselves and when you combine them. Certainly, that's something that can probably get you more bang for the buck, when you combine those. Here's the example from the literature that I took.

There was significantly decreased postural sway in this particular balance activity, in both the observation group and the mental imagery group. This suggests that you don't have to combine them, but certainly it makes sense. Again, if you're thinking how do I get the most bang for the buck. I could easily combine these two activities together, or at least make sure that I'm using one or the other in combination with my task specific practice. The last point to make about practice conditions here is about guidance versus discovery learning. I feel like in neuro rehab specifically, we do a lot of guidance. We put our hands on the patient a lot. We physically, manually cue them, and guide them, and move them in the way that we want them to be moving. Sometimes that can be helpful for learning, if I do it just a little bit. I think most of us, I definitely am very convicted of this. We do it way too much. When I don't guide the patient, they don't look so good. Their performance is pretty ugly, they're not doing the movement as well as I want them to do it. Accomplishing the skill as well as I want them to do that.

The key here is that it's most effective for retention and transfer when I go with unguided conditions. I want to encourage you to start thinking, not necessarily about giving up your manual guidance completely, but replace a lot of it with what is often times referred to as discovery learning. Allowing the patient to explore that perceptual motor workspace that was mentioned earlier. To have some of that trial and error discovery, get those best strategies and to utilize all of those perceptual cues. Allowing more of that trial and error. I think that's a hard thing for a lot of us to do, and that's something we definitely need to incorporate. We talked about practice, let's talk about feedback. I would encourage you to take just a second to think about how you think you do, in terms of feedback. Do you think you provide good feedback? Too much feedback, too little feedback? The picture on the left where the person is yelling with the blow horn. I think this is often times how we approach our patients. We are giving lots of feedback loudly, blowing their hair off kinda thing. The picture to the right there, where there's just so much information that's being passed. Usually it's just being

passed one direction. The patient's not as silly passing that all back to us. We're just passing a ton of information. I think we probably would be better suited to approach our patients more like this. Just really simplify it to you got it, you didn't got it. Maybe a little bit more than that, but really bringing it down to much more simple feedback. That's just not my suggestion, that's the feedback from the literature. There's a very well accepted hypothesis in motor learning that's called the guidance hypothesis. It says that information is provided via feedback can certainly guide the learner to the correct movement, and make them look better. Improve their performance, right. Make them look better during practice.

Frequent feedback has a negative effect. Well supported that we can use our external feedback, our augmented feedback in a beneficial way, if it helps to reduce error. It becomes detrimental when it's relied upon. That last sentence there being very important. Detrimental when relied upon. I would venture to say that many of us are giving feedback that our patients have become completely reliant upon. Then that's obviously detrimental for their ability to actually relearn whatever skills we're trying to have them learn. Let me make the point here. I keep giving references related to people with neurological injuries.

All these concepts apply with whatever types of patients. People you're retraining for sports, people you're retraining for whatever. Your patients with musculoskeletal injuries or whatever. All these things apply to them as well. My reference is all from neurological. That's why the examples I keep giving I guess. Let's just make sure that all of this applies across the board. To give you this idea of that discovery learning, too much feedback kind of thing. This was a study that was done in normals. It's just a silly little study, but I think this will make the point. They had normal subjects that were trying to learn a 70/30 weight bearing distribution in standing. They were trying to learn how to put 70% of their weight on their left and 30% on their right, lets say. They had four groups of them, and they did 10 blocks of 12 trials of practice. They would do 12

repetitions and they did those blocks of repetitions 10 times. A lot of practice, a lot of repetitions there. There were four groups. One group got 100% guidance. That meant when they stepped up on the force plates, somebody, their therapist, put their hands on the subject and put them in a 70/30 distribution. Then the subject stepped off, then they got back up there. Their "therapist" put them back in that 70/30 weight distribution. They did 10 blocks of 12 repetitions, of just being put, placed, guided, into that 70/30 ratio. The second group got 33% guidance. That meant every third trial, the therapist guided them to the 70/30. On the other two trials, they just tried to figure it out themselves. The third group got 100% knowledge of results. That meant after every trial they got up there, they tried to find 70/30 best they could. They were told you hit the mark, you didn't hit the mark. The last group got 33% knowledge of results. Which meant every third trial.

Two of the trials they just tried to figure out 70/30 on their own. The third trial somebody told them, you hit the mark, you didn't hit the mark. Which group do you think looked the best in terms of performance, in the session? Who looked the best in terms of performance? That would be the group that got the 100% guidance, because they were perfect. In practice, the performance measure, they were perfect. The group that only got every third trial knowledge of results, looked the worse in practice. What do we care about? We care about retention. We care about did this person learn the skill? In learning, when they looked at a retention test that occurred anywhere from 10 minutes to a week later after training. The group that got knowledge of results, every third trial, had the fewest errors. Essentially, the person that got the least feedback, the least guidance, had the fewest errors. Meaning they learned it the best. The group that got 100% guidance, learned it the least. They had the most errors in retention. Now you might be thinking, well this sounds stupid. When would I ever just guide my patient 100% of the time? Well, we probably don't, but there are lots of times that I don't take my hands off the patient and allow them to have that discovery learning. There are lots of times that I guide them to the movement. I make it look really good, and then I

wonder why they can't do that again. Or why they can't do that with nursing, or with their family. I hope some alarm bells are going off in your head. Let's talk a little bit more about feedback. Feedback can either be intrinsic or extrinsic. Intrinsic feedback means this is the feedback that comes from their sensory systems. This comes from visions, somatosensation, auditory. Their sensory systems are helping the person, the mover, understand is movement accurate? Is the movement meeting the goal? That's really all we wanna know. Movement accurate, did it meet the goal? Versus extrinsic feedback is the augmented feedback that we provide them as therapists, or as coaches or whatever it is.

We provide them this to supplement, it should supplement their intrinsic. As key, it should supplement intrinsic. Meaning intrinsic is really important, and we're just trying to supplement that. What do you think we do in terms of therapy? Do you think we are helping them learn to utilize their intrinsic? As a therapist, I really wanna be coaching them towards learning self management. In order to have self management, they have to rely on their intrinsic feedback. If I'm giving a whole bunch of extrinsic feedback, I'm telling them a lot of stuff. I could be making them dependent on my feedback, and they're not learning to develop their own. Key thing that we wanna think about. In terms of augmented feedback, some ways that we do that. We can do that concurrently, meaning as they're doing a task.

As they're doing a movement, I'm giving them feedback. Or we can give it terminally, meaning after it's over I give them some feedback. Terminal feedback is going to be best for true learning, for retention. Why is that? Well, if I'm just giving you feedback while you're doing a skill. You're not paying attention really to the skill, and feeling it, and hearing it, and seeing it. You're listening to my feedback. You're just attending to my feedback. That terminal feedback, giving the time to process through the skill or the movement, probably gonna be more beneficial towards retention. Immediate versus delayed. Giving them feedback right away, versus a delay after they've done a trial of

the movement. Delayed also being better for retention. Why? Hopefully you're already answering this question for me. Delayed gives them a time to process. Again, to hopefully have some self management strategies. Don't just give your patient a minute of silence, without some prompts. Many of our patients in a minute of silence would be thinking of something else. After they've attempted the task, I may give them a prompt, but not feedback. A prompt to be something like how did that walk feel for you? Did that walk feel normal? Did that walk feel safe? I'm giving them to some prompt to have some self reflection. To do some processing. Then, after they've done that, I'm gonna give them my feedback. That's the whole idea about giving it delayed. Verbal and nonverbal, we can use both of those. We just want to make sure they match. Accumulated versus distinct. Accumulated, another word could be summary. Giving them some summary feedback, versus really distinct bits of feedback. Lots of little bits of feedback.

Again, more summary probably better for learning. Knowledge of results and knowledge of performance. Terms that you probably learned about in school and promptly forgot. Knowledge of performance means I'm telling you information about the movement. About how you're doing the movement. Versus knowledge of results is exactly what it sounds. I'm telling you the outcome. I'm saying you hit the target, you didn't hit the target. You jumped up to the mark, you didn't hit the mark kinda thing. Again, knowledge of results tends to be better for learning. Versus knowledge of performance can certainly improve their performance in the practice. Too much of that is going to inhibit then retention. Looking to try to give knowledge of results more often. We wanna think about giving more cues rather than lots of instructions. Think about how you like to get instructions when you're driving. You like to get one instruction at a time, as clear as possible. Don't tell me the whole list of directions that has 15 steps. Give me just one at a time. We wanna think about cuing the patient, rather than providing them instructions. Keeping in mind that individualized feedback is not completely necessary. Observers perform as well as the models. Another words, if I

have two or three people all working on the same thing, I don't have to give individual feedback to every one of them. If the two people are watching the one person do the practice and hear my feedback to them. That's very beneficial for them as well. Maybe as beneficial as getting individualized feedback. Important to keep that in mind. Doesn't have to be individual feedback. It could be feedback to one, that other people are getting to hear and benefit from. We wanna think about how we schedule our feedback. We wanna think about first what's my overall frequency. I asked you that questions a little bit ago. How do you think you do in terms of feedback? What would you say your frequency is of feedback? Are you giving it with a high frequency? If so, you probably want to think about fading that feedback.

The literature suggests, giving knowledge of results early in practice, only about 50% of the time. Then gradually decreasing from there. Fifty percent of the trial is giving feedback and gradually decreasing from there. Using more summary, end of block practice feedback. Giving quite a few attempts before you give feedback. Five to 15 trials before you provide any feedback. Again, thinking about how we decrease this and just make this all less, and that idea of delayed knowledge of results being better. Looking at the power of our feedback.

Our feedback is very powerful. I'm sure none of us would intentionally give erroneous feedback, but there's quite a lot of literature that suggests you can actually cause somebody to unlearn something they have already learned. When you give erroneous feedback. Again, you're probably saying when would I ever do that? When would I give anybody misinformation, misfeedback? We don't typically do that, but if we're just talking so much, and providing them so much information. Probably some of its gonna end up being wrong. We just wanna make sure, I think the keyword here is to think about our feedback needs to be very intentional. This was kinda covered earlier when we talked about observation. Remember when we talked about too much feedback being bad. When the feedback is actually modeling. When a person is observing a

model do a skill. Either live or video, however that works. Too much modeling, there isn't such a thing as too much modeling. It doesn't impair retention at all. That's because we're just sort of hardwired to imitate. We're really hardwired to imitate whatever it is that we're modeling. Again, that idea of movement observation and combining that with task practice. Getting that same area of my nervous system activating when they're watching the model, as what's happening when they're doing the actual physical task. Just one more plug for that. This was an example that was from some normal subjects. Again, the group that got 100% modeling had the best retention. This idea that this is something that we can't give them too much of. Whereas we can give them too much other kinds of extrinsic feedback. I'll wrap this up with asking you.

Are you promoting or preventing motor learning? I would actually ask you to take some time. Not now because obviously I can't sit here and be silent for a period of time while I'm letting you think about this. Now that we've kinda covered what some things about motor learning mean. I want you to reevaluate that and to think about am I promoting motor learning, and specifically how am I doing it? What am I doing in terms of how I'm structuring practice and feedback, that's promoting motor learning? Make a second column. What specifically am I doing in terms of practice and feedback that might be detrimental to motor learning?

Think about then what are some action items that you can take on to make that list of how my promoting be longer than the list of how am I being detrimental or preventing motor learning. I do hope that you'll come back and actually do some reflection about that, if you haven't already been as we've been going through this. I think that in order to make this meaningful and useful in your clinical practice, you have to do some time to self reflect how does this material all apply to me. I wanted to give you some examples from the literature, and then I'm gonna give you a couple patient examples. This was a study that was published back in 2006. It gives this idea of extrinsic

feedback. I pulled this study because A, it's about a patient with a neurological diagnosis. It's not just some sort of theoretical paper that's been done on folks that are normal. Which a lot of the motor learning literature is, or at least started with, how does this work in normals? This looks at what actually happens in a patient with stroke. This was a review paper that wanted to specifically look at how extrinsic feedback impacted motor learning in people that had had a stroke. Sorry, apologize for that. There were several things that this paper brought out. A, the research is scarce. Like much of the research that we have in sort of the neuro rehab world. Some of their preliminary findings were that balance performance could improve when they received visual feedback about weight distribution. If you're thinking about how do I help my patient. What the ways that I give feedback to not make them over reliant. You're providing visual feedback is actually helping them tap into their intrinsic. It's not making them reliant so much on you.

Auditory feedback on force production could improve the performance of sit-to-stand. Helping them understand weight shifting and distribution between their feet, by using auditory feedback. Again, that's something that I, as the therapist, am providing them, or some system that I'm using is providing them. Again, it's linking feedback more to their intrinsic systems. It's a way that we're augmenting, but again, it's tapping into that intrinsic because now we're thinking about auditory. With the first one thinking about visual feedback. Providing feedback on less than 100% of the trials, giving summary or average feedback enhances learning. You don't have to give feedback every attempt the patient makes. Any kind of feedback. I've really started in the last 5, 10 years of my practice, I've really made a concerted effort to not give feedback all the time, on every attempt. I let them have a lot of them, that I don't say anything on. We'll talk later in part two, on some more details about when it is that I do give feedback related to the patients outcome. Providing that feedback less than 100% of the time. Giving more summary or average feedback as opposed to those discrete bits of lots of stuff that we just throw them. Then the last one instructions or feedback that induce an external

focus may be more effective than those with an internal focus. That's not something we've talked about yet. In part two of the motor learning series, we will get into more of those cognitive and motivational sorts of aspects of motor learning. We'll talk way more in detail about internal versus external focus. Creating a situation that gives an external focus more beneficial for motor learning than internal focus. Again, I thought it was interesting that this paper's about extrinsic feedback. The first two examples that they gave, or the first two findings that they had were really about how do we shift the patient more to intrinsic. We're using our input, but we're actually providing them some type of feedback that they're going to more internalize.

I think that's really important. As opposed to just our words that they're listening to. That doesn't have to shift them to their intrinsic system and more self regulation. The other thing that I wanted to mention which I think is kind of new in the literature in the last few years. Is this idea of the challenge point. We've mentioned that the key ingredients for neuroplasticity. To drive neuroplasticity had to do with the activities that we have the patient do. Those activities need to be complex, difficult and intensive. They need to be task specific with a rich sensory experience. From that people ask the question, well how intense, how difficult, how do we determine that? There's been some recent work that's been done at this idea of the challenge point.

The challenge point framework suggests that motor learning is optimized when the learner is A, actively involved in problem solving during the process of finding movement solutions. There has to be this balance between a challenge and an ability to eventually have success, so that they stay motivated. This is a process that we have to go through, not just a random, throw something at them and hope it's the right degree of challenge. In this paper that I've cited here from 2014. They talk about using this is a case series to promote motor learning in a stepping reactions task. We know our patients with stroke don't have good stepping reactions. What they did is they had this progressive and difficulty stepping training that they did with patients. It resulted in

improved community level walking with their improvements retained at least one year out. Not only did their balance get better, or their ability to do these stepping tasks, but their community walking improved. Which is really important. We took these discrete stepping tasks that we had the patient do, and it resulted in improved function Really important, right. Not only did it result in improved function, but it resulted in improved self efficacy, as well as movement kinematics. Lots of improvements from having this very structured progression of activity. What did it look like? They started with blocked practice of multi-direction stepping reactions. The patient was in a harness for safety, and they were on this walking belt where they could introduce these different directional stepping strategies. Induced a slip kind of thing on the walking belt. They progressed then to random practice of those multidirectional stepping reactions. Then they progress to forward and backward stepping reactions with increased cognitive load.

They introduced a dual task that the patient had to do. Again, in all these the patient was harnessed and they were on this walking belt to be able to induce those different changes in direction. The other key thing is while this was going on, from the beginning to the end, the feedback was greatly reduced to almost none. Through this step wise process, they were able to not only change and improve their ability to do these specific stepping things. Like stepping forward, backwards, laterally with the affected leg, and with the unaffected leg. Those are some of the things they practice. All the way to forward and backward stepping reactions with dual task involved. Not only did they improve the stepping reactions, but they improved their confidence for balance and improved their community ambulation. Big functional changes. I like this example. This puts into practice this idea that we have to have a more structured idea at how we reach this difficult, challenging task that we want to have the patient do. That's just one example from the PT literature that I thought was helpful. I wanted to put this into practice with a couple of patient scenarios. Just some paper patients that I have created. For the first one, you have a patient who is two weeks post a C8 spinal cord

injury. It's a complete level injury, just for the sake of ease of writing a one slide patient case here. It's complete. She has transferred to an inpatient rehab from acute care. She's stable and her spine is stable. You just initiated transfer training. She's clear for mobilization, clear for all activities. You're gonna get started in transfer training. When you initially get the patient up and you transfer her to her wheelchair, doing a level surface transfer. She's Mod Assist, then you take her to the gym and you do an unlevel surface transfer. Kinda going uphill to the mat, and she's a Max to Dependent Assist with that transfer. When you're thinking about this patient case and you're thinking about applying what you've learned in terms of motor learning. I think it's important to understand to think about this case specifically.

We have a pathology of spinal cord injury, C8 level spinal cord injury. When a person has a cervical level spinal cord injury, their motor capacity, especially a complete in this case. Their motor capacities just kinda greatly reduced. We have the upper extremities that have working motor. We have the head and neck that have a working motor, but we don't really have any trunk activation. We don't have any lower extremity activations. Movement and relearning movement for this patient's gonna be very challenging because she doesn't have a lot of the parts available to try to relearn. She doesn't have a lot of her motor parts available for us to utilize.

When we take that into account, we wanna think about what would likely be the best practice structure at this point. Remember practice, we talked about the amount of practice being important. We talked about some different practice conditions, practice structures that we might use. What would you think in terms of this person has never had to transfer in her life. Most of us don't really transfer in normal life, we just stand up and move to another surface. We don't actually do this sort of contrive squat to the transfer, or sliding board transfer, or whatever she might be doing. What do you think might be important though in how you structure her practice. Often times you and I just go in there and we say, "Okay, Mrs. Smith, here's how we're gonna teach you to

transfer." We just do it a couple times. How could we make this more beneficial for her learning in terms of thinking about practice structure. Well, we might think this is a really novel task for her. She's moving with a completely new body. She really only has her arms to move, and her head and cervical spine to move. It's very novel, it's very challenging. Totally new way of moving for her. We probably wanna start in more massed, blocked practice conditions. We certainly know we wanna progress to variability. Early on in this patient's practice we're gonna stick to more massed and blocked practice because this is so novel for this patient. It's gonna be a high degree of challenge.

Could we think about breaking it down into it's component parts? Absolutely, this would be a person that part versus whole would work really well for. Being able to position your wheelchair, lock your brakes. Figure out how do I scoot forward when I can't scoot like I normally scoot. There's a lot of parts that we could work on, but the key to part versus whole is we wanna make sure if I choose to break this down into some component parts during this session. I wanna come back before we finish, even if it's right at the end. "Okay Mrs. Smith, now let's just try. I'm gonna have you practice this one time all together.

You doing as much of it as you can from start to finish." We have to get it back into the whole, because otherwise we've kind of wasted that part practice. In terms of how you're gonna provide feedback. There's a lot of things I could say about how a person with a C8 level spinal cord injury. A lot of things to say about the transfer. I could go on explaining it for days probably. Would that be beneficial for the patient, if I gave them a lot of verbal feedback? What might be the best way that I could provide feedback for this patient to promote the most learning? Probably the feedback I could provide would be observation. Her observing someone else do it. Her observing me do it with the mechanics that she's gonna use, so that we're modeling that. I think that would be very beneficial. Otherwise we get really bogged down in the words and the

instructions. It becomes like that picture where there's just so much information flowing out of my mouth to the other person's brain that they become overwhelmed. I want to remember to provide time for processing and self reflection. With every step that I'm giving her, I want to encourage her to try to learn from those errors. What is it that didn't go right? Can you tell what didn't happen? What are the parts we need to add in to make it better? Somebody said keep it simple. Obviously keeping it as simple as possible is always good. Yeah, and keep it simple observation. Making it just really clear and really simple, absolutely. Giving her some cues for that self reflection that she needs to learn, so that she gets that self management. Having her rely on visual feedback. How do things look to you when you're doing this? What does it feel like in the parts that you can feel?

She may only have feeling in her arms, hands hopefully. What does it feel like? I need some cues to help her start to rely on that intrinsic feedback, to help her to learn that. That would be just some ways that I might think about approaching this. To enhance the patients motor learning, as opposed to just I'm gonna go in and practice this a few times. Which is sometimes what we do. I think for this patient, definitely observation is going to be really key. When I have a patient, with especially spinal cord injury, different levels of spinal cord injury. When I have a patient who can do a transfer really well, I'm always like can I get you to show this person. Or can I video tape you to be used for later so we can show, because I can really see all the good mechanics here.

Then somebody else has chimed in and says repetition and note cards. Making some cue cards is I think what you mean. Absolutely and high repetition. High, high repetition, absolutely. Again, mental practice would be great. That's gonna get in more repetitions. Adding mental practice and observation, or back and forth between those two would be really important there. I think those are things that we don't always take advantage of and utilize in our practice. The last example I wanted to flip to something that's kinda different. I move away from something that's really catastrophic kind of

injury. This is a young athlete who's working on retraining his pitching post shoulder injury. I don't need to tell you what kind of shoulder injury. I don't think those details matter, but it's some type of shoulder injury. He's retraining after this injury. Prior to injury he was able to throw a variety of pitches successfully. The full gamut of them, fast balls, breaking balls, changeups. I had to look those up, I really don't know anything about pitching too much. He could throw a variety of pitches and was successful with all them. Some pitchers can't pitch certain pitches. He was pretty good, really across the variety of pitches that were possible. My goal is to retrain him successfully to pitch in the manner in which he pitched before his injury. Again, same questions. How would you structure practice in order to maximize learning? When and how should you provide feedback?

In this patient, when I'm thinking about what this person is bringing. He had a significant knowledge of pitching. The patient before, she has no knowledge about how to transfer without the use of her trunk and lower extremities. None of us do, until we have it happen to us. We don't have that knowledge. She had kinda zero knowledge bank, and he has a lot of knowledge about the mechanics of pitching. He's still going to have to relearn how to get his nervous system, and his musculoskeletal system, and all the systems to work together to get those successful pitches. How would we do this? What would we go to to organize this?

Somebody said start with Massed Blocked, part versus whole, but progress quickly. Yeah, I think the key there is progressing quickly to random and variable. Maybe not even hitting some of those lower level things. Maybe I do start with more blocked and massed, but I really, really quickly wanna move to variable random. I wanna make him throw on demand. I'm just gonna shout a pitch just like the catcher gives him a signal. I'm gonna shout a pitch, and he's gotta pitch that. That's what we're progressing to, because then that's gonna take some of the thinking out of it. It's gonna make the pitching sequence be truly random. Part versus whole is not gonna really work too well

for pitching because pitching is a very continuous kinda thing. Certainly we can do strengthening and particular range of motions and such like that. The actual putting it together, it's kind of an all or none sort of thing, in terms of relearning. I probably would avoid part versus whole because I don't think that will work a lot with this person. You're absolutely right, I'm gonna progress really quickly to more variable, random types of strategies. Again, giving him that on demand sort of drive. I would probably in terms of the question I wrote for myself. When and how should be provide feedback? I would try very hard to give, yes Pam, less feedback certainly. With time to reflect, absolutely. I'm gonna allow quite a few trials to go by before I give any feedback first of all. I'm gonna let them do 10 throws or whatever before I even give any feedback, absolutely.

I'm gonna give more of a knowledge of result. I'm not gonna tell him a whole lot about how he's moving, how he's moving his arm, that kinda stuff. I may give a little bit of that, but I'm gonna stick with more knowledge of results. Several people got that, that was absolutely right on. I'm gonna fade my feedback, that's absolutely right on as well. I'm gonna give them cues for that reflection, and yes, knowledge of results. Absolutely. Less feedback with time, absolutely. You guys hit all of them. I'm gonna give them time, I'm going to give them less feedback.

I'm gonna give them some cues for self reflection and self learning. Again, I'm going to try to shift this pitcher so he's relying more on his feedback. His intrinsic feedback and less on mine. Roberta says, "For retention, can we use faded feedback?" Yeah, we just have to make sure that we fade it. That are frequency is decreasing, and decreasing pretty significantly. Eventually getting to no feedback really. Yes, I would definitely video tape them and have them watch. That's like really standard practice, especially in sports. We don't use that that much in our patients and we probably should. Video taping and letting them watch. Then having to come up with their own feedback. Yes, less feedback in hopes of adaptation and retention. Absolutely Melvin. Jennifer says,

"Speed feedback or placement." Oh yah, more emphasis on speed and placement of the ball. I started to say that earlier, giving him specific targets for placement. Absolutely, as well as changes in speed. Yep, absolutely, good job there. I'm just trying to catch up on the comments. Mirror or video, absolutely, absolutely. We'll talk about in part two, if you're in part two. We'll talk about why that's gonna be better then me giving a lot of knowledge of performance. Yeah, good ideas for the video taping. Yes, faded feedback does promote retention of learning over giving high frequency. If we're fading from a really, really high frequency, to still a lot. Probably that's not so helpful, but yes dialing back my feedback. Again, the literature suggests started with only giving feedback 50% of the time, and dialing it back from there. Yes, that will promote motor learning and retention.

Let him teach you, lets have him reflect on corrections, yes. I had a patient one time that really wanted to return to golf. He'd had a stroke, he really wanted to return to golf. A, I needed him to teach me because I didn't really know that much about golf. In order for me to help him, I had to learn about golf. Him teaching me, and for example, me doing the swing, and then him coaching me about what as good and not good about it. Was super helpful for his learning, and I learned a little bit about golf too. Is there any evidence on real time visual feedback versus recorded?

Christian do you mean they're watching it in real time, like as they're doing it? Versus watching it later with a recording? Is that what you're asking? Yeah, I don't know if there's any evidence about that. I think for some task, it might be hard to watch in real time. I don't know the answer to that question. I don't know if there's any evidence about that. I don't know if that's something you have some experience with. I'm happy to talk about that more here about your experience more. Hopefully those couple of examples just got you thinking about these activities. I mentioned earlier, we are doing a second course on motor learning. Just to give you an idea of what that will be about, in case you're interested. We're gonna expand the definition of motor learning beyond

the things we've talked about here. Looking at more cognitive processes, affective reactions and attentional focus. How that relates to motor learning. Drawing all of these together to help meet the task and to provide better retention, better actual learning. There are questions. You have my email address here if you have questions later. Kaylynn says, "Is faded feedback or knowledge of performance more effective for retention?" Those are two different things. If we were comparing knowledge of performance versus knowledge of results. Knowledge of results is more effective for retention. The feedback question, is really about the frequency. High frequency versus faded feedback. That to position, faded feedback will be better for retention than high frequency. Hopefully that answered your question there. I think you were kind of mixing up two constructs maybe. Is the answer to question number four on the exam D? I don't have the exam in front of me. Yah, I don't have the exam in front of me. Are there any other questions? I don't know what that question or comment from Kathryn, not sure what that was about. What is the goal for motor learning, Roberta is your question. The goal for motor learning is retention. Learning and retaining motor skill, I guess would be what I would say the goal is. Hannah, you are welcome. I'm glad it put some things in your head. You're welcome Alec. Any other questions? For all you saying thanks, you're very welcome.

- [Kalista] All right, I don't see any other questions either.

- [Jill] I think there's some more.

- [Kalista] I do see one. Yeah there's one from Kaitlynn that say can motor learning be directly measured for documentation purposes?

- [Jill] No, again, we're inferring that motor learning has occurred after some period of time after practice. Some period of time without practicing, can improve in some particular motor skill. We're inferring that motor learning has occurred, but it can't be

directly measured. Any other questions? Glad that you guys enjoyed it, very welcome. Any other questions. Kalista are you seeing any other questions? Trying to scroll through these quickly here. Lauren asked, "When is the optimal time to provide feedback in order to enhance effective learning?" I don't know, can't see all the question there. It looks like part of it may be ... Not sure why I can't see, oh thank you. Lauren, that looks like a quiz question, but that shouldn't be the quiz question from this session. That is a question that actually goes with the next segment. I'm not sure if you're asking that, it looks like you've just copied over a quiz question. I don't really know what to say about that. We will talk about that later in this second segment, but I don't know if that's a quiz question. Kalista, if that's a quiz question that got in there by accident. It's from the motor learning two course.

- [Kalista] I don't believe so. There is a question on when the second course is, and that is Wednesday, September 25th. I believe that is it. We'll go ahead and wrap up.

- [Jill] There are a couple more. Michelle says, "Should we promote reflexes, or inhibit reflexes?" I think the question is bigger than that. Are the reflexes normal reflexes, or not normal reflexes? Again, a lot of our movement occurs via reflexes, and that's very normal. I think I might need a little bit more details about that. I would also say that I would pay less attention to inhibiting abnormal reflexes and more attention to promoting movement, then I use to. If that helps with that. Daniels says, "You touched briefly on cognitively impaired patients. What strategies are most effective for them?" For patients with cognitive impairment, you're often times going to be sticking with more of a massed practice, more constant practice. As opposed to introducing a lot of variability. With people with cognitive deficits, what's gonna be the most automatic things we can get them to do? Working for more of those automatic responses, not a lot of thinking sort of responses. Hopefully that helps. Sandra says, "Can I hit the contradictory evidence for the reflex theory again?" The contradictory evidence was essentially that we don't have to have sensation in order to have movement. I can

inhibit my reflexes when necessary, or when there's a demand to. Those are really the biggest ones. Are reflexes used as a last resort for rehabilitation? No, much of my movement should occur via reflexes, as I said earlier. Anything that needs to happen quickly, most the time is driven by reflexes. I need to create a movement much faster then if I had to take it all the way up to the top of my brain and think about it and have more of a planned out, thought out response. Certainly, there are lots of movements for which we utilize reflexes. Again, I feel like some of these are just quiz questions that people are asking. I don't think I can really give you the answer to those. Can we write a goal if it can't be measured? I'm not sure what the intent was Leetha, for that questions there. I'm not writing a goal about motor learning, I'm writing a goal related to functional outcomes. How I'm helping promote them, achieving those functional outcomes is through utilizing strategies of motor learning. Hopefully that helps to clear that up.

- [Kalista] I think we'll go ahead and wrap up there. Since I did think there were a couple of questions on question four. I am gonna go ahead and have you clarify that one Dr. Seale. That question was the goal for motor learning and our treatment interventions is. The possible answers were improve performance, improved retention, and improve retention and decreasing performance, improved retention and improving performance.

- [Jill] You just want me to give them the answer to that?

- [Kalista] Yeah, and the reasoning behind.

- [Jill] Well, the goal for motor learning is not improving performance unless we're improving performance and retention together. I can see how that question might have not been completely clear. I apologize for that. Primarily the goal that we have for

motor learning is to improve retention. What motor learning means is retention. The capacity to retain the skill. Hopefully that clarified that, that it's retention.

- [Kalista] Great, all right. We're gonna go ahead and wrap up for today. Thank you everyone for attending. Again, hope to see you on the second part which is on the 25th.

- Thanks guys.

- [Kalista] Have a great day everyone.