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THE LOOKING THROUGH LENS OF SCIENCE

The Nature of Balance and the Practice of Tai Chi Chuan

PART II

BRINGING BALANCE HOME

As explained in Part I on the Nature of Balance (Issue #24 and the 10th Anniversary special edition), balance is a complicated skill that takes human beings considerable time and practice to learn. Since it is a learned skill, balance strategies differ from individual to individual and individual capabilities generally change throughout the course of a lifetime. There are three main types of balance skill: static, dynamic and adaptive. Learning and practicing Tai Chi Chuan builds skill in all three areas, thus improving overall balance for those who study and practice for a period of time.



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Part II on the topic of balance will focus on how to utilize research findings to make teaching methods more effective for students who are particularly concerned about balance. As this specific topic is explored, ideas will be generated that teachers can creatively apply to other aspects of teaching Tai Chi Chuan.

Research on balance can be divided into two main categories: feedback challenges and feedforward challenges. Feedback challenges begin with an external event, like tripping over an object. Feedforward challenges begin with anticipation of performing an action, like throwing a ball.

Reaction time affects a person's ability to balance during a feedback challenge.

Reaction time can be broken down into the following components:

1- Conversion of stimulus (e.g. tripping) into nerve impulse signals
2- Transmission of signals to the brain
3- Perceptual identification of the signal
4- Choice of response by the brain
5- Transmission of response to effectors (structures which will carry out the response, e.g. muscles, joints)
6- Activation of effectors

Research has shown that components #3, perception, and #4, choice of response take up, by far, the largest part of the total reaction time. Other important experimental findings about reaction time include the following:

1- Reaction times get longer when sensory signals in the environment become more complex.
2- Dramatic shortening of reaction time occurs when a research subject is told in advance to concentrate on one particular signal in the environment.
3- Research subjects can react faster to tactile signals. Visual and auditory signals generally require more response time.
4- Average reaction times become shorter with practice.
5- Older subjects improve proportionately more with practice than younger subjects in some studies.[1]

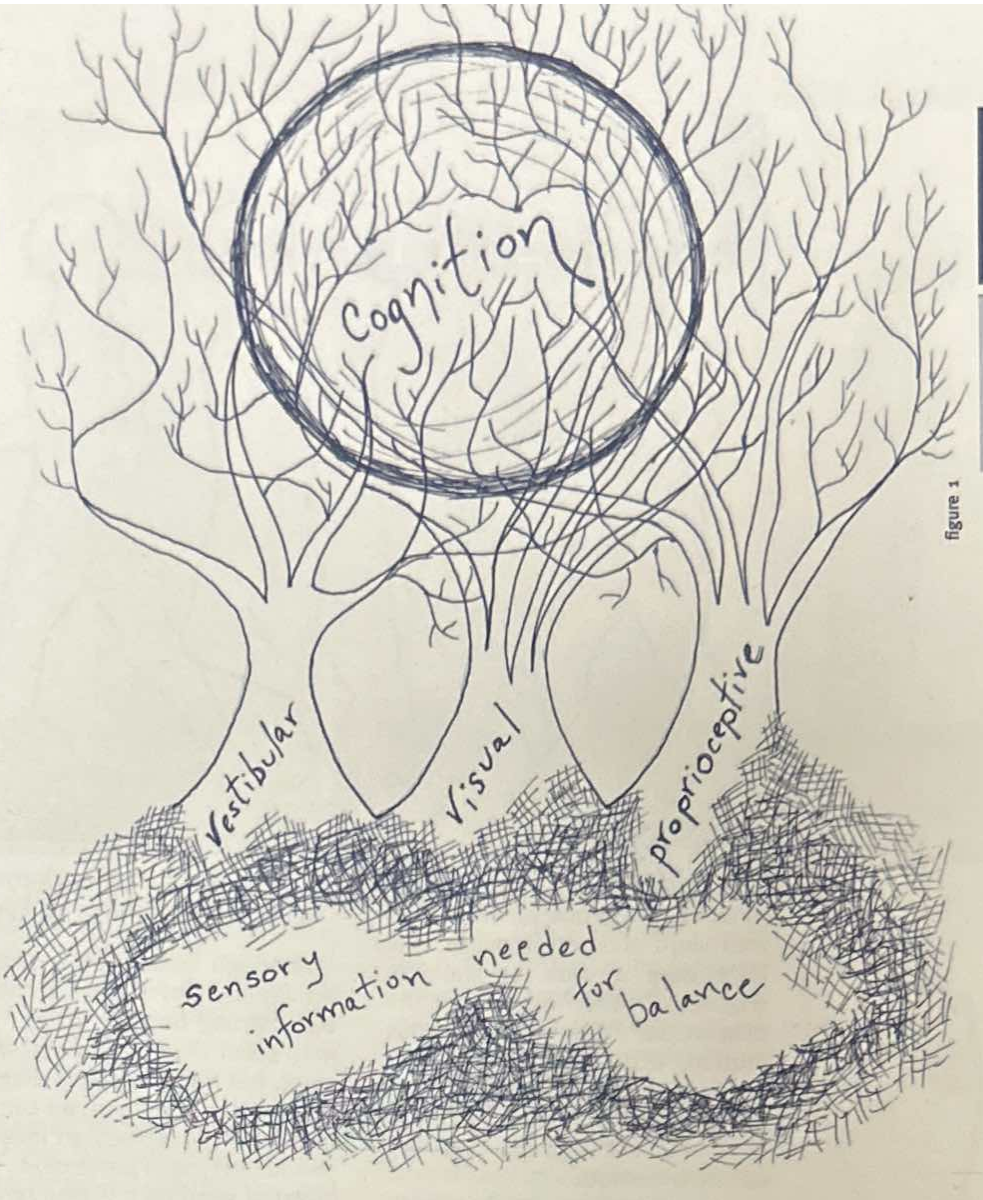

figure 1

Feedforward balance challenges, like throwing a ball, require that a balance strategy is activated in advance of the intended movement to maintain balance.

It is known that one of the age-related changes that effects feedforward situations is the slowing of nerve conduction speeds because this slows the activation of postural muscles. However, experiments have shown that deficits in cognition (i.e. knowing what to do to maintain balance) contributed more to slower response speeds in feedforward situations than the age-related changes in nerve conduction speeds.[2]

The following points can be summarized from research findings on feedback and feedforward balance challenges:

1- Balance improves with task repetition.
2- Reaction times improve when subjects are told in advance to concentrate on certain signals.
3- Complexity of signals in the environment can adversely affect balance.
4- Reaction times to feeling (tactile signals) are faster than reaction times to seeing or hearing.
5- Perception and cognition exert the greatest influence on response times in all balance situations.

How can these findings about balance be used to improve teaching methods?

First, we'll need to glance back at some concepts from Part I on The Nature of Balance. In Part I, the idea of a "dendrite forest" was introduced. (Figure 1) This fanciful image was used to explain how cognition develops links between different parts of our nervous system. I like to use the term "inner net" to describe these connections formed in the nervous system. Each person's inner net is different because it is shaped by the experiences, thoughts, and practices of an individual. Every person develops his own inner net as a natural part of being alive and it is a unique creation. The job of a teacher could be described as someone who helps students build certain skills into their inner nets.

Within every person's inner net are neural pathways. A good way to understand the concept of neural pathway is to imagine all the highways and roads on a map, all the ways that you can go from one place to another. In each person's inner net, there are many neural pathways that route sensory information to different areas of the brain and conduct nerve signals along paths that will form actions. These neural pathways are created by experience. If an experience is repeated often enough, eventually, a major highway will be created in the person's inner net.

For a teacher to help students develop their inner nets, it's important for a teacher to observe and try to understand the highways that already exist in their students' inner nets because each student will be working from those highways as they begin the learning process. Although every person is unique, neural pathways built for common movement activities like standing, sitting, and walking tend to be somewhat similar from one human to the next. These highways are the starting point for the student, so it's good for a teacher to understand some things about the existing roads in their students' inner net.

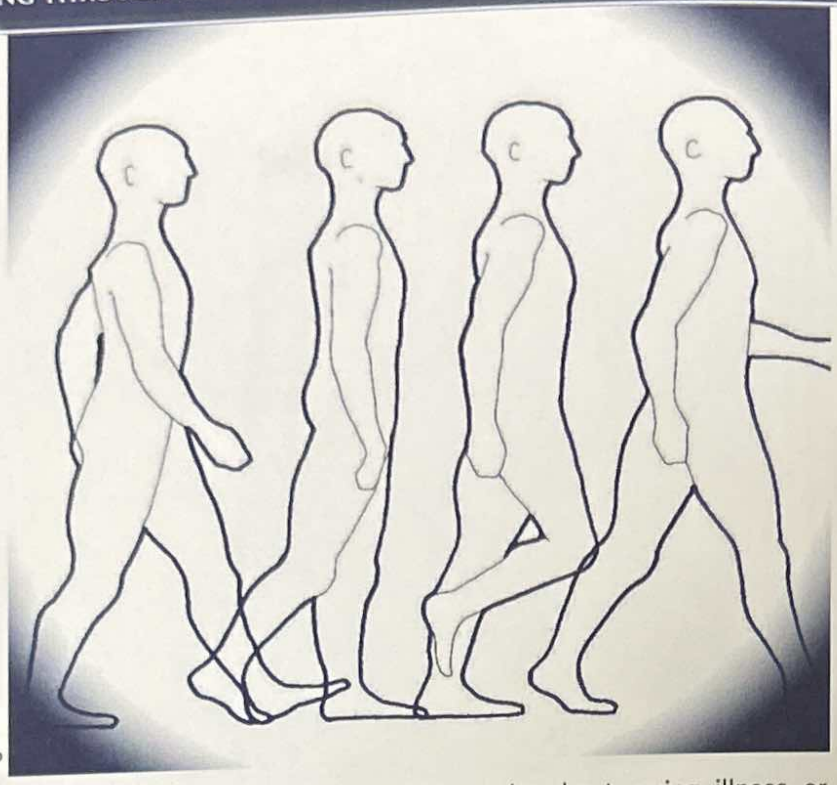

figure 2

Of all the many highways in our inner nets, the one for walking is well worn and very familiar. So, let's take a look at walking. (Figure 2) We notice from the diagram that walking is a continuous motion, distinctive among gaits because of the efficient pendulum-like movement of the legs. (Figure 3) In normal walking, the following can be observed:

- the head doesn't move up and down very much.
- the center of mass of the body is kept more or less midway between the two legs so that the body will move forward continuously in a fairly straight line. (Figure 3)
- When the weight is transferred from one leg to another, both legs are extended rather than bent at the knee.
- The faster and longer the stride, the more necessary it is to lock the forward knee at the moment of initial foot impact so that the knee doesn't buckle as the body weight moves over the foot. This pattern of locking the knee can be a standard feature of some people's inner nets, even when they are walking slowly. This pattern can also appear when the thigh muscles become weaker due to aging, illness, or immobilization following injury.

Although walking is a healthy activity for many reasons, it doesn't build strong balance skills. This may seem like a shocking statement, but if we look at a diagram of balancing (Figure 4), we can see balance skill involves an inverted pendulum type of movement. This inverted pendulum is also termed 'postural sway'. The neural pathways activated by walking are different from the neural pathways needed for controlling postural sway. This is why teachers need some inverted pendulum exercises to help students who are working on balance skills.

How do you create an "inverted pendulum" exercise?

Obviously, just standing is an inverted pendulum exercise. It is interesting that traditional Tai Chi training involved many standing exercises. If we go back to the summary of research findings presented previously in this article, we can get some ideas about how to make standing exercises more effective for building balance skills.

Research summary point #5 said that perception and cognition exert the greatest influence on

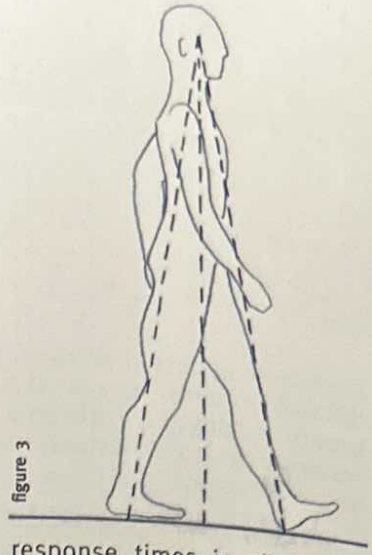

figure 3

response times in all balance challenges. Point #4 said that reaction times to feeling (tactile signals) tend to be faster than reaction times to seeing or hearing. So, how can we design an exercise that develops perception of tactile signals and cognition useful for balance?

As explained in Part I on the Nature of Balance, we know that cognitive skill is developed by mindful repetition.[3] "Mindful" means that the action to be performed has been thought through ahead of time and will also be linked to various sensory domains that will provide information before, during and after the movement. Since we want to emphasize perception of tactile information, let's begin the standing exercise by helping students become more aware of signals generated by their feet.

One way to do this is to make a diagram that helps student identify various tactile signals generated from the contact of their feet against a supporting surface. The purpose of the diagram is to show students the areas of pressure generated when the body is moved over the feet. The smoother, harder and flatter the surface the easier it is to distinguish pressure, so a good wooden floor would be perfect for the exercise. Also, removing footwear will make the sensory information more vivid but may not be practical if the surface is

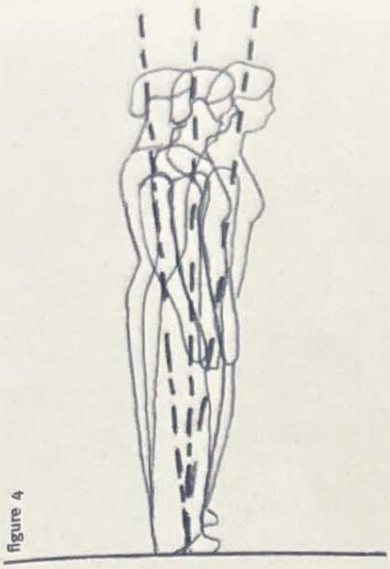

figure 4

not safe for bare feet. Footwear that has copious foam padding or orthopedic inserts will make the exercise more difficult but not impossible.

Figure 5 is an example of a "pressure map" of the foot. The dotted line indicates the location of the ankle joint. The circle behind this line shows where the pressure of the floor against the heel bone can be felt and the crescent shape behind this circle shows the "rim" of the heel, the last possible point of contact with the floor when the pendulum of the body is swinging backwards.

In front of the dotted line of the ankle joint, there is a long expanse of white paper indicating lack of pressure, for this is where the arches of the foot are located. In this area, the surface of the foot is lifted up by the suspension system of the arches. Moving forward, past the arches, there are circles linked together within a broad band of pressure. This part of the foot map shows the metatarsal joints, the "middle joints" of our toes. They are the workhorses of our feet, large and sturdy, built to withstand and distribute pressure. Almost everyone knows about the metatarsal joint of the big toe, it is frequently called "the ball of the foot". However, students may not realize they have a total of five metatarsal joints, each playing an important role in balance, particularly the metatarsal joint of the 5th (or, "little") toe. In front of the metatarsals, there is a circle toward the end of each toe, indicating the toe pads that are the last point of contact with the floor when the pendulum of the body is swinging forward.



figure 6



figure 7



figure 8

It would be a good idea to color code the pressure map that you make for your students. This way, you can talk about the various areas of pressure by color, which may be a little easier than using anatomical names. Also, you can use color coding to indicate warning and danger, borrowing from traffic signs. For instance, the color of the heel pressure circle could be yellow (indicating caution) and the rim of the heel crescent could be red (indicating danger) because, as you can see from the foot map, there is not too far for the body to swing back behind the ankle joint before falling backward off the heel. The metatarsals could be colored blue to indicate a calm area of even pressure, and the toe pad circles could be colored green because they are the last point of contact before stepping forward when we walk.

Having shown students the foot map and explained it, you can now use it to perform an inverted pendulum standing exercise. The purpose of the foot map is to teach students how to focus on sensory information that will help them balance. With each repetition of the exercise, students will be developing their inner nets and cognition so they will be able to anticipate what to do, how to do it, and then be able to analyze the results of their performance.



figure 5

To begin the exercise, instruct your students to stand with their weight supported just in front of their ankle joints, so they can feel a light and even pressure across their metatarsals. (Figure 6) Then, have them move their weight back behind their ankle joints, so they feel a pressure signal from their heels, then have them cautiously move their weight back until they feel pressure on the extreme rim of their heels. (Figure 7) At this point, have them move forward again, feeling the heel pressure diminish as their body weight crosses their ankle joints. As they continue to move forward, the next pressure zone they feel will be the metatarsals and the next will be the toe pads. (Figure 8) Once pressure is felt in the toe pads, it is time to let the pendulum swing back towards the ankle joints and heels once more.

It is important for the teacher to keep relating the pressure zones that the students are feeling (tactile signals) to the foot map diagram (visual information) to the words that identify the different zones of pressure (auditory information). As the students are moving through the exercise, the teacher can provide helpful dialogue, such as: "Moving back, behind your ankle joint, you can feel you are entering the yellow caution zone of the heel, then the red zone of the rim, that's the signal that it's time to move forward. Swing forward slowly, crossing to the front of your ankle joints, continuing forward you can feel the broad blue zone of your metatarsals, then the green 'go' zone of your toe pads, now it's time to swing back." In this way, sensory domains are linked together, the activity becomes about mindfulness and cognition is developed. Also, students are learning to identify tactile signals that inform them if their body pendulum is swinging too far, thus enabling them to react faster to a balance challenge.

The next step in the exercise is to give students a strategy for maintaining balance when their body pendulum has swung a little too far. What is it? Bending at the hips, knees and ankles while they keep their bodies relaxed, or, in Tai Chi language: sinking. Have your students practice sinking when they have reached the rim of their heels on the backward part of their pendulum swing and have them practice sinking when they have reached the toe pads on their forward swing. Bending the joints of the legs in order to stop the pendulum swing of the body will probably not be intuitive for your students. When they feel their body swinging too far they are more likely to lock their knees in an effort to stabilize and lift up their arms to try to grab hold of something. This response represents existing pathways in their inner nets, mindful practice will allow them to create a response that is more effective during a balance challenge because it reduces, rather than increases, postural sway by lowering the center of mass.



figure 9

Initially, the inverted pendulum swing should be practiced with weight on both feet. When students are secure and confident with the exercise, it can be done as a single leg balance exercise. Ideally, the students should practice with their arms relaxed down, keeping their attention focused on feeling the different zones of pressure in their feet and learning to recover their balance by sinking when they have reached the near limit of their balancing range.

The last important consideration is repetition. It takes a great deal of repetition to develop new pathways in our inner nets. Encourage students to practice this exercise whenever they can to help them increase and maintain their balance skills. This exercise can also be practiced as a two person exercise, one person swaying, the other person providing security in case balance cannot be recovered. (Figure 9)

This is only one example of a balance building exercise, many others could be developed from the important points summarized from research studies on balance. When you develop a balance exercise, keep in mind:

- Repetition is essential.
- Students will do better when they are told in advance what is important to notice as they are doing the exercise.
- Don't ask students to pay attention to many things at once. Identify a few distinctive pieces of sensory information (signals) on which to focus their attention.
- Signals that involve feeling (tactile signals) will allow faster responses.
- Tell them how to respond in order to maintain balance most effectively.

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