Neuroplasticity 101

Opening a dialogue in the Alexander Technique community

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Publishing history

An earlier version of this article was published as a series of three articles in AmSAT News starting in Spring 2009 (issue no. 79).
This version edited by David Gibbens and revised by the author, August 2015

Abstract

This is an introduction to the topic of neuroplasticity—physical changes in the neural organization of the brain contingent on experience—and its relevance for teachers of the Alexander Technique. Part I explores the concept of neuroplasticity. A basic definition is provided; structural and functional neuroplasticity are distinguished; the varieties of use-dependent plasticity are discussed; evidence of neuroplasticity in response to learning and trauma is described. Part II considers the role of training as a means to induce neuroplastic changes in a desired direction and the emergence of a popular discourse around "brain training". It reviews in turn six main features of effective training—safety; focused attention; task-specificity; intensity; repetition with variation; feedback—and situates these in the context of typical Alexander Technique teaching situations. Part III examines more closely the role of feedback and points to experimental evidence that challenges some strands of Alexander thinking about where attention should be directed for best results, citing the research of Gabrielle Wulf and colleagues about the contrasting effects of External Feedback as against Internal Feedback.

Part I: About neuroplasticity

What is neuroplasticity?

Neuroplasticity is one of the hottest topics both in science and the public sphere right now, and the focus of much research, many books, and ongoing media attention. It was the subject of four high-profile plenary lectures at Lugano's 2008 International Congress of the Alexander Technique, generating a great deal of interest and discussion. But just what is neuroplasticity? And what does it have to do with the Alexander Technique?

Neuroplasticity is the brain's ability to continuously change its structure and function in response to experience. This certainly is relevant to our work as Alexander Technique teachers and trainees. When we learn the Alexander Technique or give a lesson, we are changing the brain. A larger question looms, however: Just *what* is being changed and *how*? In this article I'll define neuroplasticity and describe some of the basic principles. The aim is to lay the foundation for later discussions on more precise points of intersection between neuroscience and the Alexander Technique.

With the advent of brain scanning technology over the last half of the 20th century, many assumptions about the brain have been disproved.[1] One such assumption is that the brain is "hard-wired" i.e. that the number of neurons and their connections remain fixed throughout life once the critical period of early development has finished. This theory went unchallenged for decades, but a true revolution in brain science has taken place in recent years. The brain now is viewed as a dynamic organism with synaptic connections that are fluid and constantly changing throughout the life span. These changes are both structural and functional. Structural plasticity means the brain can:

- grow new neurons (neurogenesis);
- alter the distribution of where neurons are located (somatotopic mapping);
- promote new, extensive synaptic networks in response to virtually any stimulus, regardless of age, condition, or type of experience. [2]

The functional implication of neuroplasticity is that the brain is always learning. The brain is actively growing, changing, and learning throughout life. This has a positive influence on memory, cognition, emotion and motor learning—virtually anything that affects quality of life. If we can "train" the brain properly (direct it towards a positive learning experience), then perhaps deterioration (or negative behaviours) can be slowed, stopped, or even potentially reversed. This clearly has broad implications for our work in terms of just what elements might best lead to healthy, long-term changes, especially for posture and movement.

At present, there is much publicity around brain "fitness." Bookstores, TV shows, and the internet offer a variety of ways to tap into brain plasticity to transform cognitive processes to keep one young, alert, lively, and in balance. Lawrence Katz's *Keep Your Brain Alive: 83 Neurobic Exercises*, John Medina's *Brain Rules*, Sharon Begley's *Train Your Mind, Change Your Brain*, as well as websites with downloadable software (e.g. Posit Science: www.positscience.com/science), are a few examples of resources for brain fitness that are becoming increasingly accessible to the public.

It seems that many of the things your mother said were good for you actually do lead to improved synaptic growth: get plenty of rest (improves consolidation of motor skill learning and motor performance), exercise (actually helps neurons grow and stay primed), and don't let stress get to you (it negatively affects learning). This not only gives all of us the prospect of staying healthy, but also brings hope to many individuals struggling with attention deficit disorders, autism, memory loss or other changes associated with aging, and traumatic or degenerative diseases (such as stroke or Parkinson's disease).

What Actually Changes in the Brain?

F. M. Alexander placed the concept of personal "use" at the centre of his method.[3] For Alexander, "use" was not a noun denoting any one part (or even the whole) of the body, faculty, or element of one's persona. Likewise in brain science, there is no place, centre, seat, or essence in the brain that we can call "I" or "me."[4] Yet we have a strong sense of ownership (of our body parts) and agency (that we are in fact, the person who is acting in any given situation). Neuroscientists explain this as a "body schema."[5] The body schema is comprised of neurons representing not only parts, but also the spatial and temporal aspects of functional movement, which are "mapped" in the cortex of the brain (and in lower centres, as well).

Remember the "homunculus" (the odd-looking little figure of a human body representing the distribution of neurons located in the sensory or motor cortex)? Other body-centred maps are widely distributed in many parts of the brain and not only contain the neurons for specific muscle activation (somatotopic mapping), but also link to our intentions, and even other's actions (mirror neurons). Moreover, these maps are incredibly plastic. They change with everything we come in contact with, enabling us to incorporate elements of daily life into the map of our body schema. If we use a fork, put on a hat, use a cell phone, or talk with another person, these worldly actions become embedded in our body schemas and alter our brain maps. But while this neuroplasticity appears seamlessly automatic, appropriate changes in our body maps do not simply happen just as a result of contact with the world.[4,5] *How* we interact with the world plays a large role in whether our maps stay flexibly adaptive in a healthy sense. The brain can change in a number of ways, but it needs a stimulus to do so. This stimulus is experience or, simply, functional use. This implies that there are different ways of using ourselves functionally and that different "use" patterns affect the brain differently.[6]

Use and the Brain

Neuroscientists call functionally-induced change in the brain "use-dependent plasticity,"[7] a term that can get all of us pretty excited! But neuroscientists employ this term a bit differently from F. M. Alexander's concept of "use." F. M.'s writings suggest the interplay between mental processes such as "conscious control" and "sensory appreciation" guides action in everyday activity. For neuroscience, the first meaning of "use" is similar to the dictionary's: "to put into service" or "employ." Use-dependent plasticity, however, means that certain types of functional use can have either a positive or negative effect on brain changes. Three models of use-dependent plasticity predominate:

- healthy plastic responses, in which people learn new skills or develop new strategies (improve their use) in response to movement (motor) training (mainly researched in rehabilitation);[8]
- unhealthy responses to trauma (such as *disuse* of a limb after stroke or traumatic amputation); and
- repetitive strain injury (*misuse/abuse*).

Whether learning new skills or rehabilitating bad ones, the hope is that the right training will stimulate adaptive, appropriate, and resilient changes in nervous system learning.[2] The brain has a number of ways of changing itself in response to use:

- expanding its sensorimotor maps in response to synaptic alterations;
- substituting one type of sense for another;
- "unmasking"[9] new areas of the brain to uncover new functions, or enabling parts of the brain to compensate for less-able areas that might be damaged.[10]

Healthy Plasticity

Exciting research has been done which uses brain scans to reveal changes in cortical maps of the fingers in response to learning new finger patterns. The sensorimotor maps of the fingers readily expanded in response to guitar[11] and piano practice[12] and in learning to read Braille.[13] For example, when novices learned a new fingering pattern on the piano, post-intervention scans showed that the maps representing the hand expand quickly (5 days) when the novices learned the new finger pattern. Interestingly, the maps also expanded commensurately when the subjects merely imagined the same finger pattern (without physically executing it). In the study on novice Braille readers, the researchers showed that the brain map representing the hand grew markedly on learning to read Braille over a week's time, and shrank to baseline when the readers went on vacation for a few days, lending credence to the adage "use it or lose it."

Disuse

Even more rapid plasticity can occur after amputation. Sensorimotor maps begin to change in response to the trauma within minutes. For example, if a hand is amputated, neurons discretely mapped in the hand region of the brain compensate for the loss by "invading" neighbouring areas of the brain. This accounts in part for the "phantom" phenomenon in which the person suffering amputation may feel his "phantom" hand when a researcher strokes his face.[14] Phantom limb pain appears to be less problematic when the amputee is given early, intensive rehabilitation with a prosthesis (a mechanical replacement of the body part) and continues to use it in normal daily activities.

Other (slightly less traumatic) examples of disuse include having a limb immobilized (in a cast, e.g. post-fracture),[15] or in "learned non-use",[16] where a person with stroke learns quickly to compensate by using the unaffected arm, avoiding the use of the one weakened by the stroke. In the former case, the neuronal map of the immobilized limb "shrinks" in response to being casted, implying that rehabilitation should be ongoing while the person is in the cast, even if isometrics or visualization are the only tools available to prime the sensorimotor pump. In the case of stroke, compensation for stroke-induced weakness leads to negative alterations in the body schema, as if the affected limb were "erased" from the cortex; and intensive rehabilitation is needed to regain ownership and agency of the limb.

Abuse

Repetitive strain injury and focal dystonia are good examples of neuroplastic abuse (negative changes in brain maps).[17,18] Normally, neurons representing individual functions of the fingers (flexion, extension, etc.) are contained in discretely mapped territories within the sensorimotor cortex. Researchers suggest that rapid, alternating finger movements (piano playing or computer use) under conditions of highly focused, goal-oriented demand can lead to "smearing" of these maps: the neurons from one portion of the map of one functional area "bleed" into another.[17] Sensory input can no longer be interpreted by the brain as sequential, (alternating between flexion and extension), but rather is perceived as simultaneous (resulting in co-contraction of flexor and extensor muscles, i.e. non-movement). Hand cramping, pain, dys-coordination, and immobility result. If the "strain in the brain" goes on without rehabilitation (re-training), the problem can lead to focal dystonia.[18]

Neuroscience is presently in a period of intense exploration and discovery to understand better just what kind of stimuli can support appropriate neuroplastic processes to sustain long-term improvements in movement coordination. While we have good models to explain disuse (non-use) and abuse and some inkling about methods of rehabilitation to help steer recovery, the science underlying "misuse" of physical coordination in the Alexander sense remains at the frontier of investigation. In the next segment we'll look at training elements that have been shown to drive new plastic activity in the brain and relate these to our pedagogy.

Part II: Training the Brain

Introduction

Part I introduced the scientific basis of neuroplasticity and the paradigm shift in brain science. Essentially, the brain is neither static nor hard-wired; rather, both its structure and function are dynamic, constantly changing in response to experience (i.e. use).[19] This relatively new concept emerged largely from brain mapping (neuroimaging) research,[20] which permitted neuroscientists to "see" changes in the brain in response to thinking, feeling, and action. We now know that meaningful changes occur readily in the brain through training, leading to improvements in function and quality of life.[21]

What *kind* of training best suits a particular circumstance is a complex issue. Permanent and positive learning depends largely on a complex sequence of enriched, graded, and varied stimuli.[22] While the brain readily reorganizes itself in response to a variety of stimuli, the outcome isn't always positive.[5][23] Subjecting the brain to the "right" stimuli, brings about meaningful change: that is, "right" use of the brain leads to learning. "Wrong" use leads to diminished and degraded brain functioning. The latter is easier to identify: If, for example, the brain suffers deprivation of stimuli (as in the isolation tactics employed with prisoners) or becomes enslaved to compulsive behaviours (as seen in obsessivecompulsive disorders), a poverty of synaptic connections results.

In the first part of this article, I described several examples of improper use that resulted in plasticity gone awry—that is, that led to degradation of learning. In this second part, I will focus on specific training elements which, when practised, promote positive neural plasticity (learning). This article introduces research that supports the kind of training approaches that lead to long-term (i.e. permanent) learning. This topic is enormous, so to address the issues most relevant to our practice as Alexander teachers, I'll omit discussion of pharmacological methods of promoting brain plasticity (neuro-enhancing drugs) or training programmes that address cognitive improvement alone. Rather, I'll focus on *perceptuo-motor* learning.

Perceptuo-motor learning results from the integration of perception and action and involves the (re-)learning of everyday skills (dressing, eating, walking) as well as advanced (athletic/artistic) skills. Sensing, and interpretation of sensory stimuli, along with motivating behaviours such as planning and intending, foster motor learning.[24] Formerly considered the domain of learning in infancy and childhood,[25] perceptuo-motor learning currently is of interest among neuro-rehabilitation specialists working with adults who are (re-)learning motor skills.[26,27] Because of the complexity of the subject, I'll later introduce six perceptuo-motor training elements,[28] illustrating relevant examples for AT teachers.

A Revolution in "Brain Fitness"

Research in neuroplasticity began with advances in neuro-rehabilitation which focused on recovery in individuals whose brains had been damaged by diseases like stroke.[29,30] Today, however, the concept of neuroplasticity has filtered outside the world of neuroscience research to the general public. A flurry of interest in brain training shows that the brain can be "fit,"[31] meaning that, through training, deterioration in the brain can be slowed, arrested, and even reversed, regardless of age and condition.[32] The type of training for brain fitness revolves around a range of sensory, mechanical, and other physical stimuli that afford the brain a higher capacity for self-regulation[33] (an improved capacity for attention, impulse control, and self-efficacy).[34] To date, most of the studies have tested training approaches for attention deficit hyperactivity disorder in both children and adults, memory deficits among the elderly, and physical rehabilitation among those recovering from trauma (such as stroke or amputation).[34,35] In these populations, training approaches that promote plasticity include cognitive (thinking strategies), motor, visuomotor (eye movement/visual perception), and perceptual (other sensory) tasks.[22,34] "Brain fitness" for the public, however, is a commercial market offering a dizzying array of movement exercises, videogames, and cognitive puzzles and games designed to stimulate cognition and help the brain stay fit. For example, the popular "Brain Gym"[36] has found its way—for better or for worse[37]—into a number of primary school programs designed to keep children (and the elderly) alert and focused.

Without a doubt, Alexander Technique lessons change both brain and behaviour. Empathic communication (verbal, non-verbal, and tactile) evokes changes in the student's use—indirect evidence of neural plasticity. During a lesson, students often demonstrate adaptive (plastic) changes in thinking and behaviour, report an experience of ease in postural support, and readily demonstrate improved use when they walk out the door. But is "demonstrating" good use an actual manifestation of permanent skill *learning*?[38] Often, the retention rate from the previous lesson is poor and when the student returns the same stimuli need to be repeated and reinforced. Clearly, students don't learn everything there is to know in one Alexander Technique lesson. Such neuro-wizardry simply isn't possible when it comes to something as complex as brain/body interactions. Any eagerness on our part for students to "get it," only results in end-gaining. Our enthusiasm for the wealth of information we can offer must be tempered by patience, our own good use, and customizing the learning pace to each individual's ability. Hopefully, though, we are interested in "permanent" changes in the use pattern (indicative of long-term learning and autonomous use).

The brain loves learning and readily soaks up experience.[39] When it comes to perceptuo-motor learning, what makes the brain more "fit" and ready to learn? What training elements bring about change and lead to life-long achievement of desired and meaningful movement goals and ultimately, an appreciably improved quality of life? In Part I we learned that plastic changes in the brain are "use-dependent." For neuroscience, this implies living an enriched life, continuing to "feed" the brain new experiences (e.g. Chinese, Sudoku, piano, Tango, bridge, traveling, etc.). If you keep your brain "physically" active throughout your life, you will minimize the negative consequences for neuronal processing. Aging, for example, appears to happen faster in the brain if people "rest on their laurels," i.e. succumb to a more sedentary (relatively low risk) lifestyle, and circumscribe their activities physically and intellectually.[34] Disuse (lack of novel experience) dampens cortical drive (strength of neuronal connections) and cortical representation (body schema).[40] These factors lead to "noisy processing" (disorganization of thinking), and weakened modulation (slower and weaker neural signals), leading to poor learning and retention.[34] But, even this general model needs a lot of fine-tuning. Simply learning to play a cool videogame will not improve your balance for walking. The training needs to be highly specific!

Training Elements

Exercise physiologists and trainers know that any exercise prescription must contain certain key ingredients to induce a "training effect." [41,42] This means that a number of factors need to be included in the exercise program to "drive" improvements in the muscular and cardiovascular systems. A good exercise prescription includes:

i) the *mode* of exercise (e.g. weight training);

ii) the *intensity* (the amount of weight, i.e. pounds, and number of repetitions in the exercise bout);

iii) the *duration* (how long you carry out the exercises); and

iv) the *frequency* (how many times you perform the whole routine).

For example, if you are just starting a strengthening program, the prescription might look like this:

i) bicep curls using free weights (mode)

ii) each weighing five pounds (intensity)

iii) performed for three sets of 10 repetitions, with a rest of one minute in between sets (duration)

iv) the whole exercise repeated three times a week (frequency).

Similarly, introducing a training effect for the brain requires some of these same elements, but the outcome is more complex with perceptuo-motor learning than with anatomical adaptation (e.g. muscle hypertrophy). Depending on how tenaciously lodged in one's behaviour the psychophysical habit might be (e.g. a lifetime of postural misuse) or how severe an injury the individual has sustained (e.g. traumatic brain injury), the stimuli needed for training must be carefully weighed, i.e. added or subtracted, rearranged, and carefully titrated throughout the training.

Six interrelated ingredients appear critical in fostering permanent perceptuo-motor learning:

- safety
- focused attention
- task-specificity
- intensity
- repetition with variation
- feedback.

(Alas, I must leave out touch (so important to us!), as scientists would consider it another confounding variable!)

1. **Safety**. Any educational (and therapeutic) process that involves the whole person must start in an environment that feels safe. This is important not only for fostering a sense of personal trust and security, but also for enhancing motivation, curiosity and engagement in the lesson. Scant neuroscience research exists that addresses this particular factor, emphasizing instead the aspect of focused attention as foundational among training elements in brain education. To my mind as an Alexander Technique teacher, my first job is to help my students feel comfortable, both in my learning environment and in our mutual engagement. To me, this first means not having an agenda for students other than to help them explore the issues brought to the session. My end-gaining as a teacher, rushing into an agenda of improving use without taking this factor into consideration, can lead to a disastrous lesson. (But then, I imagine I am preaching to the choir!) Further, it is important to align my somatic sensibilities with those of the student's, a process somatic philosopher Elizabeth Behnke call's "matching."[43] Matching involves kinesthetic resonance without end-gaining into an agenda for the student to make a change. Rather, the student will more readily feel safe and willing to make a psychophysical change if the misuse pattern is acknowledged ("owned"), appreciated and accepted.

Besides these psychological and social aspects, we teachers normally create a space in our studios designed to help our clients feel comfortable, and employ a complex educational process including touch and verbal cues to focus their attention within chosen tasks (e.g. sitting, standing, walking). I've rarely walked into a teacher's studio that did not offer an airy, spacious room with lots of light streaming through windows, a sparse bit of furniture (chair and table), and select learning tools (skeleton, mirror, and books). Distractions are minimized, with colours, textures, and objects carefully chosen to provide a nurturing atmosphere that invites a sense of security and confidence. This kind of "nest" for learning appears to enhance a sense of safety and focused attention on sensory appreciation within the context of task learning.

2. **Focused Attention.** Attention is the basis of goal-setting behaviour, planning, decision-making, judgment, and consistency of execution. Focus implies that the brain is aroused, alert, and oriented enough to attend to a task for a prolonged period of time (at least five to 10 minutes). Children and adults with attention deficit (hyperactivity) disorder (commonly called ADD or ADHD), struggle with "effortful control." This means that their lack of control over focused effort and inhibitory processes causes their attention to fluctuate rapidly and markedly.[44] The nature, timing, and amount of stimuli presented to ADHD individuals are critical variables in harnessing and maintaining focus. Rehabilitation specialists struggle with these variables when working with patients in the early stages of

traumatic brain injury, when a stimulus might not have any perceptual impact or might result in agitation or hyper-arousal. In either case, the patient suffers from an inability to attend to a task even for 10 seconds.

As Alexander Technique teachers, we put a good deal of non-doing effort into keeping attention lively through ongoing "sensory appreciation" and "selective attention" throughout the lesson. We use our hands locally, but ask the client to perceive globally, taking in the whole of the environment and the task. What is important for us to recognize is the value of *novelty* in harnessing the student's focus. As one young neuroscientist states, "nothing focuses the brain like surprise."[45] Novelty enlivens the perceptive and cognitive processes, enabling a person to stay focused and interested in the task at hand. A novel stimulus is, to paraphrase British anthropologist and social scientist Gregory Bateson, "a difference that makes a difference."[46] We are aware of this as Alexander Technique teachers, as well. We readily change our tactile cues when a stimulus does not seem to make sense to the student, is confusing, or when repetition does not yield an "ah ha" moment of meaningful sensory awakening. The more skilled the motor behaviour in question, (standing and sitting, riding a horse, playing the violin, etc.) the more brain processes must be refined in their selectivity, sensitivity, and fidelity.[34] Novel stimuli need to be embedded in various activities to promote motor problem-solving. Again, to quote Bateson: "The human mind is located in the interaction of the brain, the body, and the environment, all three being essential elements." An example of this in a lesson might be introducing chair work using four different kinds of chairs—wooden, metal folding, therapeutic ball, and ergonomic—all of which keep clients' attention in self-organizing away from habit while teaching them to avoid end-gaining by not attempting to find the "right" way to sit.

3. **Task Specificity**. This is an easy one for Alexander teachers, too. Our work thrives on intentional, meaningful tasks that occur in everyday life and in skilled performance. Meaningfulness is perceptually stimulating and arrests our attention. Lifting an arm is a purposeless gesture, unless the whole self is engaged in reaching, lifting, carrying, dancing, hugging, etc. The task must be meaningful within the context of the student's repertoire of behaviours. The more we customize the task for the student, the more meaningful and engaging it is for the individual, and the greater the likelihood we'll have success in promoting learning (good use). Furthermore, encouraging "thinking in activity" presents challenges that stimulate problem solving and the brain's capacity to learn. For Alexander Technique teachers, this suggests that spending lesson time in hands-on stimulation alone might not be as powerful in perturbing habit and promoting permanent learning as linking the new sensations from hands-on work directly into a familiar task.[47] Table lessons, for example, are superb, especially when the student's misuse problem is so deep-seated that initiating even the simplest of familiar movements (sit-to-stand) is met by startle and end-gaining. But because table lessons also are so pleasurable (and therefore addictive), unless the student is brought off the table into activity during the lesson, the new somatic learning gained on the table can easily be seen as an extraordinary sensory phenomenon that happens only during the lesson and might not readily carry over into the real world.

It should be clear from the foregoing that the Alexander Technique lesson is an effective "controlled environment" for learning flexible, adaptive, and poised control in activity. But once this "home base" is established, other elements need to be introduced to foster permanent change in the brain and behaviour (i.e. positive plastic changes). While the brain changes itself through virtually any experience, many changes our brains make are evanescent. How does experience "stick"? What makes the difference between a short-term shift in attention and permanent learning is practice.

4. **Intensity.** Practice is perhaps the first "power law" of motor learning.[48] Regardless of the task, few things are learned without repetition and reinforcement. Brain imaging now confirms what we have suspected from the time of Pavlov's dogs: repeated exposure to similar stimuli leads to permanent change in brain structure and function.[49] As Alexander Technique teachers, our lessons normally include repetition of certain activities—sitting, standing, sit-to-stand, walking, writing, etc. As we repeat these tasks, Alexander Technique principles (sensory appreciation, "means whereby" etc.) are embedded and reinforced throughout the lesson. Perhaps this is one reason why 25 to 30 lessons are advocated for newcomers for the work to "take."[50]

5. **Repetition with variation.** Additionally, while each lesson bears a resemblance to the previous one, it is hardly a robotic replication. Rather, with each lesson, we introduce a few new variables within the learning context. This "practice variability" keeps the brain lively. Exposure to consistent stimuli which become progressively more complex over time reinforces learning.[51] Variability can come in the form of changing the environmental conditions (e.g. varying the types of chairs or lying on the floor instead of the table), the tempo (faster or slower chair work), our hands-on placement as teachers, and/or the choice and scheduling of our verbal instructions and feedback.

6. **Feedback.** It's in the area of verbal instructions and feedback that the plot thickens! In a typical Alexander lesson (both on and off the table), we are training attention and perception. For example, we may engage the student's attention to what is happening in her overall movement pattern at various phases of movement within

the larger scope of what is happening in the room. The teacher pays attention (cognitively and kinesthetically) to the student's use in order to notice changes in tone and thinking as the student conceives, considers, initiates, and carries out the movement. During these critical moments, the teacher offers tactile and verbal instruction and feedback about how the student is doing so that she begins to grasp the concept of good use. Such instruction is essential in guiding the student towards the "correct" movement pattern, as well as for providing important information about error. In *Constructive Conscious Control of the Individual*, FM describes how to use verbal and manual guidance to keep the student from "going wrong."[52]

Part III: the question of feedback

Knowledge of performance vs. knowledge of results

Another well-entrenched training principle in motor learning is called "the guidance hypothesis."[53] According to this hypothesis, motor skill learning improves if the learner receives timely and appropriate instructions about actual movement performance (defined as "knowledge of performance" or KP) and its outcome (defined as "knowledge of results" or KR[54]). These instructions help the learner access important, intrinsic information about successful accomplishment. They also help stabilize the learning across repeated trials (in and out of the chair, for example). KP is instruction offered during the actual movement about what the person needs to do to complete it successfully. An example commonly used by Alexander Technique teachers is "Allow your neck to be free," as the person prepares to stand up. KR is what we say after the movement is completed, often summary feedback about how things went (for example, saying, "Good!" if the client kept their primary control working well while doing the task).

Internal vs. external focus

Clearly, this is a complex subject and comprises a good deal of the art of our practice! Let's take a look at one aspect of instruction: the way verbal cues (directives) help harness attention in skilled coordination. Does the manner in which we focus our attention affect coordination? Of course! Now, the question becomes: To what, then, should the student attend to when learning a motor skill? Motor learning scholar Gabrielle Wulf describes two types of feedback instructions used in engaging attention to learn motor skills: internal focus (IF) and external focus (EF).[55] With IF, the teacher verbally draws the performer's (mover's) attention to his or her bodily *sensations* accompanying an action. An example of this would be paying attention to how your hands are holding a baseball bat during the wind-up phase of waiting to hit the ball. With EF, the teacher verbally draws the performer's attention to the environment in which the movement is occurring (for example, the batter watching the pathway of the ball as it approaches, or the pitcher focusing on where he wants to throw the ball).

Interestingly, in study after study (by Wulf and others), EF resulted in better performance in terms of speed, accuracy, and coordination as well as better retention of the learning.[56] This was true in many different types of sports—baseball, darts, tennis, football, etc. (sports that require an object to manipulate), as well as in non-object sports (swimming and gymnastics), and even artistic endeavours, such as piano. These results were consistent regardless of the stage of learning (novice or expert), as well as for older populations and those with neurological problems (Parkinson's, for example). Further, EF appeared to be a superior form of instruction and feedback, not only in terms of the activity, but also when there were additional features added such as stress ("make sure you do the movement correctly") or incentives ("you'll get $100 if you finish the task quickly"). Those who employed EF, time and again, not only performed better, but also retained the learning of the task longer ("task retention"). Finally, subjects were able to use the task adaptively ("task transfer"), e.g. basketball could be played in the water or on land with little additional instruction.

For those of us who believe in the value of body-based sensory awareness as essential in cueing coordination, results of these many studies are disturbing: not only did they show that EF is superior to IF in helping improve motor learning and performance, but they also repeatedly showed that paying attention to specific body parts or to what the body feels like (IF) actually was *detrimental* to learning. Performers utilizing IF showed slower timing, more errors, and/or greater muscular effort. For example, golfers used much less muscular effort as measured by an electromyogram (EMG) if they focused on the anticipated trajectory of the ball and not on the manner of holding the golf club.[57] Why?

Self-focused attention appears to disrupt the automatic self-regulation in motor control that typically characterizes skilled performance. It appears that paying attention to one's body parts interferes with more automatic aspects of skill learning. The complex neuromuscular patterns for even the simplest movement are chosen in the moment and non-consciously. Attending to individual body parts actually interfere with the automatic, synergistic organization of the whole, resulting in a poorer outcome. Performance suffers. Such self-focus distracts the performer, as in the well-known phenomenon of "choking" in sports, when the athlete becomes too self-conscious and ultimately distracted from the flow of movement execution.[58] Golfers, for example, who experience "yips" (involuntary hand movements that interfere with putting) tend to show increased muscle activity in wrist muscles as well as increased heart rates.[59] Perhaps it is time to re-visit FM's story of "The Golfer Who Cannot Keep his Eyes on the Ball," where the golfer's inability to attend to the environmental elements of the task was, in fact, rooted in his misuse.[60]

A challenge to Alexander assumptions?

These results might come as a surprise to our community. Some Alexander Technique teachers might argue that we need to focus on body-based sensory cues in a quiet, slow-paced environment in order to re-educate postural coordination (primary control). Sensing the postural errors at critical phases of movement decision-making and helping students redirect towards support, ease, and freedom of movement is definitely our forte! However, this was not Wulf's experience in studying balance tasks using EF and IF. For example, in a study using a ski simulator in which the standing body oscillated quickly from side to side, participants showed improved balance when they focused on markers on the machine delimiting the distance travelled, rather than on the sensation of grounding their own feet.[61]

Sensory information clearly is a vital part of our exploration and discovery of who we are, how we are, and an indicator of the need to redirect. The way Alexander Technique teachers use sensory cues is barely understood in human movement science. What FM Alexander called "sensory appreciation" involves the whole use of the self—person, environment, and task. Nevertheless, the research on focus of attention in motor learning invites us to re-examine our teaching methods.

We may carefully craft our lessons, but can we say what is really working? In what ways are our verbal cues and directives effective? Do they really result in the challenge that leads to long-term, permanent changes in coordination? Or, are we offering our students too much body-based instruction that might interfere with autonomy and empowerment? At what point during the re-education of the use of the self do we need to switch from IF to EF, to help clients become more aware of their involvement in space-time? Perhaps "fewer words, more space" might be a useful motto to follow.[62] We might look for the links between our habitual use and the way we use space, and we might seek more ways to incorporate our awareness of the environment while we think in activity. Finally, we need to practise in real space-time, employing the use of the whole self within multiple daily contexts—challenging the client with plenty of balance opportunities, for example, while sticking to principle with inhibition as we direct!

Concluding remarks

In summary, all movement emanates from the felt, living body and is grounded in experience. Without experience shaping both the goal of our intentions and the instructions to achieve them, we cannot know how to move. Or, to state it more eloquently, "Experience is not just something that happens *because* one thinks and acts; it is the formula *by* which one thinks and acts."[63]

Lots of possibilities to ponder as we live our practice!

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