The Alexander Technique and Neuroscience: Three Areas of Interest

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Introduction

Tim Cacciatore's recent comments on the lack of research into the Alexander Technique (AT) (*Statnews* Vol.7 Issue 6) should perhaps be seen as a call to arms. Over the last decade there has been an explosion of neuroscientific evidence which is of *possible relevance to*, even if it is not explicitly *about,* AT. With this in mind, I have outlined three areas of interest which might provide a broad context for further scientific investigations of AT. I have been careful not to 'explain' the Technique in the light of this research, but at the same time my background as an Alexander teacher has meant that I have teased out those findings which seem to me to have particular resonance with our unique discipline. Simply put, the three areas I highlight comprise hemisphere difference and attention, evidence for two pathways to action in the brain, and movement awareness. These areas are deeply interconnected, and the connections between them – and with AT itself – will become clear as the article progresses.

1. Two Hemispheres: Two Worlds

According to Iain McGilchrist – who has conducted the most comprehensive review of the neuroscientific literature on hemisphere difference to date[1] – the fact that humans and other vertebrates have a divided brain is highly significant. The traditional 'toy cupboard' model of the brain, whereby brain functions were thought to be housed in either hemisphere according to the dictates of space, is no longer supported by the evidence. Every human activity is now known to be served at some level by both sides of the brain, meaning that the difference between the hemispheres cannot fundamentally be one of 'what they do'. Instead, McGilchrist's work has demonstrated that each hemisphere sustains a profoundly different 'take' on reality, making the distinction between them one of 'howness'. The experiential worlds the hemispheres deliver to us are both individually coherent, yet because their perspectives are fundamentally incompatible, it appears that evolution has necessitated a strict separation between the two.

On the one hand, there is the right hemisphere: receptive to the immediacy of sensory experience, it enters into profound relationship with whatever is present beyond the self. It is a *pre-reflective* mode of being concerned with the world in its ever-changing particularity, not categorizing, dividing, or wresting things from their context, but attending to the uniqueness and sheer quiddity of life as it unfolds in the here and now. Importantly, the right hemisphere does not admit of the usual distinction between subject and object, since it responds to the world before analysis has transformed it into anything else. It experiences wholeness or (in McGilchrist's term) 'betweenness' with the Other, with whatever lies outside ourselves. And since experience is forever in flux – or as Heraclitus remarked, one can never step into the same river twice – the right hemisphere is tuned into whatever is emerging, ambiguous or uncertain.

In stark contrast to this mode of being is the left hemisphere, which aims to step back from the immediacy and flow of experience. In McGilchrist's terms, if the right hemisphere 'presences' the world, then it is the left hemisphere which 're-presents' it. The left hemisphere's prime motivation is *power*, and to that end it separates itself from the immediate environment to build an abstract 'off-line' version of the world. Through division, categorization and modelling, its goals are clarity and fixity, since clarity and fixity enable it to manipulate and bend reality to its own will. Yet, as a result, the left hemisphere's world is ultimately a confabulation, like a series of tangents forever approximating a circle without ever achieving it. The left hemisphere is essentially utilitarian and optimistic: brushing off ambiguity in order to create certainty, and believing strongly in its models for achieving whatever goal it has in mind.

Underpinning these two opposing world views are, broadly speaking, two different types of attention. On the one hand, the right hemisphere favours a wide, vigilant attention to allow whatever 'is' to come into being. In contrast, the left hemisphere makes use of a narrow, focussed attention in order to enable it to manipulate its surroundings. This fundamental difference can be illustrated with respect to vision: the right hemisphere takes in the entire field of vision across the right *and* left, including peripheral vision. In contrast, left hemisphere focus is only on *a narrow portion of the right half of space*, its primary concern being to manipulate the world with the *right* hand. This remarkable phenomenon – demonstrated by right hemisphere stroke patients as part of a condition known as 'hemineglect' – has nothing to do with the functioning of the primary visual system itself.

Despite these two radically opposing versions of reality, our conscious minds seems to flit effortlessly between the worlds delivered by each hemisphere, thereby presenting us with a seamless experience of the world. Only a few writers appear to have deduced, phenomenologically, the essentially divided nature of attention. Marion Milner is one author whose insights in this regard are extraordinary, given that they are so in tune with modern neuroscientific data. She writes,

> [I]t occurred to me that there must be two quite different ways of perceiving. Only a tiny act of will was necessary in order to pass from one to the other, yet this act seemed sufficient to change the face of the world, to

> make boredom and weariness blossom into immeasurable contentment.
> (1) Narrow attention. – This first way of perceiving seemed to be the automatic one, the kind of attention which my mind gave to everyday affairs when it was left to itself. The psychology books seemed to agree in this. They said that you attend automatically to whatever interests you, whatever seems likely to serve your personal desires; but I could not find anywhere mentioned what seemed to me the most important fact about it, that this kind of attention has a narrow focus, by this means it selects what serves its immediate interests and ignores the rest. As far as I could see it was a 'questing beast', keeping its nose close down to the trail, running this way and that upon the scent, but blind to the wider surroundings. It saw items according to whether they served its purposes, saw them as a means to its own ends, not interested in them at all for their own sake. This attitude was probably essential for practical life, so I supposed that from the biological point of view it had to be one which came naturally to the mind. But since it saw everything in relation to something else, as a means to some end, contentment was always in the future.
> (2) Wide attention. – The second way of perceiving seemed to occur when the questing purposes were held in leash. Then, since one wanted nothing, there was no need to select one item to look at rather than another, so it became possible to look at the whole at once. To attend to something and yet want nothing from it, these seemed to be the essentials of the second way of perceiving. I thought that in the ordinary way when we want nothing from any object or situation we ignore it. Or if we are forced to attend to something which does not offer us any means of furthering our desires, then sheer habit makes us attend in the narrow focus way, looking at separate details and being bored. But if by chance we should have discovered the knack of holding wide our attention, then the magic thing happens. This at least was how I explained what had happened to me.[2]

McGilchrist's observations about the brain go further than outlining differences between the hemispheres: he presents a strong case for an essentially *asymmetric* relationship, in which the world created by the left hemisphere is both derived from and dependent – 'parasitic', even – on the right. This he terms the *temporal, logical and ontological primacy of the right hemisphere* where, essentially, wide attention takes precedence over focussed attention, wholeness over division, and experience over 're-presentation'. Further, various lines of evidence point to how referential language ('the left hemisphere's most powerful tool') has its origins in the body and the right hemisphere, and how thought, affect and their expression, as well as the unconscious will, also all originate in the right hemisphere. Finally, McGilchrist even argues that the functioning of the nervous system itself – with its non-linear and 'reverberative' reciprocity at the neuronal and cellular level – is right-, rather than left-hemisphere, congruent.

2. The Two Action Systems (2AS): Two Attitudes Towards Movement

Goal-directedness may not be the only 'computational principle' underlying movement,[3] but it plays a central role in the human motor system. There is evidence that 22 week-old human foetuses will execute movements 'with kinematic patterns that depend on the goal of the action'.[4] Also emerging at a young age is the dominance of goals in action planning.[5] In some elegant experiments, a "Mirror Game" was played with pre-school children in which they were asked to copy the six possible actions involved in using one or both hands to touch one or both ears.[6] While the children all achieved the final goal of the action (touching their ears), in 40% of trials involving a hand movement across the body, they used the wrong hand to do so (see figure 1). The experimenters concluded that, due to limited cognitive capacity, the final goal of the action often trumped any other consideration. More sophisticated studies have shown that adult imitation also tends to be goal-directed and hierarchical, with Wohlschlager and colleagues noting that 'the goal of an action is so strong that the other aspects of an action are more or less neglected, even if the subject knows explicitly about all aspects and tries his/her best to copy all of them as exactly as possible'.[7]

In recent years, there has been growing evidence for two neuroanatomically distinct pathways to action in the brain. The 'Two Action Systems (2AS)' model is an interpretation of this data, distinguishing as it does between actions based on object structure, and actions based on functional manipulation.[8] The former 'Structure' system is *bilateral*, involving a pathway which terminates in the superior parietal lobe (SPL) of both hemispheres. It constantly integrates visual and proprioceptive information in real time,[9] and as such is responsible for the *'bottom-up' online control of action*. It calculates a 'dynamic representation of the body … coding the

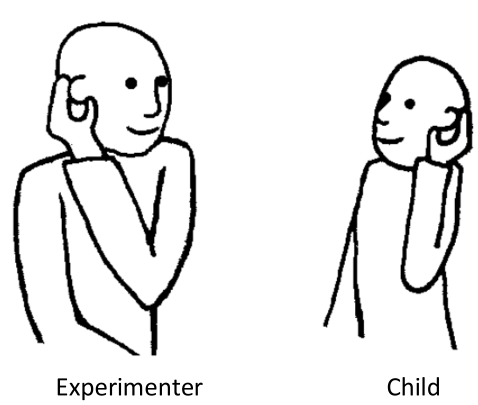

Figure 1 | The 'Mirror Game'. In many instances, a child will copy the goal of an action (touching the ear), and not the movement itself.

locations of body parts with respect to one another (intrinsic coding), and with respect to external objects in the environment (extrinsic coding)'.[10] Remarkably, this system does not conceptualize, responding only to the physical properties of objects such as their size, shape, location and orientation. Not relying on representations, it enables the imitation of meaningless gestures.[11] It also operates extremely quickly, and patients with disruption to this system have difficulty making accurate online corrections to their movements, especially in their peripheral vision.[12]

In contrast, the 'Functional' system is *lateralized to the left hemisphere*, with a pathway that terminates in the inferior parietal lobe (IPL). It is 'largely unconstrained by information from the environment',[13] and instead *uses conceptual information in a 'top down' manner to control action*. The Functional system computes and stores representations of skilled actions with familiar objects ('tool use' representations), so that when an action such as hammering is performed multiple times, it 'extracts the features of the action that remain constant across instances'[14] adding to an 'offline' repertoire of skilled movements. 'Motor equivalence' – the ability, for example, to sign one's name with one's foot even though the movement was learned with the hand – is explained by the existence of these abstract representations.[15] Being a conceptual system, it knows what objects are *for* and *how to use* them, and so it specializes in the planning and control of purposive, goal-directed actions.[16] Apraxia – the 'inability to perform purposeful movements; loss of ability to 'do''[17] – is predominantly a symptom of damage to this left hemisphere system.[18]

As Buxbaum and colleagues note, 'The two systems are richly interactive, and in many everyday cases, both contribute to processing'.[19] It is also likely that they give rise to different experiences of movement. Only the right parietal lobe has a conscious, whole body image which, according to Iain McGilchrist, is not so much representational as 'intimately linked to activity in the world – an essentially affective experience'.[20] It therefore follows that, if an action strongly engages the left-lateralized Functional system, our sense of the body as a whole is likely to 'disappear'. This notion has striking similarities with the phenomenon of bodily disappearance explored by Drew Leder in his study *The Absent Body*:

> It is possible, though, to recognize certain sorts of activities in which one or the other mode predominates. For example, when taking an early morning walk in the forest I am caught up in the sounds and smells of this world. Striding vigorously down the trail, I pause to pick wildflowers and dip my hand into a nearby brook. It is as if I dwelled fully within my corporeality, existing its [sic] sensory powers and reawakening its muscles. My body is taken up primarily in its focal disappearance as a variegated mode of disclosing the world. This would be particularly refreshing if the previous week had been spent at the typewriter. There, thoughts and fingers alone in motion, I ignore all sensory allurements that might distract me. I perch in a chair for hours suspending large portions of my corporeal existence in order to proceed with my specific task. This body is largely placed into background disappearance though I still use limited regions and maintain a marginal awareness of the potentials from which I hold back. Such activities, respectively emphasizing focal or background disappearance, define the extremes of a complemental series filled with intermediate cases.[21]

Leder's idea of two extremes on a continuum reflects well the scientific observations about the Two Action Systems: the relative involvement of each depends on environmental and task-related factors, as well as the intentional/ attentional mindset of the individual.[22] Moreover, due to the longevity of conceptual representations in the brain, it seems that, over the long term, *the Functional system may often interfere with the Structural system, thereby 'winning the race' for the control of behaviour*. In the words of Jax and Buxbaum, 'repeatedly using objects may bias the motor system to activate use responses when viewing objects, even if those particular objects were not recently used'.[23] The notion that the processing of action might become more entrenched along the left-lateralized Functional pathway fits with the broader concept of 'hemisphere utilisation bias', and the contention that modern life has in general seen a 'shift to the left'. For McGilchrist, the general consequences of the left-hemisphere perspective are not only a conceptual 'hall of mirrors' ("we do not so much experience the world as experience our representation of the world"[24]), but also that everything that exists must be purposive, or 'for' something else. Thus, we see a drive to exploit the natural environment, to use art or music *for* relaxation, or to insist that the *purpose* of meditation might be to reduce our blood pressure or make us more effective stockbrokers.[25] If these are the general effects of the left-lateralized view, what might be the specific effects on the motor system of left hemisphere dominance?

The left-lateralized Functional system will tend to produce abstract, stereotyped movements – imagine, for example, pantomiming a hammer motion without actually holding a hammer. It therefore needs input from the Structural system to 'specify the particular kinematic or force requirements for a specific hammer, or for a given set of spatial constraints'.[26] As well as being physically constrained, the Functional system also needs to be embedded in real time, since its nature is always to look ahead to some future goal.[27] In general, only the right hemisphere – with its 'crucial powers of recognising reality'[28] – can fulfil this grounding role. *The right hemisphere provides the context for action in the widest possible sense*. Only with the right hemisphere can we appreciate the continuous flow of time, or accurately perceive the spatial relationships between the body and other objects.[29] The right hemisphere is specialised for proprioception,[30] and for integrating visual and proprioceptive information to guide movement.[31] It is also responsible for online error correction: its frontal regions alone are able to inhibit a predominant motor response or representation, substituting a response appropriate to the current goal of a task.[32] The right hemisphere controls exploratory (rather than preprogrammed) movements,[33] and is particularly active when a new motor skill is first being acquired.[34] As noted earlier, the whole body image of the right parietal lobe is fundamental in its contribution to movement, since (in the words of Daprati and colleagues) 'Every motor activity must refer to this representation. Voluntary actions presuppose that attention is directed to, and by, this representation'.[35] If the right hemisphere has a holistic, *Gestalt* sense that 'I *am* my body', the left hemisphere instead sees that 'I *have* a body': it views the body as an 'assemblage of parts' or a 'thing' from which we are relatively detached.[36]

Finally, the right hemisphere contextualizes action in another crucial sense: it is dominant in the control of posture.[37] In healthy individuals, postural activity 'envelops' movement: so-called Postural Adjustments (PAs) anticipate, accompany and follow voluntary motor acts in a continuous stabilizing response to gravity and other perturbations.[38] These PAs have been shown to function abnormally in conditions such as low back pain and Parkinson's Disease.[39] Although postural control was historically believed to be entirely subcortical, it is now known to be under the influence of conscious control,[40] with the right hemisphere playing a significant role in controlling body orientation with respect to gravity, and in constructing an internal model of verticality based on visual, somatosensory and vestibular information.[41]

On the evidence presented above it is therefore plausible that, under sustained preferential processing of movement by the left hemisphere Functional system, a whole range of right hemisphere faculties are in danger of becoming neglected or desensitized.

3. The 'Comparator' Model of Motor Awareness

Prediction is at the heart of motor control, playing a fundamental role in the survival of even the most primitive of species.[42] A chameleon thus shoots its tongue towards the future position of a fly it intends to catch, and a human infant even at six-months can time its reach in order to intersect an object travelling in a straight line.[43] For human adults, the motor system is constantly predicting the consequences of events, not only in the external environment (such as the trajectory of a tennis ball) but also those occurring within the body itself. While simply standing still, anticipatory postural adjustments in the legs and torso will maintain balance by pre-empting the changes in centre of mass caused by lifting an arm or even breathing.[44] Even passing an object from hand to hand entails prediction. This is neatly demonstrated by the 'waiter effect' where a waiter can keep a tray full of bottles stable while lifting one off with the other hand to give to a customer. A prediction in the waiter's brain keeps the transfer of weight from one hand to the other smooth, yet if a customer were to take a bottle without warning the tray would lift up unexpectedly. In short, the problem the motor system is continuously trying to solve is the fact that *events always precede the feedback signals that derive from them*; in the words of von Hofsten, expertise in action only develops by 'becoming able to represent events that are not directly available to our senses.'[45]

Predictive or 'forward' models are central to theories of motor control. They work on the premise that, when a motor command is selected and sent to the muscles, a copy of this command is created (the so-called 'efference copy') to estimate the sensory result of the movement. Then, if the sensory feedback at the end of the movement matches the brain's prediction, the sensory feedback can be ignored.[46] The forward model estimate is seen as essential for fast actions, because sensory feedback takes a relatively long time to inform movement (around 70-150 milliseconds[47]). Forward models are also understood to enable mental rehearsal of actions: we can compare our intentions with our predictions imaginatively and so improve motor control without even lifting a finger.[48] Until ten years ago, the predictive power of the brain was seen as so complete that the role of feedback in movement control was significantly downplayed, with forward models enjoying what has been termed a 'hegemonic domination'[49] in the understanding of motor control.

The debate has moved on in ten years, with greater recognition of the role of sensory feedback in guiding even rapid movements.[50] However, there is still considerable scepticism over the extent to which sensory signals are *consciously* accessible. In an extraordinary contradiction of terms, movement 'awareness' is instead deemed to be largely *non-veridical*; that is, 'unreal' because it is based mainly on intention and prediction. For example, Blakemore and colleagues have suggested that 'there is only limited awareness of the actual state of the motor system whenever it has been successfully predicted in advance … under normal circumstances we are aware only of the predicted consequences of movements'.[51]

Various forms of evidence support such a view. Deafferented patients (patients whose sensory nerve fibres have been destroyed) report being 'aware' of movement, although no sensory signals are present.[52] Further, when Libet and colleagues[53] asked neurologically intact individuals to estimate the moment at which they became aware of a voluntary motor act, they tended to indicate a time that preceded the actual initiation of the movement – that is, before sensory signals from the moving muscles could have informed awareness. Finally, there is evidence from a number of experiments in which a mismatch was deliberately created between what a person senses as a result of their actions and what they actually do.[54] For example, Fourneret and Jeannerod asked subjects to draw straight lines between a starting position and a target, using a stylus on a digital tablet (see figure 2). The results were displayed to them on a computer screen, and their hand was not visible. On some trials, the line they saw was made to deviate electronically by up to 10% from the line they actually drew. In these instances, although the participants continued to draw lines which reached the target, they did not report any awareness of having to correct for the deviation. In the words of Jeannerod, 'they tended to adhere to the visible aspect of their performance, and to ignore the way it had been achieved'.[55] The paper concluded that 'normal subjects are not aware of signals generated by their own movements'.[56]

Such a view has been reiterated by others more recently: 'Actual sensory feedback has a remarkably limited role in the experience of action in neurologically healthy individuals'[57]; 'Subjective awareness does not seem to be involved in "how" actions are performed'[58]; 'Obviously, the neural mechanisms underlying consciousness have more important things to do than controlling the low-level executive details of our actions. It may even seem optimal, in terms of neural economy, to assume that a movement unfolds as planned when it reaches its goal'.[59] The argument is summed up most starkly by the neuroscientist Chris Frith:

> I reach for my glass and all I experience is the look and taste of the wine as I drink it. I don't experience the various corrections made to the movements as my brain navigates my arm through the various obstacles on the table to reach the wine glass. I don't experience the change in the angles of my elbow or the feel of the glass on my fingertips as they adjust perfectly to the size of the stem. I feel in control of myself because I know what I want to do (have a drink) and I can achieve this aim without any apparent effort. As long as I stay in control, I don't have to bother with the physical world of actions and sensations. I can stay in the subjective world of desires and pleasures.[60]

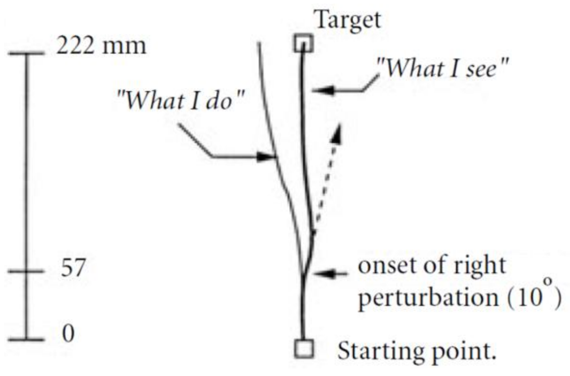

Figure 2 | 'normal subjects are not aware of signals generated by their own movements'. *Reprinted from Neuropsychologia 36(11), Fourneret, P and Jeannerod, M, Limited conscious monitoring of motor performance in normal subjects, pp.1133-40, © 1998, with permission from Elsevier.*

This version of movement carries strong overtones of the left hemisphere Functional system described in the last section. Not only does Frith's description lay itself open to a *reductio ad absurdum* (if the purpose is to drink, why bother even tasting the wine?) but it is also a view of movement that would seem anathema to most movement professionals. For example, dancers, athletes and Alexander Technique teachers (believe they) are acutely conscious of – and take great pleasure in – their senses during movement itself. Cole and Montero have termed this awareness 'affective proprioception':

> … in playing golf, for example, pleasure arises not only from the camaraderie, the walk and being outdoors but also in the feel of the club and feeling the movements during the swinging of the club. To be sure, part of the pleasure in golf comes from the experience of a successful executed result—the ball in the hole. But pleasure is also found within and during the execution of a good stroke and even, possibly, in the realisation that a successful stroke has been chosen—in the successful translation of intention into action. We frequently overlook a prime element in these forms of exercise: the simple ineffable pleasure of, and of being in, action.[61]

Given the phenomena described in such accounts, is there not a scientific model which would accommodate the possibility of a larger role for the senses in the awareness of movement?

One recent account of motor awareness put forward by Preston and colleagues[62] is helpful. Their explanation emphasizes the importance of 'comparators' in the motor system (see figure 3, following page). These authors argue for the existence of at least three comparators, the role of which is to compare and respond to differences between the desired and predicted state (C1), the desired and estimated actual state (C2) and the estimated actual and predicted state (C3) of physical movements. In other words, *intention, prediction and sensory feedback are all compared to give rise to our awareness of movement*. This model of motor awareness has been developed through studying stroke patients with abnormal motor awareness. Particularly useful have been studies of *anosognosia for hemiplegia*, a condition in which (predominantly right-) brain damage has caused patients to pathologically deny their own paralysis. These patients' erroneous claims that they can move their paralysed limb are believed to occur because their 'awareness' is 'constructed entirely from intact predictions of intended movement'[63] – in other words, *using the non-veridical 'C1' comparator alone*.

If the predicament of such patients sounds similar to the apparently non-veridical construction of motor awareness among 'normal' subjects, this is unlikely to be coincidental. With a certain kind of left hemisphere attention to action –

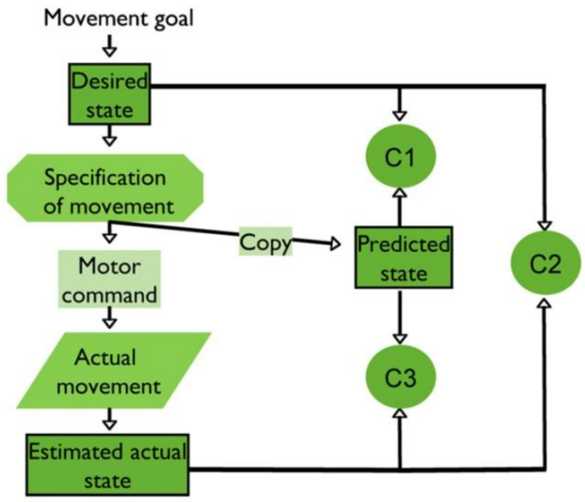

Figure 3 | The 'comparator' model of motor awareness. Under certain conditions, the C1 comparator can give rise to movement 'awareness' without sensory feedback. *Reprinted from Neuropsychologia 48 (12), Preston, C. et al., Anosognosia for hemiplegia as a global deficit in motor awareness: Evidence from the non-paralysed limb, pp. 3443-50, © 2010, with permission from Elsevier.*

narrow focussed and goal-oriented – it is likely that veridical awareness only becomes important when something goes obviously wrong, triggering what Jeannerod calls a *prise de conscience*.[64] Evidence points to the fact that it is the networks in the right hemisphere alone – with its wide, sustained attention – which give rise to veridical motor awareness, even if the relevant comparators are perhaps located elsewhere in the brain.[65] It has been shown that individuals can more fully access veridical awareness than normal, for example when they are instructed to attend in a particular way, or are in a state of mind where they are not strongly predicting the outcome of their actions.[66] Conversely, studies in proprioception have shown that this 'envelope' of veridical awareness can also be significantly narrowed when attentional resources are consumed by another task.[67]

If veridical motor awareness is indeed right-hemisphere dependent and has the flexibility indicated above, there are two likely explanations for those experimental results suggesting that motor awareness in humans is largely constructed non-veridically. Firstly, experiments which encourage a focus on the goal of an action are likely to discover that sensory feedback contributes little to motor awareness because subjects will be paying attention in a left-brain narrow fashion. Secondly, in a culture which may well accentuate a left-brain approach to movement in general (as suggested by McGilchrist's work), normal subjects' baseline sensitivity to veridical motor awareness is in any case likely to be impoverished.

On a final note, the 'comparator' model of motor awareness – which seems well suited to accommodate the potential for veridical awareness – could provide a context for the study of motor awareness in movement professionals, whose sensory acuity is likely to be significantly enhanced relative to normal subjects, as has recently been demonstrated in dancers.[68]

Conclusion

As I explained at the beginning of this article, my intention is not to 'explain' AT in neuroscientific terms, because the relevant research into AT simply does not exist. Having said this, some of the parallels with AT concepts are undeniable. McGilchrist's work has demonstrated beyond doubt that the experience of psychophysical unity is right-hemisphere congruent, and insomuch as AT is not concerned with 'doing', it seems to me that inhibition and direction are likely to be phenomena related to right-hemisphere attention. The similarity between an end-gaining mentality and the left-hemisphere Functional system of the 2AS seems to be particularly strong, as does the relationship between unreliable sensory appreciation and non-veridical awareness. I very much hope that my survey of the neuroscience will stimulate further debate among Alexander teachers, and perhaps the prospect of further scientific research.

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