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EXPLORING THE BRAIN

Lecture 7

MOVING

by

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Susan Greenfield: GRESHAM LECTURE 7
EXPLORING THE BRAIN: MOVING

'From a whisper in the forest to a felling of a tree, 'tis all movement'. So Charles Sherrington, one of the greatest pioneers of physiology during the first half of this century, summed up the all-pervasive contribution of movement to our lives. From the subtleties of body language to the precision of the spoken word to the unambiguity of a simple hug, virtually all communication relies on movement. However global or imperceptible, all movement depends on the contraction of some muscle group somewhere in the body. If contraction of all muscle is defunct, all that is left is the ability to drool or cry.

Although plants can move in the sense that they may turn to the light, they cannot generate movements as we do. Outside the realm of science fiction, no plant locomotes from one place to another. In clear contrast, all animals are on the move, animated. The very term 'animated' means moving: we are animals, hence we move about from one place to another. Interestingly enough 'animus' is one word in Latin for consciousness, that special property of brains. If you move about and you are a multi-cellular organism then you always have, at the very least, a primitive kind of brain.

The importance for moving creatures of having some kind of brain is best illustrated by an observation initially made, surprisingly, by the late Emperor Hirohito of Japan, for whom the study of marine life was a hobby. The tunicate in question is known as a 'sea squirt'. When it is an immature larva the sea squirt spends its time swimming around: not only is it capable of coordinated movement, but it also has a primitive vibration sensitive device, crudely comparable with an ear and a primitive light sensitive device, roughly analogous to an eye. In fact, the sea squirt could be said to have a modest 'brain'. However, when it becomes mature the sea squirt changes its life style and attaches to a rock. Once there it no longer has to swim around anymore, because it now lives by filtering sea water. It is at this stage that the sea squirt then actually performs the remarkable act of consuming its own brain.

The clue to brain function provided by this tale, is that you only need a brain when you are moving. For stationary life forms, a brain is no longer necessary. The whole point is that for an animal moving around, there is an interaction with an environment that is incessantly changing. You need a device for telling you what is happening very quickly and also, and most importantly, for enabling you to respond to what is happening, to get out of the way of predators or to chase after prey. So the brain, in whatever shape, size and degree of sophistication that it comes, is somehow connected in a very basic way with ensuring survival as both a consequence and as a cause of movement. According to the life style of the animal there will be different types of movement. The trapeze artistry of the swinging monkey, the precision gliding of the eagle, or the co-ordination of the legs on a millipede, are all examples of specialised movement accommodating particular lifestyles.

But how is movement of any sort actually achieved? The contraction of the appropriate muscle occurs following a signal sent down from the brain, along the spinal cord. Nerves controlling all the different muscles leave the spinal cord in an ordered fashion, according to the location of the muscle in the body. Hence people that, tragically, have injuries to their spine will be unable to move to varying extents according to the level at which the spinal cord is damaged.

Sometimes the spinal cord can function more or less autonomously, without descending instructions or control from the brain. Such movements are reflexes. A reflex can be defined as a fixed response to a particular trigger: the most obvious example is the knee jerk. The knee jerk reflex is triggered when the knee is tapped, and in response the lower leg consequently shoots out 'on its own'. Neuroscientists refer to this familiar sequence of events as the 'stretch reflex' because the tap at the critical point on the knee in effect compresses a tendon by which the muscle in the lower leg is suspended, thereby exerting extra pressure on the muscle, and stretching it. In order to compensate for this lengthening of the muscle, the muscle contracts, so that the leg shoots forward.

But our normal repertoire of movement is not one of fixed responses to rather artificial triggers like the neurologist's delicate hammer. We do not wait around for someone to tap our knee so that we might jerk up our legs. Many of the movements that we make such as walking, swimming, running, involve more complex co-ordination of muscle groups. But even these movements are, in a sense, semi-automatic, almost reflex. These kind of rhythmic, sub-conscious movements are caused by signals coming down from the brainstem. Different groups of neurons in this brainstem region send signals down the spinal cord to cause the appropriate contraction of muscles in an appropriate, repeating sequence.

There are four such brain motorways, coming down the spinal cord from the brainstem. One underlies semi-reflex rhythmic movements, like swimming, whilst another co-ordinates movement with visual and sensory information; yet another is important for balance, and finally the fourth mediates the moving of individual limbs. However, there is yet a further type of movement which we tend to take for granted and which is not controlled by any of these four systems: fine movement of the fingers. Dexterity with our hand distinguishes us primates from all other animals. It enables us to fashion and use tools and thus to attain a lifestyle that other species will never be able to realise. The dexterity of a violinist where fast, controlled, independent movement of the digits is critical, is a spectacular feat of evolution.

Such fine movements are generated by signals from a fifth motorway, which is particularly well developed only in primates. Unlike the other descending spinal routes used for the contraction of muscle, the all important messages instigating and controlling fine finger movement do not originate from the brainstem at the top of the spinal cord but from the very top of the brain, a strip-like region of the cortex fitting across the brain a little like a hairband, and known as the 'motor cortex'.

The motor cortex controls fine movements by sending signals directly to the digits in question. However it also indirectly influences movements generally, by sending other signals to the four motorway centres in the brainstem, which would in turn be activated and set in train the appropriate contraction of muscle. Different parts of the motor cortex are allocated to controlling different parts of the body. One might think that such an allocation would correspond to the size of the body part in question: presumably a tiny area such as the hand would be controlled by only a tiny part of motor cortex, whereas a large area like the back would have the lion's share of motor cortex to control its movements. Nothing however could be further from the truth.

The critical factor turns out to be not size of the particular part of the body, but rather the precision of the movement that that body part needs to make. The more precise the movements generated, then the larger the area of the brain that is devoted to them. Hence the hands and the mouth have an enormous allocation within the motor cortex compared to, say, the upper arm or the small of the back, which does not seem to have much representation at all. But then, the kind of movements you make with your back are not that fine or precise.

The motor cortex is pivotal to the generation of movement: not only does it have direct control of some of the muscles controlling the hands, and hence of precision movements, but it also exerts a hierarchical influence over the other four movement motorways. In the previous chapter the idea of a single command centre for any one function was rejected: but surely here it seems that the motor cortex is well qualified to be the Movement Centre of the brain.

Although the motor cortex does play a critical role in the control of movement, it does not have a monopoly. Two other areas in particular , the 'basal ganglia' and 'cerebellum' would also be worthy contenders for the title of 'Movement Centre'. If either of these regions, which are far away from the motor cortex, is damaged, then movement is dramatically impaired in various ways.

The cerebellum, the little brain at the back of the main brain, takes up far more of total brain volume in cockerels and fish for example, than in humans. Presumably, the functions of the cerebellum dominate movements needed in the lifestyle of these other species far more than it does our own. Pecking at food or swimming through the sea necessitates an ability to co-ordinate the information constantly coming in through the senses with appropriate movements. There would be no time for thinking or planning out a movement, as the world streamed by, or other animals were looming close to the crumbs in the barnyard. Automated action would be of an enormous advantage. Perhaps then the cerebellum is important for automated movements triggered by outside events rather than by internalised, proactive thought processes.

It is quite remarkable that has long ago as 1664 the physician Thomas Willis had also formed this view of the cerebellum, which he referred to as 'The Cerebel'. Willis viewed the cerebellum as a truly isolated structure from the rest of the brain, responsible for unconscious movements:

'The Cerebel is a peculiar fountain of animal Spirits designed for some works, wholly distinct from the Brain. Within the Brain.......all the spontaneous motions, to wit, of which we are knowing and will, are performed.... But the spirits inhabiting the Cerebel perform unperceivedly and silently their works of Nature without our knowledge or care'.

Over three hundred years on, this description could still apply. Patients with damage to the cerebellum can move, but in a clumsy way. They have particular difficulty in making movements requiring the type of sensory motor co-ordination which characterises skilled movements such as playing the piano or dancing. The cerebellum is important for movements where there is a continuous, ongoing feedback from your senses which in turn will trigger or influence the next type of movement. Imagine, for example, that you had to trace a complex pattern on to paper. Your hand would be under constant surveillance from your eyes: this would be an example of a 'tracking movement' which people with cerebellar damage find particularly hard.

However we humans engage in many more additional, sophisticated activities, not dependent on the immediate triggers in the environment. Our more flexible and versatile repertoire of movement would reduce the centrality of the cerebellum in terms of the fraction of our brains it constitutes, compared to the cockerel or the fish. The cerebellum is nonetheless of vital importance since it is the sensory motor co-ordination it generates that underpins skilled movements which are also the type of movement not requiring conscious thought. These types of movements improve with practice to become almost 'sub-conscious'. For this reason the cerebellum has been dubbed by some the 'autopilot' of the brain. How delightful that this epithet fits so closely with the description formulated by Willis so long ago.

However, there is also another type of 'sub-conscious' movement which is not modified by continued, up-dated information from the senses. Unlike movements controlled by the cerebellum, those associated with another brain region, the 'basal ganglia' cannot be modified once they have been initiated. This class of movement is referred to as a 'ballistic' movement because it resembles a cannonball exploding out of a cannon mouth: once started it cannot be stopped, nor its trajectory modified. When, for example, someone takes a golf swing, the ball quite often stays mockingly on the tee because the movement cannot be corrected at the last moment: it is, literally, hit or miss. Another example of a ballistic movement in everyday life would be swatting a fly.

The area of the brain associated with these ballistic movements, the 'basal ganglia', is really a group of various interconnected brain regions. When any of these regions are damaged, there are devastating consequences for movement. According to the part of the basal ganglia that is impaired, there can be wild, involuntary movements (Huntington's Chorea), or the exact opposite, difficulty in moving at all, combined with muscle rigidity and tremor (Parkinson's disease). Huntington's Chorea and Parkinson's disease affect respectively two different parts of the basal ganglia (the striatum and substantia nigra respectively) which seem to work, normally, in a kind of power-balancing act, locked together so that the first region counteracts the second, a little like a see-saw or arm wrestling. Normally, as with a see-saw or with arm wrestling between two equally matched individuals, one brain region keeps the other in check.

But imagine now a scenario in which one person on a see-saw was much lighter, or an arm wrestling opponent was much weaker, than their colleague: the balance would collapse. Hence if one brain region is under-active, the other becomes too active: it is this imbalance in activity that appears to lead to abnormal movements. In the case of Huntington's Chorea, the deficient region in the dialogue is towards the front of the brain, the 'striatum': on the other hand, in Parkinson's disease, it is the moustache-shaped, black-pigmented region towards the back of the brain, the substantia nigra which is lost.

Because these two regions are normally so closely linked with each other, any drug that restores the balance of power between them, will be effective. Hence in Parkinson's disease, drugs that dampen down activity in the striatum have a similar effect to those enhancing the activity in the substantia nigra, namely an amelioration. Conversely any drug that reduced activity in the substantia nigra or enhanced activity in the striatum, would be pernicious in Parkinson's disease but highly beneficial in Huntington's chorea. Even within one general brain region, the basal ganglia, the component parts themselves are not autonomous but are functioning in an incessant dialogue with each other.

So there is no single Movement Centre after all. Rather, movement can be split up, although we are not consciously aware of it happening, into different types, which are in turn controlled by different basic brain areas. However even these different brain areas, such as the cerebellum and basal ganglia, do not function as autonomous units, but are in turn in dialogue with different parts of the outer layer of the brain, the cortex. The cerebellum, for example, has strong connections with a part of the cortex which lies distinct from and in front of the motor cortex (lateral premotor area), whilst the basal ganglia is in intimate contact with yet another area of cortex known as the 'supplementary motor area'.

Indeed, damage to the supplementary motor area can lead to impairments strikingly similar to Parkinson's disease.

In the normal situation, an attractive though speculative scenario is to view the non-cortical regions as controlling the movements that do not rely on any contribution of conscious thought. For example, pressing the brake when the traffic lights are red seems to be an 'automatic' movement, which is in fact associated with the cerebellum. On the other hand if you finally decide to drag yourself out of the armchair on a Sunday afternoon, the actual movement requires very little conscious planning. There is no immediate sensory trigger, but the standing up will be 'automatic' nonetheless. Some neuroscientists even go so far as to refer to this type of movement as a 'motor programme'. Whatever the label, this type of internally triggered movement which most of us take for granted is controlled by the basal ganglia. It would be particularly hard, however, for a Parkinsonian patient. The basal ganglia and cerebellum would in these cases be freeing up the cortex for other roles beyond the hum-drum minute by minute task of motor control. On the other hand, some movements, be they ballistic or sensory-triggered might require different degrees of conscious control. In this case the supplementary motor area and lateral premotor area would dominate more fully in the respective dialogues over their subcortical partners, the basal ganglia or cerebellum.

There is no such place in the brain as a 'Movement Centre'. The generation of movement is the net result of many brain regions acting together as individual instruments do in a symphony.