Mind and Motion

Alain Berthoz
Mind and Motion: The Brain's Sense of Movement
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As a teacher of movement and awareness for twenty-five years, I have from a practical perspective been working with the relations between movement, sensation, perception, and cognition to guide my pupils and clients to improved human functioning, and increased awareness. I have observed during this time with myself and many others that improvement in one aspect, for example movement coordination, translates to other areas of cognitive functioning such as perception and cognition. I work most directly with attention and sensory awareness, particularly as to how one senses one's self in moving. To give a very simple example, I might ask what do you sense in your ribs and spine as you shift your weight sitting from one side to the other and how are the sensations different on the right and the left? As an alternative I might just gently bring my hand to the area of interest while the person is moving, which awakens then the sensory awareness for the person of aspects of moving normally unattended to. Something then is perceived in the action that was not available to one's conscious state. The interesting thing is that these changes have so profound an effect. A person who has difficulty with balance may find this functioning easier. Another person may find a change in eyesight, and another an easing of low back pain. Others may find that un-sensed and unacknowledged emotions may arise. (For more details see Ginsburg, 1999.)

It is hard for most people to appreciate how little they know of themselves in regards to these basic aspects of living, or how these simple and apparently uninteresting aspects of ourselves can have an influence on the higher aspects of human life and culture. As Alain Berthoz, in his groundbreaking book, The Brain's Sense of Movement, points out, "Plato forgot the body." It is a huge omission that continues into today and affects thinking in all our attempts to understand such aspects of ourselves as perception, cognition, emotion, and that major topic of this journal, consciousness.

There is a change happening. One sees recently a revival of interest in thinkers such as Husserl and Merleau-Ponty who pioneered in rediscovering the importance of body in philosophy (see Petitot, 1999), and a whole spate of books taking the new buzzword, "embodiment" quite seriously, Damasio, 1999, Lakoff and Johnson, 1999, Lakoff and Nunez, 2000, Port and van Gelder, 1995. Recent issues of the Journal of Consciousness Studies, Nunez and Freeman, 1999, and Thompson, 2001 have developed the theme further. This is just a small sampling.

Freeman, 2000, contrasts two approaches to understanding such nervous system processes as perception. The approach that he labels materialist and cognitivist sees perception as passive, involving the transfer and processing of information from the outside world that is transduced by receptors into neural activity that cascades through brainstem and thalamus into a sensory cortex. Further processing results in a

binding into a representation of an object, and sends activity to other centers resulting in some sort of motor activity. This has been the majority view. Freeman labels his own contrasting approach, pragmatist. Here perception is considered as an active process. Freeman states that humans and animals maintain a stance of attention and expectation where the focus is on the limbic system, which has the neural machinery for directing action in space-time that is in essence intentional. Movement and perception are inseparable. Up to recently most neurological research has supported the materialist – cognitivist view in part because it was historically easier to look at individual neurons and trace neural pathways, in part because in the laboratory it was easier to keep an animal still and often anesthetized while presenting to the passive animal a target stimulus, (one could thereby keep the number of variables minimal), and in part because it seemed reasonable to investigate one sensory system in depth as exemplary of other systems. A lot was found out this way, especially about vision. Much of it fits with our engineering notions and the invention of the computer. It is easy to imagine that cognition can be modeled as one can design software for a computer.

In terms of what I understand out of the phenomenon of my own work, this cognitivist view seems incompatible with what I am observing out of my personal first person experience and the experience of my working with others. It can be that as I am not conscious of the inner workings of my nervous system, that conscious experience is simply epiphenominal and thereby irrelevant to understanding the machinery of my nervous system. I think not. The structure of experiencing is ignored at the peril of forming serious misconceptions as to the nature of what we are investigating. There are, however, numerous other difficulties with the cognitivist approach, not the least of which is the binding problem. Where does it all get put together? Even in considering movement, action and activity are integrated and bound into a coherency.

Inadequate scientific conceptions often have a life of their own. Consider the long reign of behaviorism in psychology. But fashions do change as new tools and new understandings evolve. It is now becoming more clear to many researchers that perception is multi-sensory, that movement is the essential result of brain activity, and that an integrative dynamic understanding is needed that is more biologically oriented. We need good scientific work to substantiate this view. In The Brains Sense of Movement Alain Berthoz, who is a professor at the College de France, and director of the laboratory of Physiology of Perception and Action, brings together the evidence in a clear, comprehensive, and coherent manor, much of which may be new to even readers of JCS.

To put the contributions of Berthoz into perspective I would like to take a very common and seemingly over simple example to expose the complexity of our embodied life. Since we share this with other animals, I chose a scene of my playing with a dog.

I am out on the grass with my dog. The dog sees a stick on the ground, picks it up in his mouth, and runs towards me. He stops when he gets near and looks up with his eyes until he sees that we make eye contact. He tips his head and looks up towards me again. I do not respond. He then drops the stick at my feet, runs away from me at the same time watching, and comes back until I pick up the stick and throw it. Now he runs in the direction in which I threw the stick. He stops a moment, perks his ears; the stick falls, and the dog runs in the direction of the sound. He picks up the stick,

runs back towards me and drops the stick at my feet. I throw it again. We continue until one of us feels enough is enough and the game is over.

I am sure that nearly everyone is familiar with this common scenario. As A human being I have the advantage, or perhaps disadvantage, of being able to describe the event. I can say or write the word, stick, play, game, etc. The dog does not share this possibility with me. Even without language the dog can communicate his desire to interact with me and play the game.

Let us then take language and human cognition out of consideration to look at the event in more detail, except in so far as we need language to communicate about the event itself. I mean by this to examine the raw sensory and perceptual experience. This is difficult because how we think, that is, how we make concepts, theories, and models about our selves and the world that we live in is constrained by the mediums in which we must operate and communicate. These include the domains of social activities such as languaging, philosophizing, and making scientific experiments. We are equally constrained by the nervous system itself, and in our ability to sense, and perceive. Thus what can be put into a cognitive mode such as language depends in part on what language we have to use. Even more so how we attend narrowly, or open our experiential space has a strong effect on our conceptual conclusions.

One thing that can be noticed by an observer and myself in the event is that the behaviors of the dog and myself are coupled together. The dog looks at me; I look at the dog; our eyes track each other. You could say that our actions are coordinated with each other. We are also coordinated around the outside event of the moving stick. We both watch the stick and listen for and anticipate the sound of the stick hitting the ground. I can sense my own attending and also notice the dog's eyes and ears and the behavioral signs that he is attending. It must be that both the dog and I perceive the stick as an object in the external space. Otherwise our actions with the stick do not make sense. One some level both the dog and I have an awareness of the stick as a vehicle for the "game," which is an activity that we both have experienced before and therefore remembered as pleasurable. It should also be clear from our behavior that I perceive the dog, and the dog perceives me. The dog and I may not share language or some other higher cognitive processes, but we must have some common processes, cognitive events, brain and body processes, to produce the common awareness. Perhaps we have even some common feeling of enjoyment.

I am going out on a limb here to postulate what the dog is consciously experiencing. Nevertheless, the evidence of the dog's behavior, his energetic excitement, the attentiveness of his eyes and ears, the way he runs for the stick, and so forth is similar enough to human behavior to make an educated guess.

If we look further at the dog's behavior, there is considerably more to notice. As the dog sees the stick on the ground, he lowers his head, brings his mouth to the stick, opens his jaw and grasps the stick. He then lifts his head and begins his run back towards me. How does he accomplish such a complex series of actions and tasks? Somehow he must put his head at the right distance to take the stick with his teeth. He must grasp the stick and with a complex synergy of muscular actions of his jaw muscles and know when the stick is securely held. Other synergies are involved so that he can lift his head, focus his eyes on me to see where his is to run toward and

begin his run back to my position. To do this he must perceive his own action, and anticipate the consequences so that he can match the perceptions of his own body with the stick, the external space of his environment, and where I am in the space. When I pick up the stick to throw it, I do the same thing. I also anticipate the feel and perception of my action before I act and with almost automatic movements and without forced or narrowly focused attention, match the results of my action against the anticipated perception. I am conscious, but most of what happens is subliminal, and the actual activities of my nervous system itself, unconscious. My conscious perceptions when I attend to them include my self-movement, the orientation of my body parts to each other in my internal space, my orientation especially of my head to the gravity field, the external space around myself and what is present there including the dog, the ground and the stick, the stability of the visual space, the timing of the various actions that I carry out, and so forth. The coordination of all of this is so well learned and organized, so accomplished that it is easy for me to act without reflecting on how I do it or upon what I need to attend to, or even thinking there is any importance to any of the processes involved. And yet the complexity involved is huge. There are philosophical and scientific questions here that have confounded thoughtful human beings throughout history and on into this present time. Even before we tackle the so-called hard problem of consciousness, there are many problems here that have not been addressed. Unfortunately many thinkers have been seduced into thinking that either the problems here are handled by what we already know about the nervous system, the physiology of movement and cognitive processes, or that these are the easy problems of the brain, mind and body.

What is not attended to can sometimes turn out to be far more important than what we put in front of our noses. What we do not see or notice is not named, and therefore missing from our conceptual structures, the pictures we make of our selves and the world. Our conceptual notions are then limited by these blind spots, as are the ways in which we act upon these notions. Getting out of this trap is not easy. We are entranced by what we think we already know.

Alain Berthoz is out to fill in the blind spots. He has been doing this through the work of his own laboratory, but he also has a grasp of the burgeoning literature in the field. He necessarily opposes those trends in modern cognitive science, such as functionalism (what Freeman labels materialist-cognitivist), in which it is postulated that cognitive functions can be separated from the organism in which they are operative. Although, as he points out, such a tactic can be valid in engineering applications where we can separate software from hardware, biological systems really are different. The computer may be a useful metaphor at times, but it is also a dangerous one. For one thing it obscures the nature of both the way the nervous and corresponding physiological systems function in real living organisms, and the way we understand our own lived experience. I have created the story of the dog and myself to bring out the point, and phrased the story to introduce some of the notions used by Berthoz to grapple with the problems involved.

This blind spot about the "body" while not universal has a number of causes. One of which is that for many of us in daily life we are limited in the way we attend to our sensing, feeling and perceiving of our surroundings and ourselves. Another is that once a conception is established and passed through generations, it becomes fixated in people's understanding. Lastly there is the question of language. For a long period of history only five senses were enumerated. With regard to the sense of

movement, proprioception, sometimes noted as a sixth sense, Berthoz asks, "By what twist did language suppress the sense most important to survival?"

Berthoz introduces his book with a quote from Kant: "Plato left the world of the senses, as setting too narrow limits to … the understanding and ventured out beyond it on the wings of the ideas, in the empty space of pure understanding." And, "It is indeed the common fate of human reason to complete its speculative structures as speedily as may be, and only afterwards to enquire whether the foundations are reliable."

Berthoz says, "Plato forgot the body. This book is an apology for the body." Berthoz isn't alone in this. As I have pointed out, the concept of embodied cognition is today beginning to be more accepted. What Berthoz does though is to create a more solid ground to stand on. His basis includes neurological studies related to sensing, perceiving, and moving, studies of sensory physiology, the psychology of perception, studies of movement itself, and the relation of all of this to phenomenal experience. He reports on his own scientific investigations and on what he discovers through an overview of the scientific literature on related research. His theme is the relationships between perception and action. This he says is the preferable model for studying the functions of the nervous system. As he points out, "Unlike language they (such studies) lend themselves to analysis of human and animal behavior as well as to the neural mechanisms that underlie them, across the multitude of species that evolution has produced."

A Second point he makes is that perception is more than just an interpretation of sensory messages, and is both constrained by action and involves the internal simulation of action. To put it as J.J. Gibson did some years ago, one must move in order to perceive, but also perceive in order to move. A third point is that the senses need to refer to perceptual function. One needs to notice that there are far more than five senses. Clearly the vestibular senses, and the proprioceptors of the muscles and joints, as well as special senses such as echolocation and the magnetic sense that exist for certain species need to be included. One could also add in relation to perceptual functions, the sense of movement, space, balance, effort, self, etc. What is given to the senses is actually sought out in relation to the needs of the organism in terms of where it is going and what it wants to do. The brain filters sensory information picked up by the sensory surfaces according to its own plans. A fourth point is that survival depends on movement that is commanded or controlled in relation to anticipation with extremely fast and dynamic processes. It is something that is vital for both predator and prey in nature, no matter which one succeeds in the end. Berthoz puts it, "The brain is above all a biological machine for moving quickly while anticipating."

In order to carry out functions in this biological sense, a nervous system cannot process sensory information independently. Berthoz emphasizes that there is a necessary factor that has barely been identified let alone studied and discussed. This is coherence. Without it perceptual and motor disturbances are the consequence. Coherence is a strange, hard to define term. Yet it is to be seen as fundamental to understanding biological systems. Varela (1986) contrasted two modes in biological thinking. In what he designates as the standard current view, living organisms are conceptualized as if they were a collection of independent parts, where each part contributes to the overall functioning. The emphasis is on understanding the components. Varela calls this a logic of correspondence. The alternative is to

recognize the autonomy of living organisms and notice that an organism will act in its environmental medium according to its own internal structures, and its sense of regulation and balance. Varela designates this as a logic of coherence, where coherence emphasizes the interconnectedness, internal consistency, and unity of the living system.

Berthoz points out that sensory inputs are in essence ambiguous. For example the vestibular sensation of accelerating is the same as the sensation of braking in the opposite direction. Sensory inputs are also staggered in time. If you try to move your finger in synchrony with your foot the signals from the foot arrive at the cerebellum in twice the time it takes for signals to arrive from the finger. For the tongue the delay is by a factor of ten. And sensory inputs are often fuzzy. Yet through perception we can move finger, foot and tongue to the same beat. Or we can view a pointillist painting and perceive a scene even though the painting consists of small points of color. We can detect our accelerating or slowing in space. Sensation is necessary, but not enough. Coherence is essential and the loss of it devastating to functioning and stability.

Let us examine some details about proprioception as revealed in experimental work in applying a small 50 to 100 Hz vibration to a muscle of the arm. In a number of laboratories, including that of Berthoz, two phenomena are observed. If the arm is free to move, there will be a reflex contraction or activation of the vibrated muscle. If the arm is placed immobilized on a table as the vibration is applied, the subject in the experiment will experience an illusion that the arm is moving without being controlled along with two different perceptions. These are a feeling of change of position of the arm in space and a perception of the velocity of the illusory movement. Now the opposing (antagonist) muscle is activated rather then the muscle to which the vibration is applied. Berthoz describes this as, "The brain activates the muscle, perceived to be in motion, as if it were the perception (and not the sensation triggered by the receptors) that leads to the contraction." Note also that it is the perception that is consciously experienced and not the sensory signals.

The myotactic or stretch reflex, that had been discovered by Sherrington at the beginning of the twentieth century also turns out to be much more complex than was first understood. The reflex, which is triggered by the spindle receptors in the muscle, allows the arm, for example, to resist a force exerted on the arm, say the sudden weight of an object placed in the hand. The spindles when stretched emit nerve signals proportional to the elongation of the muscle and the velocity of the stretch. Muscle tissue actually contracts slowly. If the reflex were just a simple reaction to the stretch, the reflex would not be able to match the force. There would be no coordination of holding the object. The spindles as it turns out are also responding to velocity, that is the first derivative of the force. This allows for a dynamic anticipation such that the timing of the muscle contraction matches the timing of the stretching. Anticipation here is preconscious. Yet it is built into the nature of the sensory receptors in the muscles. What I didn't know myself before reading Berthoz is that nearly all sensory receptors detect the derivatives of the variables that activate them. Berthoz notes, "Evolution obviously selected receptors capable of predicting the future." We have moved a long way from stimulus response models of how sensory systems work.

The vibration in the experiment simulates stretching, but what about the illusion? Illusion must involve activity at higher levels of the nervous system and they have their place in resolving sensory ambiguities. Different illusions are created, depending on whether the subject of the experiment is seated or standing or leaning on the arm. From the activation of the receptors and the context of the global state of the body, the cerebral cortex works out a perception of displacement and activates the muscles that correspond to the perception. Berthoz says, "The brain assigns a status to sensory information based on its assessment of the general state of the body. We are very far from a simple potentiometer."

Berthoz also details the functioning of the vestibular system and its relation to visual and spatial perception particularly related to the detection of body movements. It is now known that the sensory receptors here are capable of detecting the second derivative of angular displacement and some receptors are even sensitive to the third derivative of movement or jerk. Evolution has enabled the nervous system through the receptors to simplify the creation of perception by the nervous system by reducing or eliminating the need of calculating in the senses that we commonly understand it. Again coherence is the consequence, for example, that in our visual perception of the world the world stays still rather than moves, as would be the case as images move on the retina. All of this relates to the movement of the eyes, the balance in gravity, and the body image itself. The loss of this coherence or its lack of development can be seriously disabling to those few individuals who have this problem.

There are practical consequences to this new understanding. I have had the experience of working with a number of persons whose difficulties relate to some disturbance in the integration of the vestibular and proprioceptor systems. Often the difficulties are unrecognized by medical experts and the persons themselves except in that they are aware of the experience of difficulties in functioning, and or confusion and may have vestibular symptoms such as motion sickness or nausea with certain movements of the eyes or head and neck. In two instances the persons and I discovered that they had no stability in their visual world, which jumped or moved in their own movement of their eyes or head. One of these persons suffered from severe and unrecognized dyslexia as a child because the words on a page did not stay still in his visual field. The second person suffered nausea while exploring simple movements of her head and neck or when she changed something in the organization of her right side. I discovered with this person that her balance was disturbed on her right side as well as her body feeling on the right which she said felt empty or blank in her experience. She also had trouble in crossing her hand across the midline to the right in her internal visual field. When she was able to improve her balancing through feeling the movement of her ribs and spine on the right side, a good deal of the other symptomology was relieved.

I mention these examples to point out how little we know about the integrative activities of the nervous system, and how little we understand about perception. I find that in working with individual persons that I must explore what is happening at the phenomenological level since there is so little good theory to rely on. Or perhaps that is a blessing, since in my exploring with a person I have so few preconceptions. Berthoz is humble enough to point out the many areas in which we are ignorant. Although he devotes a whole chapter to coherence, even pointing out that such conditions such as autism seem to involve disturbances in the development of coherence, he notes, "A genuine theory of coherence has yet to be constructed."

Or at another point he mentions, "The neural basis of the sense of effort remains to be discovered." On the other hand he shows how detailed investigations of the colliculus have revealed how the brain handles spatial and temporal coherence of messages from different senses, or how different senses are combined despite the neural time shift that I mentioned before.

This book then is a treasure of material relating to my complaint in my previous paper (Ginsburg, 1999) that "reductionism is neither a pragmatic nor effective approach … to understanding the integrative aspects of the nervous system." How much this book contributes to the field of consciousness studies depends upon how one sees the relation of nervous system processes to experience. Berthoz is not only cognizant of the importance of phenomenal experience, but shows how his laboratory science relates to what is experienced as conscious perception. Merleau-Ponty is an important resource for him.

I believe that this is an important book, filling a gap that has needed filling for a long time. There are areas that Berthoz skirts such as the emotions, or does not include such as learning and development. A book that covers as much ground as this needs to limit itself at some point so as to be accessible to the reader. There is more than enough here to challenge our thinking. I thus highly recommend it. I particularly recommend it to those already committed to the opposing camp. It should at least bring some to question the already established view.

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