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On being of two minds

The structure of scientific evolution

Astonishing strides have been taken in the last few years in detecting the physical workings of the human brain, and these have inevitably affected the prospects of our understanding human behaviour and educating it. In an essay that playfully draws an analogy between the behaviour of neurons and the behaviour of people, Brown draws a moral or two about the manner in which groups of people should pursue science, especially in a period when a time-honoured paradigm may be reaching the end of its usefulness. The implication he draws from what we know of the complementarity of the brain's two halves points towards the restoration of a balance in education - a balance long distorted by a bias towards logic at the expense of intuition - if we are to use our brains efficiently in the way they were designed.

The single most important fact that we have learned about neurons is that they are gregarious. The composite bits of our brain are continuously eager to exchange information, to talk to one another. They are usually constrained by time and space - as are the members of any social unit - to pay the most attention to those nearest and most familiar to them. However, when isolated in a tissue culture, they are quite content to start forming relationships in a group of total strangers with no hesitation and little apparent shyness. They appear to share none of the social awkwardness and introversion of the larger neuronal aggregates (us). For most neurons, communication appears to be an end in itself.

The preferred form of communication among neurons is the formation of a synapse, defined by Sir John Eccles as "a very intimate contact." It is the structure of the synapse which defines the relationship between the cells involved. Far from being the static entity it was originally imagined to be, this structure is as richly variable and flexible as any spoken conversation. The all-purpose strategy of the neuron appears to be to receive and to transmit data (with suitable editing) under any circumstances. When new input registers, synapses are activated, modified, and, if the news is important enough, grown. The loss of information, either through injury or through lack of input, also triggers off a re-defining of synaptic contacts in an attempt to re-structure existing information. Either way, the impulse to find out what is going on and to pass it along, after modifying the news in an individual manner, is paramount. By my last count, neurobiologists had discovered at least a half dozen different ways in which two cells can vary the process and structure of their synapses. The synapse functions to allow two or more neurons to sum their respective messages: to say **we** instead of **I.** It is this summation which defines modules of neurons, allowing them, in combination, to exert a far-reaching effect both on other modules and on the organism as a whole.

Outside of this matrix of communication it is hard to think about neurons at all. Much like a single note of music or a lone thought, an isolated neuron does not make any sense. Considered apart, a cell which has the sole purpose of making contact with other cells becomes a paradox. Without the symmetry of the larger pattern and the resultant similarities and contrasts, a neuron is just another random event. Only a community of neurons can have any meaning, perform any function. Within this organization a neuron becomes important, and especially so to those others in its immediate group, who have the same common interests. Similarly, these units are defined by their relations to other units, forming a module and so on. What becomes evident is the interdependency, the stake each cell has in maintaining the environment; any discussion of the ecology of neurons inevitably involves consideration of the structure of the brain itself.

Considering the enormous complexity of the brain, it is astounding that more things don't go wrong. Each module contains up to 10,000 neurons in continuous contact with one another. At the next level of magnitude, there are about one million modules in each cerebral hemisphere. The potential for information exchange is of such staggering proportions that verbal descriptions are hopelessly inadequate - an attempt to put a tiny frame around a vastly more complex reality. Even the calculations of our most sophisticated thinking machines, while just fine for supervising the most advanced of our current technological hardware, cannot begin to provide us with an adequate description of the neuronal matrix. For my money, the closest thing we have come to anything near a full model of the brain is Bach's **St. Matthew Passion.** Perhaps it could serve as a pattern for future models, both in breadth of inspiration and sureness of craftsmanship. As the problem is approached, there is a growing conviction that words alone will not be enough; something more is necessary.

Me and me, in stochastic process

Perhaps we need a new mode of description, or maybe two at once. Neurophysiological evidence suggests that such modes are available. The lateralization studies of the past two decades (particularly with people who had undergone commissurotomy, the severing of the connections of the two hemispheres) have confirmed the clinical evidence of over one hundred years: we are of two minds about everything. A concept of duality in our nature has been present in every major religion and in much of our everyday talk about ourselves. It would appear that every function of our conscious (or dominant, or verbal) hemisphere is paralleled by similar, complementary, but not identical, functions in the other. The part of me called **I**, the part which pays the bills and has always believed it runs the show, now appears to be sharing control with a not so silent partner. One of me is analytical and time-oriented, continuously pre-occupied with breaking things into composite parts and ordering the parts sequentially. The other me has no sense of time (a fact long suspected by colleagues) or formal logic.

Despite this, I/he seems to manage quite nicely performing virtually everything that is of importance to me/us. This self has synthetic and mechanical abilities as well as the types of non-verbal thinking often referred to as imagination or intuition. A slice serve in tennis, the harmonies of the third Brandenburg concerto, and the occasional split-second recognition on meeting a new acquaintance that this person will become a close friend, are all within the domain of this other self. Two distinct modes of thinking appear to operate, each with specific tasks. I don't know how I hit upon this division of labour, but I appear to have thought of everything.

The results of the "split brain" experiments, and the increase of interest in establishing the differences in hemispheric function, have not escaped the notice of the popular press. The results have been rather a lot of pop meta-phychologic theorizing and the acquisition of a whole new set of short-hand personality descriptions for the trendy. Descriptions of modes of thinking are used as nosology: "It will never work out, she is a right-brained person, while he is totally into his left hemisphere" is used to describe the marital prospects of a baseball player and his wife. While arguably a significant improvement over the jargon of the human potential movement, or the indiscriminate use of psycho-analytic epithets of bygone days, this view overlooks the most important point of all. Though the two modes of thinking are different, and problems can arise if we ignore this difference, they are also complementary. In the undamaged human they are inescapably intertwined. We appear to be wired up on the macroscopic level for the same sorts of intimate, continuous conversation that the neuron has on the microscopic level. The **corpus callosum,** which connects the two hemispheres, carries over two hundred million fibres from one to the other. These connections provide an exact mirror linkage, a one-to-one correspondence between each major cortical area and its twin in the opposite hemisphere.

The single most important finding of the split brain experiments is not that there are two modes of thinking, but that the two work together with considerable elegance. The clear isolation of functions in each hemisphere after surgery does not obscure all that is lost in interrupting the flow of communication. Not only is the integration of the two modes disrupted, but it is also strikingly clear that each hemisphere is much poorer in its own specific tasks when working separately. The diminished potential of the whole is reflected in the impoverishment of each of the two halves. Choice, the use of two parallel modes simultaneously, appears to be the key. Without choice, without the chance of exploring other options, each hemisphere is a parody of its former self. What we are describing is a stochastic process.

Stochastic comes from the Greek **stochazein,** literally, to shoot with a bow at a target. A stochastic process is one which combines two components, one random and the other selective, in order to achieve a specified outcome. The process combines the flexibility of a number of possible alternatives with the precision of applying any which best fit the situation. It is the common factor in all biological systems, or at least those which survive and continue to evolve. Evolution itself is the largest example, with the genetic inheritance continually producing new choices and the current environment selecting what is most useful or adaptive. Each is separate, but neither means anything when considered outside of its relationship with the other.

So it is with our two minds. One produces a random selection of patterns while the other fits them to the task at hand. It is the relationship which defines them both. Without it, each is an evolutionary dead-end, a pointless jumble of biologic syntax. The sharing of new information, otherwise known as learning, requires a process which can both generate new possibilities and apply them in trial and error fashion. If the two function more or less simultaneously, then a new dimension is added in the same way that depth perception is the result of two monocular views of the same scene. The results of intimate communication at the hemispheric level are a deepening of perspective and a widening of the variety of choices in any situation.

Perhaps it is not so surprising that an analogous situation occurs at the next level of organization as well. The benefits of contact with new modes of arranging information are evident when people are working together. At our best we have many of the attributes of a collection of neurons.

The neuronal dialectic, the greater whole

A model of group scientific thinking has been described by Thomas Kuhn in his book **The Structure of Scientific Revolutions.** Kuhn suggests that what is defined as the body of accepted fact by the scientific community working in a particular area constitutes a **paradigm** or model of reality. In effect, the paradigm is a structure of beliefs which organizes the perceptions that will be accepted by the group, and also dictates the course of further investigation. As such it is both a necessary support and, ultimately, an artificial restraint. While the paradigm saves us from having to continually re-invent the wheel, it also, by necessity, discourages other avenues of investigation - alternative ways of looking at problems.

The paradigm functions reasonably well for a period of time, and then things begin to go wrong. Data begin to accumulate that are incompatible with the official version of reality. If the new data cannot be dismissed or refuted then the paradigm (or the consensus of minds which holds it together) begins to disintegrate. The stage is then set for a Copernicus or Einstein to provide his particular contribution which, if picked up by the other members of the network, leads to the formation of a new paradigm. A new and, usually, more useful map of reality is available.

The comparison between what goes on at different levels between neurons, hemispheres, and people is inescapable. The sharing of information generously and incessantly is what we do best. More precisely, that sharing gives us definition and purpose. On a human level, learning and re-making our descriptions of reality are the results of the stochastic process of science. The paradigm and any counter-paradigm currently available are the two complementary parts of the same process. Neither exists without the other. As we shape our knowledge we simultaneously shape ourselves.

The process never finishes. The final step in any sequence only serves to trigger off the other mode, producing a series of themes and variations which, in turn, are themselves elaborated upon. So it goes. The two modes of thinking intertwine in a contrapuntal fashion. All of which leads me back to the nature of neurons and their addiction for contact with one another.

In a system with these characteristics the need to receive and pass on information is inevitable. Communication is never quite done, as each new message prompts further exploration, ultimately coming back to the starting point not as a complete answer, but as a more satisfying question. Surrounded by this incessant flow, the neuron has no choice except to be insatiably curious. The biologic given is to share information, and to do it with both diversity and specificity as the part of a greater ensemble. The neuronal dialectic leads always to the formation of a greater whole:

> If they be two, they two are so
> As stiffe twin compasses are two;
> Thy soule, the fixt foot, makes no show
> To move, but doth if th' other doe.
>
> Such wilt thou be to me, who must
> Like th' other foot, obliquely runne.
> Thy firmness drawes my circle just,
> And makes me end where I begunne.

John Donne

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