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OPINION

Decade of the brain: Reflections on some Indian concerns in cognitive neuroscience*

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'Of all the wonders nothing is more wonderful than man, who has learned the arts of speech, of windswift thought, and of living in neighbourliness.'

— Sophocles

Brain, the organ of reason: The early search and the outcome

Nearly two hundred years of search for a physiological basis of behaviour more precisely for the organ of reason which was thought to be the heart by Aristotle, ended in the hippocratic proclamation¹, 'And men should know that from nothing else but from the brain come joys, delight, laughter and jests and sorrows and griefs, despondency and lamentations and by this in an especial manner, we acquire wisdom and knowledge and see and hear and know what are foul and what are fair, what sweet and what unsavoury... and by the same organ we become mad and delirious and fears and terrors assail us, some by night and some by day, and dreams and untimely wanderings, and cares that are not suit-

able and ignorance of present circumstances and unskilfulness. All these things we endure from the brain, when it is not healthy, but is more hot, more cold, more moist or more dry than natural, or when it suffers any other preternatural and unusual affliction.'

Since then biological disciplines have made remarkable progress towards understanding the structure and function of human brain and the mechanisms which underlie behaviour. However as Seymour Kety² wrote, '... but in the area of information, content, and experience, stored as it is in the complex interrelationships of 13 billion neurons, biology is extremely pretentious if it thinks that it can unravel them by means of its tools. There will no doubt be a biochemistry or a biophysics of memory — but not of memories' (emphasis mine). It is significant that nearly three decades later, *Science*, the journal which published Kety's article brought out a special issue on cognitive neuroscience³ dealing with the question: How do we think?

The decade of the brain: Advances in cognitive neuroscience

It is also significant that the American senate declared that this decade will be

a decade of the brain, giving the necessary impetus and thrust to researches towards understanding the human brain. Several other countries followed this example. The number of interrelated disciplines engaged in understanding the mechanisms underlying normal and abnormal mental processing are numerous and include anatomic and computer studies of neural circuits, animal and human lesion studies, neurophysiology, neuroimaging, neuropharmacology and experimental cognitive psychology. While the approaches to understanding schizophrenia and Alzheimer's disease as a dysfunction of specific cognitive systems may lead to amelioration of disease, understanding the normal working memory and consciousness will bring numerous rewards because of its relevance to our daily lives in terms of language as a means of communication, memory and planning. The intensity and the excitement of such recent global endeavours in brain research are palpable. As a result of these efforts, it is becoming clear that the processing of information that leads to complex behaviours such as learning and memory involves multiple brain regions that must operate in an interactive synchrony.

The advent of two spectacular techniques namely, measured brain activity

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indexed by regional cerebral blood flow (rCBF) and functional magnetic resonance imaging (fMRI), in recent times are enabling researchers to examine the responses of distributed brain networks while an individual is performing a task. Three very significant articles, based on either one of these techniques or both appeared during 1995-97 (refs 4-6). Fink *et al.*⁴ in their analysis of the perceptual world which is organized hierarchically (the forest consisting of trees and the trees consisting of leaves) discovered that when the visual attention is directed towards the overall picture (global form), the right prefrontal cortex was activated. On the other hand, when the visual attention is directed to the focal details of a scene (local components), the left prefrontal cortex was activated. The findings provide direct evidence for hemispheric specialization in global and local perception in normal subjects. In this experiment Fink and his colleagues used letter-based hierarchical stimuli. However when they used⁵ object-based hierarchical stimuli, the hemispheric specialization was reversed. There was now greater right-sided activation for local processing and greater left-sided activation for global processing, which is the opposite of that seen with letter-based stimuli. This is quite in agreement with the celebrated discovery of lateralization of hemispheric mechanisms for language and object processing in the split brain patients by Roger Sperry⁷. Shaywitz *et al.*'s work⁶ is far more significant in that they succeeded in isolating specific components of language and in relating these language processes to distinct patterns of functional organization in brains of neurologically normal individuals. Using functional magnetic resonance imaging, during orthographic (letter recognition), phonological (rhyme judgment) and semantic (content) tasks, they showed that the inferior frontal gyrus (IFG, roughly encompassing Brodmann's areas 44/45), is uniquely associated with phonological processing on rhyme judgments. What is remarkable is that, in females there is significantly greater activation of IFG in the right hemisphere. Thus they have demonstrated remarkable differences in the functional organization of a specific component of language, phonological processing between nor-

mal males and females. More significant is their concluding remark, 'Further studies designed to examine either gender differences in language function or the neural mechanisms related to language, for example should be specific for the component of language assessed and determined in both males and females'.

India's intellectual, linguistic and literary traditions: The science of mind

The quest for truth as a tradition rather than an avocation has been the hallmark of India's ancient civilization. So also the pursuit of beauty and knowledge has been the hub of its literary and artistic traditions. While several ancient Sanskrit texts can be alluded to as proof of these statements, suffice it to ponder over the following, written in one such ancient text, *Tripura Rahasya* (The mystery beyond the trinity)⁸: 'Just as the cognizer, cognition and the cognized are identified with mind in dream, so also the seer, the sight and the phenomena are identical with the mind in the wakeful state.' The entire text is a discourse on the nature of self and its brain, consciousness and intelligence, perception and memory. While the approach in these texts may be philosophical, some of the conclusions arrived at seem valid scientifically. This kind of intuitive knowledge about mind/brain was given in modern times by Aurobindo when he stated in 1910 (ref. 9) (five decades before Roger Sperry came up with much the same knowledge gained through his ingenious experiments on split brain patients), 'The intellect is an organ composed of several groups of functions, divisible into two important classes, the functions and faculties of the right hand, the functions and faculties of the left. The faculties of the right hand are comprehensive, creative and synthetic, the faculties of the left hand critical and analytic ... The left limits itself to ascertained truth, the right grasps that which is still elusive or unascertained. Both are essential to the completeness of the human reason. The important functions of the machine have all to be raised to their highest and finest working power,

if the education of the child is not to be imperfect and one sided'.

As for the linguistic and literary richness, it is well known that the effectiveness of Sanskrit as a medium of communication is being rediscovered with the advent of computational machines and the all-important software to be fed into these 'artificial brains'. Some of the other Indian languages have close affinity with Sanskrit and draw heavily upon its grammar and idiom. One such language is Telugu, spoken in Andhra Pradesh in South India. There is a tradition in this language, called *Ashtavadhanam*^{10,11}, wherein a poet engages eight questioners (*Pruchakas*) simultaneously, and recites extempore, poems to the metrical order, prescribed by the questioners. (I am not aware if such tradition exists in other languages.) The poet who performs this task is called *Ashtavadhani*. There are others who can engage one hundred questioners at a time and these poets are called *Sathavadhanis*. Basically what an *Ashtavadhani* does during this public performance involves letter processing (composing a poem to the desired metrical order), phonological processing (rhyme is also prescribed), and semantic processing. While one questioner forbids the usage of a letter likely to be used by the poet (*Nishidhakshari*), another questioner prescribes that a particular letter must be used at a particular position, in a line such as 13th letter in the first line, 16th in the second and so on in a poem of four lines (*Nyasthakshari*). While the poet is engaged in these tasks, a third questioner makes an attempt to distract the attention of the poet by indulging in, 'eulogizing the irrelevant' (*Aprasthutha prasangam*), to which the poet is expected to respond/react through a pleasant repartee! One other questioner prescribes that a given sum be distributed into sixteen squares in such a way that the addition of individual figures through columns, rows or diagonally must yield the same given sum (*Chitraganithamu*). While all other tasks involve linguistic skill and memory, this particular task involves spatial memory. What this means is that the poet is able to put different regions of the brain both in the left as well as the right cerebral hemispheres to rapid use for formulation as well as retention

much beyond the capacity of an average individual¹².

The agenda in focus

It is easy to dismiss this exercise as that of a special group endowed with special talents. In reality however, this is not true. While undoubtedly any such task requires some training of the mind, there is apparently nothing extraordinary about it, as seems to be the case with a prodigy(ies). Nor is the ability confined to the language teachers. Though not many in number, there are *Ashtavadhanis* of very young age such as 10–15 years. I was informed that there are nearly 35 *Ashtavadhanis* in the state of Andhra Pradesh. I am emphasizing the fact that *Ashtavadhanam* seems to fall within the realm of normal mental abilities without remotely attempting to discount the erudition and the aplomb with which an *Ashtavadhani* keeps answering the *Pruchakas*, merely to point out that raising the brain/mind's potential to a higher level through training and sustained application seems possible.

What is important is to discover through such techniques as fMRI, how the poet's brain handles the information flow, builds up on it, retains and recalls what is built anew in his mind/brain in the form of poems. Will the lateralization of hemispheric functions show up while he engages in orthographic, phonological and semantic processing? Will there be gender-based differences? What kind of training does the mind/brain require to accomplish such an intellectual feat? Answers to these questions will surely find their utility in our day-to-day mundane world. Can India address these questions before the decade of the brain comes to a close in the year 2000 (ref. 13)?

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10. One such performance lasting two and a half hours by *Ashtavadhani*, Vidwan Kota Rajasekhar, was videographed by me on 8 April 1997. The performance was given before the general public and invited audience at Kavali, a coastal town in Andhra Pradesh. I thank the Rotary Club of Kavali which sponsored this programme and the poet for permission to videofilm the event.
11. 'Towards understanding the components of cognitive neuroscience in *Ashtavadhanam*'. Invited lecture delivered at the second congress of The Federation of Indian Physiological Societies, SV University, Tirupati during 15–17 September 1997. Certain theoretical propositions were made regarding hemispheric mechanisms involved in the performance of *Ashtavadhanam*. While the poet composes a poem, essentially he maps the chosen letter strings on to phonological representations within a given metrical order. Will the left inferior frontal regions be activated predominantly during this process? When he switches to the task of completing the *Chithraganitham* involving spatial memory, will there be greater right-sided activation of prefrontal cortex or left-sided activation? The answer to this latter question depends on whether there is predominant local processing (paying greater attention to the individual number in each square) involving right-sided activation or predominant global processing (paying greater attention to all the sixteen squares as a whole) involving left-sided activation. The task of *Ashtavadhani*, thus offers exciting challenge and opportunity to try and

discover how lateralization of hemispheric mechanisms/functions mediates orthographic, phonological and spatial memory so efficiently and with such rapidity!

12. The other four questioners deal with *Dathapadi*. (Poem to be composed using four words and a theme of the questioner's choice.); *Varaganithamu* (The day on which any particular date of the questioner's choice within the past 100 years falls is to be given by the poet.); *Ashukavitha* (Poem to be composed on any given topic to the desired metrical order); *Samasyapuranam* (Problem solving – composing a meaningful poem using a given problem phrase such as for e.g. 'A boulder walked with its feet').
13. It is heartening to note that the Department of Biotechnology, Government of India announced the establishment of a National Brain Research Centre, at New Delhi, while the proof of this article was being read.

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