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Guest Editorial

INFLUENCE OF YOGA ON BRAIN AND BEHAVIOUR : FACTS AND SPECULATIONS

It was more than 40 years ago that Professor B.K. Anand and his colleagues at All India Institute of Medical Sciences published their classical observation that the electroencephalograms (EEG) of yogis had a preponderance of alpha waves (1). Further, they observed that sensory stimuli such as a loud bang or a cold/hot object, which normally block the alpha rhythm, could not do so in yogis during meditation. These findings were initially received not without some scepticism. One of the doubts expressed was whether those who had a preponderance of alpha waves were not more likely to be attracted to yoga. The question, scientifically perfectly valid, however reflects a deeply-ingrained image of the characteristics of the brain in neurobiology. The classical image evoked by the brain is that of a robust structure made up of a set of neurons of which neither the number, nor the connections or neurotransmitters can be altered, except in disease. But this image is no longer valid. Recent studies indicate that while the broad outline of neural connections is genetically determined, finer details are mutable (2). Further, besides connections, the efficacy of synaptic transmission and neurotransmitter profile are also subject to change. This flexibility in neural structure and function is called neural plasticity. Neural plasticity is of three types: developmental, experience-related, and regeneration-related. The influence of yoga on brain is due to experience-related plasticity.

Prof. Anand's observations were confirmed in extensive studies on those practising transcendental meditation (TM). Power spectral analysis of those who have been practising TM has shown an increase in the alpha/delta power and a decrease in the beta/alpha power. Further, it was found that there was a better balance and synchrony in the EEG recorded from the left and right side, and from the frontal and occipital leads (3). However, there has also been a recent report of higher beta 1 and beta 2 activity in practitioners of sudarshan kriya than in healthy controls (4).

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Some recent studies have shown that unilateral forced nostril breathing (UFNB) affects cerebral hemispherical dominance. Left-sided UFNB leads to right-hemisphere dominance and improves spatial skills. On the other hand, right-sided UFNB induces left hemisphere dominance and increases verbal skills (5).

Galvanic skin response (GSR) has frequently been used in studies on autonomic function. In general, yogic practices tilt the autonomic balance in favour of the parasympathetic division. It has been shown that those who practise TM have fewer spontaneous GSRs than non-meditating controls, indicating lower reactivity to stressful stimuli. This was confirmed when the subjects were exposed to a series of auditory stresses. As compared to non-meditators, the meditators got habituated to the stimuli faster, and their GSRs were smoother (6). The results indicate lower reactivity and greater stability of the sympathetic nervous system in meditators.

Studies at Swami Vivekananda Kendra, Bangalore, have shown that asanas, pranayama, meditation and tratakas, and attending devotional sessions for 10 days led to significant improvement in fine co-ordinated movements (7). Similar practices for a month led to a reduction in the degree of illusion created by Muller-Lyer lines. A combination of yogasanas has been shown to raise the critical fusion frequency (8).

The changes seen after yoga described above have remarkable similarities with learning. Yoga can be considered an experience, as a result of which there are sustained changes, some of which translate into improved performance. Therefore it is reasonable to assume that, as in other types of learning, the changes associated with yoga would also involve changes in synaptic function such as long term potentiation or depression, or changes in neurotransmitter profile, or change in the number of synapses. Further, neural plasticity is more than synaptic plasticity. Over the long term it also manifests as altered connectivity of neurons.

Why does yoga affect the brain ?

Neural plasticity in response to sensory experiences and motor processes is now reasonably well established (2). The mutability of sensory and motor maps of the brain has been shown most convincingly in the rearrangement that occurs after injury (9). But cerebral cortical plasticity has been demonstrated in mammals using classical conditioning as well as operant conditioning paradigms (10). Functional magnetic resonance imaging (fMRI) has made it possible to demonstrate cortical plasticity also in human beings. It was found that there was more activation of primary motor cortex for a practised sequence compared to an unpractised sequence of movements (11). The overall conclusion from such studies is that changes in perceptual acuity or motor skill are the result of changes in the cortical representation of the relevant sensory or motor aspects of the task (10). Yogic asanas involve practice of motor movements, and some yogic practices involve repeated sensory experiences. Meditation itself may involve efferent attenuation, sensory attenuation and non-analytic attention (12). Thus it is only natural that yogic practices utilize neural plasticity to bring about sustained changes in the structure and function of the brain.

Speculation

Yoga is a profound physical, emotional and cognitive experience, and each of these is capable of influencing the brain. While there is considerable experimental evidence for sustained changes in neural structure and function in response to sensory and motor (i.e. physical) experiences, the effect of emotional and intellectual experiences on the brain belongs largely to the realm of speculation. Here some hypotheses which have been advanced about postnatal cortical specialization associated with cognitive development may be relevant (13). The first hypothesis is that with increasing experience of a specific type, there is increasing localization of function within the cortex. This hypothesis implies that while the areas of cortex involved in an experience may be initially widespread, eventually the function gets localized to a narrow area best suited for the function. The second hypothesis is that with increasing experience of a specific type, localized cortical activation within a region or area becomes more selective for that function. The first and second hypothesis are not mutually exclusive. The third hypothesis is that a specific experience might in the beginning activate a cortical area only to subthreshold levels but with increasing experience the activation exceeds the threshold. The development from an infant to adult is comparable to that from an initiate to an advanced sadhak: the latter development is, if anything, a much longer journey and qualitatively a more radical transformation. Further, we now know that considerable cortical plasticity is retained even in the adult. Therefore the same hypotheses would apply to the cortical processes associated with yoga.

John Skoyles has advanced a hypothesis regarding the neural substrate of activities such as reading, mathematics and chess which arose after our evolution (14). Yoga is an ancient discipline but certainly it arose much after the evolution of our species. Hence his hypothesis applies as much to yoga as to other cognitive activities. He argues that four things fortuitously came together to make our novel, nonevolved cognitive activities possible: one, neural plasticity; two, large chunks of functionally uncommitted cortex in the prefrontal, temporal and parietal lobes; three, the ability of their neural circuits (due to neural plasticity), if trained, to take on novel skills; and four, a large prefrontal cortex which could use its working memory as a tuition management sketch pad in which to train them. The crucial points in the hypothesis, evidently, are neural plasticity as a process; and prefrontal cortex, where the process had a large playing field available. Neural plasticity is an old process, present even in invertebrates; but a large prefrontal cortex is an essentially human acquisition. That is why Skoyles calls the prefrontal cortex the missing link that explains why the human mind is so different from that of other apes. He feels that the prefrontal cortex evolved probably to exploit neural plasticity for creating novel competence in regard to dexterity and speech. But its large size in humans made possible so much diversity in new skills that the sky virtually became the limit to creativity. Yoga may be considered an advanced version of this creativity. Yoga, more than a sensory-motor experience, is an emotional experience. Emotions are intimately linked to the somatic system. Antonio Damasio has argued the case for a brilliant hypothesis that makes emotions part and parcel of cognition (15). His hypothesis runs somewhat like this: in order to deal with a situation we use reasoning to arrive at a few alternative courses of action. We again use reasoning to anticipate the consequences of each option. Some of these consequences are pleasant, some not so pleasant, or frankly unpleasant. We anticipate the emotions each consequence would lead to, and choose the option likely to lead to the most pleasant consequences. The hypothesis has a strong resemblance to Skinnerian psychology. But the emphasis here is on the intimate relationship of emotions with cognitive activities, and explains why patients with prefrontal lesions, who have lost the capacity to feel, even with reasoning fully intact, end up taking decisions which are not in their own interest. Does it mean that yogis, with their profound equanimity, are also likely to take wrong decisions ? The answer is yes, and no, depending upon the perspective. 'Yes', because to a person in yoga many things which matter a lot on the basis of ordinary reasoning, do not matter. Therefore he may make a big donation, or spurn the offer of a prestigious position, and these decisions of his may be viewed as 'wrong' decisions. However, the answer is also 'no', because there is one profound difference between yoga and prefrontal damage. In prefrontal damage, the person does not feel because he cannot feel. In yoga, the person does not feel but can feel. Since the yogi has not lost the capacity to feel, he still retains one emotion: the emotion of love–not self-love, but universal love. However, a decision based on universal love may be detrimental to the individual's immediate personal interests. But in the case of a yogi, it is a conscious decision based on the emotion of love, not an error of judgement due to the incapacity to feel. His apparatus for decision-making is normal – a combination of reasoning and emotion–but his yardstick is unusual.

It is worth speculating whether the thought content influences in any way the nervous system of an individual. While the details of each individual thought may not leave behind a permanent trace, the general trend of thoughts might. For example, the tilt towards parasympathetic dominance in yogis may be the result of not just the physical postures but repeated reflection and prolonged practice consistent with a self-denying, non-judgemental, all-loving, all-embracing philosophy. Starting from the cerebral cortex down to the peripheral autonomic nerves via the limbic system and hypothalamus, there may be an increase in number and efficacy of synapses leading to parasympathetic outflow, and an atrophy of those leading to sympathetic outflow.

It can also be debated as to what comes first: the neural connections and neurotransmitter profile, or the thought process. For example, is the intellectual and emotional framework of yogis different from usual because their brain is different to start with; or do they start thinking differently with a 'standard' brain, and that induces changes in the brain, which in turn makes their unique thought process second nature to them. It is a bit like the similar question regarding the chicken and the egg. In terms of yogic philosophy, one is inclined to believe that the thought comes first, and structural and chemical changes in the brain follow. The dominance of mind over matter is coming to light in many other ways as well. A person can literally suffer a heart attack due to a 'broken heart' (16), or laugh his way to recovery (17). After all, the material universe was created by the Creator from non-material precursors, and we have the essence of the Creator within. As the Upanishads say, "Brahman grows by his energy at work, and then from Him is Matter born, out of Matter life, and mind and truth and the worlds, and in works immortality" (Mundaka Upanishad 1, I: 8).

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REFERENCES

1. Anand BK, Chhina GS, Singh B. Some aspects of electroencephalographic studies in yogis. *Electroenceph Clin Neurophysiol* 1961; 13: 452–456.
2. Kaas JH. *The Mutable Brain: dynamic and plastic features of the developing and mature brain.* Amsterdam: Harwood Academic Publishers, 2001.
3. Kras D. Transcendental meditation and the EEG. In: Orme-Johnson O, Farrow JT (editors). *Scientific Research in the Transcendental Meditation Program: Collected Papers,* Vol. 1. New York: MIU Press, 1975.
4. Bhatia M, Kumar A, Kumar N, Pandey RM, Kochupillai V. Electrophysiologic evaluation of Sudarshan Kriya: an EEG, BAER, P 300 study. *Indian J Physiol Pharmacol* 2003; 47 (2): 157–163.
5. Jell SA, Shannahoff-Khalsa DS. The effects of unilateral forced nostril breathing on cognitive performance. *Intern J Neuroscience* 1993; 73: 61–68.
6. Orme-Johnson DW. Autonomic stability and transcendental meditation. *Psychosomatic Medicine* 1973; 35: 341–349.
7. Manjunath NK, Telles S. Factors influencing changes in tweezer dexterity scores following yoga training. *Indian J Physiol Pharmacol* 1999: 43: 225–229.
8. Raghuraj P, Telles S. Muscle power, dexterity, skill and visual perception in community home girls trained in yoga or sports and in regular school girls. *Indian J Physiol Pharmacol* 1997; 41: 409–415.
9. Kaas JH. The reorganization of sensory and motor maps after injury in adult mammals. In: Gazzaniga MS (editor). *The New Cognitive Neurosciences.* Cambridge, Massachusetts: MIT Press, 2nd edition, 2000: 223–236.
10. Recanzone GH. Cerebral cortical plasticity: perception and skill acquisition. In: Gazzaniga MS (editor). *The New Cognitive Neurosciences.* Cambridge, Massachusetts: MIT Press, 2nd edition, 2000: 237–247.
11. Karni A, Meyer G, Jezzard P, Adams MM, Turner R, Ungerleider LG. Functional MRI evidence for adult motor cortex plasticity during motor skill learning. *Nature* 1995; 377: 155–158.
12. Deepak KK. Neurophysiological mechanisms of induction of meditation: a hypothetico-deductive approach. *Indian J Physiol Pharmacol* 2002; 46 (2): 136–158.
13. Johnson MH. Cortical plasticity in normal and abnormal cognitive development: evidence and working hypotheses. *Development & Psychopathology* 1999; 11: 419–437.
14. Skoyles JR. Evolution's ‘missing link’: a hypothesis upon neural plasticity, prefrontal working memory and the origins of modern cognition. *Medical Hypotheses* 1997; 48: 499–501.
15. Damasio AR. *Descartes' Error: emotion, reason and the human brain.* New York: Avon Books, 1994.
16. Ornish D. *Dr. Dean Ornish's Program for Reversing Heart Disease.* New York: Ivy/ Ballantine, 1996.
17. Cousins N. *Anatomy of an illness an Perceived by the Patient. Reflections on Healing and Regeneration.* New York: WW Norton/Bantam Books, 1979.