Neural plasticity: don’t fall for the hype

Mirko Farina warns us not to get over-excited by claims for brain improvement

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‘Neural plasticity’ is by no means a recent discovery: evidence about it has been accumulating over the last century. So it isn’t surprising that neural plasticity has long been viewed (in both psychology and neuroscience) as an important property of the brain at all levels and across all species.

Neural plasticity (also known as brain plasticity or neuroplasticity) is the capacity of the brain to compensate for injury and adjust its activity in response to new situations or changes in behaviour or environment.[1] This is achieved through the promotion of brain reorganisation. This capacity is not necessarily restricted to infancy, and is typically retained by the individual throughout the lifespan.[2]

The changes occurring in the brain take place mostly at the level of the connections between neurons. New connections can form or old ones can be rewired so that the overall organisation of existing synaptic connections can change. This process typically leads to structural (anatomical/morphological), functional (physiological) and neurochemical changes in our brains, but also – sometimes – to the generation of new neurons. This latter phenomenon is called neurogenesis, and it has been proved to exist across all mammalian species.

Recent neuroscientific research has confirmed the central role of neural plasticity in human cognition, and highlighted how training and intensive practice can cause such changes (structural and functional). This can be illustrated through the following case studies.

Case studies

In a widely discussed study, Eleanor Maguire and colleagues[3] showed that extensive training in spatial navigation can result in increased size of the hippocampus – a seahorse-shaped structure located next to the midbrain which, among other things, is involved in the consolidation of information from short-term to long-term memory, and in the representation of a person’s current location and heading, or spatial cognition. In Maguire’s research the subjects tested were all London taxi drivers, who varied significantly in the number of years of experience. London streets are intricate and highly complex, and cab driving requires a considerable amount of ‘improvisation’: the cab driver has to find short cuts, needs to avoid traffic jams, and must be able to change routes on the fly as a function of the day of the week. Cab driving in complex cities such as London thus necessitates incessant retrieval of appropriate episodic memories and rather complex, strategic driving decisions.

To find out whether or not extensive cab driving could cause structural changes in the brain, Maguire *et al.* performed magnetic resonance on the brains of London cab drivers and then analysed the volume of their hippocampi. Researchers found out that relative to

1. Neural plasticity has been defined as ‘the changes in neural organization which may account for various forms of behavioural modifiability, either short-lasting or enduring, including maturation, adaptation to a mutable environment, specific and unspecific kinds of learning, and compensatory adjustments in response to functional losses from aging or brain damage’. G. Berlucchi and H. Buchtel, ‘Neuronal plasticity: historical roots and evolution of meaning’, *Experimental Brain Research*, 192 (2009), 307–319.

2. See for example M. Farina, ‘Three approaches to human cognitive development: Neo-nativism, neuroconstructivism, and dynamic enskillment’, *British Journal for the Philosophy of Science*, 67:2 (2016), 617–641.

3. E.A. Maguire, D.G. Gadian, I.S. Johnsrude, C.D. Good, J. Ashburner, R.S. Frackowiak and C.D. Frith, ‘Navigation-related structural change in the hippocampi of taxi drivers’, *Proceedings of the National Academy of Sciences*, 97 (2000), 4398–4403. E.A. Maguire, K. Woollett and H.J. Spiers, ‘London taxi drivers and bus drivers: a structural MRI and neuropsychological analysis’, *Hippocampus*, 16 (2006), 1091–1101.

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the hippocampi of matched control subjects (including bus drivers who drive the same number of hours but on rigid routes), the posterior portion of hippocampi of the cab drivers showed a substantial enlargement. This structural difference was likely related to cab driving because it was proportional with the number of years of experience as a taxi driver. This study is interesting because it shows how the overlap of and integration between long-term memory and spatial cognition, in response to environmental demands, can lead to local plastic changes in the structure of an adult human brain.

Several other studies also report evidence of functional cortical changes following perceptual deficits and/or training. One striking example in this context is the case of sensory substitution.[4] The term sensory substitution refers to the use of a sensory modality to supply environmental information normally gathered by another sense. Sensory substitution devices thus provide through an unusual sensory modality (the substituting modality) access to items of the world that are generally experienced through another sensory channel (the substituted modality). The principles of sensory substitution have been aptly formulated by Bach-y-Rita, who – among the first neurologists to recognise the enormous potential for recovery that brain plasticity offered to patients suffering from losses caused by brain damage – conducted experiments with the potential of the skin as a medium for transmitting pictorial material. Bach-y-Rita's seminal endeavours have led to the production of two categories of systems. Visual-to-tactile substitution devices that convert images into tactile stimuli, and visual-to-auditory substitution systems that transform images into sounds. Recent research on sensory substitution suggested that these systems work by exploiting the cross-modal plasticity of the sensory cortex; the ability of the sensory cortex to pick up some types of information about the external environment irrespective of the nature of the sensory inputs it is processing. Specifically, these studies have shown that blind people, after consistent training, can substantially rewire their occipital lobe, normally recruited for vision, to perceive objects via other sensory modalities (touch or hearing).

Analogously, it has been shown that stroke victims can occasionally regain mobility in their paralysed limbs through intensive physiotherapy that compels them to train the paralysed arm by constraining the mobile one.

The hype

All these case studies – examples of serious and grounded scientific practice – demonstrate that neural plasticity is central to contemporary neuroscientific research. They also show the importance of neural plasticity for the development of some of our unique cognitive functions.

However, the study of neural plasticity has also inspired a plethora of popular science books[5] that have transformed the notion of neural plasticity into a panacea to solve all sort of difficulties and problems that humans can encounter throughout their lives. These

4. See M. Farina, 'Neither touch nor vision: sensory substitution as artificial synaesthesia?', *Biology & Philosophy*, 28 (2013), 639–655. M. Auvray and M. Farina, 'Patrolling the boundaries of synaesthesia: a critical appraisal of transient and artificially-acquired forms of synaesthetic experiences', in *Synasthesia: Philosophical and psychological perspectives*, edited by O. Deroy (Oxford: Oxford University Press, in press). J. Kiverstein and M. Farina, 'Do sensory substitution extend the conscious mind?', in *Consciousness in Interaction: The role of the natural and social context in shaping consciousness*, edited by F. Paglieri (Amsterdam: John Benjamins, 2012), pp. 19–40. J. Kiverstein, M. Farina and A. Clark, 'Substituting the Senses', in *The Oxford Handbook of Philosophy of Perception*, edited by M. Matthen (Oxford: Oxford University Press, 2015), pp. 659–78.

5. For example, S. Helmstetter, *The Power of Neuroplasticity* (2014); R. Hanson, *Hardwiring Happiness: The practical science of reshaping your brain – and your life* (2013).

books hype plasticity, and claim to teach their readers methods to rewire the brain to change attitudes, improve health and fitness, reach personal goals, overcome negativity, increase mental sharpness and clarity, and have even promised to super-charge thinking through a set of strategies that help harness mental powers.[6]

Even acclaimed researchers have sometimes indulged in the hype. For instance, in his most recent book, Michael Merzenich pitched a particular subscription-based brain training programme which he argues can teach a number of 'scientific methods' to rejuvenate, remodel, and reshape the brain at any age.[7]

Studies of this type have led to the development of a fast-growing brain training industry, which basically aims to make profits out people's fears and hopes. Particularly popular in past years was the *Mozart effect* – presented in a set of studies and books[8] that led parents to play musical pieces to their infants in the hope that this would induce improvements on their mental development and spatio-temporal reasoning. Other examples of popular 'brain training' apps include *Luminosity*, *Peak*, *Elevate*, *Fit Brains Training*, and *Cognito*, which all claim to improve cognitive and perceptual skills through reiterated training, thereby allowing their users to perform better – for example, at school or at work.

How to avoid the hype

At this point a number of questions naturally arise. When studying neural plasticity, how can we avoid the rampant 'neuroessentialism' – the invoking of evidence from neuroscience to justify claims at the psychological level[9] – that has become so dominant in contemporary popular science? And what sort of evidence is required to make scientifically valid claims about our brains and their plastic nature? These are difficult methodological and conceptual issues in both neuroscience and philosophy of science. I certainly don't have all the answers to these questions, but can put forward a few basic suggestions that might be helpful for any plasticity enthusiast willing to explore these issues further.

We certainly require serious scientific studies (like Maguire's), which make modest, testable, precise and accurate claims about the nature and scope of neural plasticity. When studying neural plasticity, and when relevant, we also need clearly to highlight the mechanisms through which it happens – e.g., homosynaptic mechanisms, which involve changes in the strength of a synapse that are brought about by its own activity; heterosynaptic mechanisms, which involve changes in the strength of a synapse brought about by activity in another pathway; biochemical (molecular) mechanisms underlying protein synthesis – as well as the level to which it applies (individual, species).

When talking about the power of neural plasticity, we also require more systematic and careful analysis of the different kinds of neural plasticity which are normally invoked to account for such diverse phenomena as neuronal changes, the growth of new neurons, or improvements in specific cognitive abilities after rehabilitation or training. Most importantly, we must be extremely careful in avoiding the empty usage of scientific terms from neuroscience to justify claims at the psychological level. So we must avoid referring to the general notion of neural plasticity to explain all sort of changes (neural, cognitive, psychological, etc.) that take place in our brains.

But even if we do all this, and manage to avoid the hype, the study of neural plasticity on its own is unlikely to bring any revolutionary insights into the study of human cognitive development or evolution. This is because these phenomena are too complex to be understood by studying just neural plasticity. Thus, an important way of improving and enriching our explanations of complex phenomena in which neural plasticity may be directly involved is to identify the many different forms of plasticity (besides neural plasticity) that may actively contribute (jointly or independently of it) to such phenomena. So, when studying neural plasticity it is crucial to emphasise that this is only one of the many varieties of plasticity observed in humans (along with, for instance, morphological, physiological, or behavioural plasticity), and that the study of neural plasticity can benefit from being placed in context.

The fact that the adult brain is much more malleable or flexible than previously thought is certainly an important take-home message and perhaps even a liberating one. A richer, deeper, and more encompassing understanding of neural plasticity surely promises the possibility of a better world where people can recover from physical and emotional damage to their brains, and maybe even augment their capacities so as to allow for greater productivity, intelligence, or socialisation. But it is paramount, when looking at this phenomenon, to pay attention to the actual details of the research and not just extrapolate vaguely about 'rewiring' and its potential amazing applications. It is also important to learn the specific conditions that bolster neuroplastic changes in our brains, and so it is crucial not to inflate its potential significance into excessive realms of nonsense. Neural plasticity is certainly a ubiquitous phenomenon but is no panacea to all our problems. Don't fall for the neural plasticity hype!

6. M. Feldenkrais and M. Kimmey, *The Potent Self: A study of spontaneity and compulsion* (1992).
7. M.M. Merzenich, *Soft-wired: How the new science of brain plasticity can change your life* (2013). The programme is Brain IQ (www.brainhq.com).
8. For example, D. Campbell, *The Mozart Effect: Tapping the power of music to heal the body, strengthen the mind, and unlock the creative spirit* (1997).
9. https://mindhacks.com/2010/06/07/neuroplasticity-is-a-dirty-word/