The Brain as a Cultural Artefact

Steven Mithen & Lawrence Parsons

Where does biology end and culture begin? While the human body is now widely accepted as being both biological and cultural, the brain is still considered by archaeologists as being a biological entity that provides the capacity for culture and is subject to no further change after the evolution of Homo sapiens. *This article reviews recent research that suggests that the brain has continued to evolve at an increasing rate in recent times under the influence of culturally created environments and that both the anatomy and function of individual brains can be manipulated by cultural behaviour. It describes an experiment in which one of us successfully changed his own brain in response to his cultural activity.*

The body, whether living or dead, is as much a cultural artefact as a biological entity. Just as ceramic vessels can be moulded into specific shapes and decorated, so too can human bodies. Scarification, tattooing, piercing, head binding, neck stretching and what we now politely refer to as 'cosmetic surgery' are just a few of the ways in which bodies are manipulated as cultural artefacts; so too are both exercising to build muscle and eating or not eating to either increase or reduce weight. There are, of course, limits as to how far a human body can be culturally manipulated arising from the need to maintain it as a functioning entity and the inherent nature of the material — the flesh, blood and bone — one is working with. But there are also functional constraints on ceramic drinking vessels or flint knives; the forms that these can take are also conditioned by the raw materials one has to work with, clay and stone. In general, human bodies need to be considered as items of material culture (Sofaer 2006).

Once human bodies are no longer living, their potential as cultural artefacts becomes even greater. Archaeologists are constantly reminded of this by the contexts in which human bones are found and by learning how they had once been used for social interaction and been imbued with symbolic meaning. A recent and startling example is Gunther van Hagen's recent 'Body Worlds' exhibition in which the soft tissues of recently deceased bodies, preserved by 'plastination', are displayed within a gallery.

Dead brains can also become cultural objects. The brains of notable individuals such as Albert Einstein and Paul Broca were preserved after death, while those of anonymous individuals are displayed within science museums. Brains become cultural objects when consumed as food, especially in ceremonial contexts. The Fore people of Papua New Guinea consumed the brains of relatives during funerary contexts, this having been a direct cause for the prevalence of kura disease within their communities (Rhodes 1997).

What about living brains? Should these also be considered as cultural artefacts? We normally think of brains as providing us with the biological basis of culture in terms of the capacity for making and manipulating artefacts, language, music, dance, and complex social interaction (e.g. Mithen 1996; Brown & Parsons 2008). So while Palaeolithic archaeologists are concerned with the human brain up until the appearance of *Homo sapiens* and/or modern behaviour, between 200,000 and 70,000 years ago, the brain is normally taken as a biological constant for archaeologists concerned with later periods. Recent research in cognitive neuroscience, and indeed a long held understanding about the brain, requires archaeologists to revise this view. Although hidden from view within the cranium, the living brain is both an artefact of culture and a cultural artefact.

The brain as an artefact of culture

By describing the brain as an artefact of culture we mean that both its anatomy and function have been unintentionally influenced by the cultural contexts

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in which it has evolved and in which it develops within each individual. A common assumption is that the brain has effectively stopped evolving with the emergence of *Homo sapiens*: hence all members of our species, past and present, share the same biologically based capacities for culture. This has now been challenged on the basis of both human genetics and of cranial morphology showing how the relative proportion of different brain areas has undergone relatively recent and increasingly rapid evolution.

The cerebellum is the part of the brain that occupies the posterior cranial fossa, the volume of which can be accurately estimated from skeletal remains. As such it can be compared with cranial volume as a whole so that the relative contribution of the cerebellum and cerebral hemispheres to the brain can be estimated. Weaver (2005) has shown that during the Holocene the cerebellum became relatively larger and the cerebral hemisphere relatively smaller than in Middle Pleistocene and Late Pleistocene humans. This reversed the previous trend of relative increase in the cerebral hemispheres over the cerebellum that had occurred in human evolution during the Early and Middle Pleistocene. In interpreting these data, Weaver cites evidence that the primary role of the cerebellum may be to enhance and sharpen the precise timing of neural events and to promote the smooth control of rapid stereotyped responses, regardless of whether it is processing sensory, motor or cognitive signals (Bower & Parsons 2003). Hence, she argues, its relative increase during the Holocene has permitted increased cognitive efficiency without an overall increase in overall brain volume. The significant issue for this article is that this evolutionary change has occurred in the context of complex cultural behaviour: it was the world of artefacts, social institutions and so forth that created the selective pressures for this aspect of brain evolution. The brain has become an artefact of culture.

Evans *et al.* (2005) and Mekel-Bobrov *et al.* (2005) argued that two genes which are likely to have consequences for brain function have continued to evolve in the relatively recent past. These are microcephalin and ASPM, both of which play a role in causing microcephaly, a severe reduction in brain volume while retaining normal brain structure. Both genes are known to have come under strong natural selection since the time of the common ancestor with the chimpanzee 5–7 million years ago, implicating both in the dramatic brain expansion prior to the origin of *Homo sapiens* at 200,000 years ago.

The new research indicates that these genes have also undergone more recent natural selection. Evans *et al.* (2005) determined that a favoured microcephalin allele arose at 37,000 years ago (with a 95 per cent confidence interval between 14,000–60,000 years ago) and suggests an association with the dispersal of modern humans into Europe and the cultural elaborations of the Upper Palaeolithic. Mekel-Bobrov *et al.* (2005) found that a favoured allele of ASPM arose at 5800 years ago (with a 95 per cent confidence interval between 500–14,000 years ago) and suggests an association with the emergence of sedentism, farming and cities. Strikingly, the rate of positive selection for many human alleles has apparently accelerated greatly over the last 40,000 years. This is the conclusion of two recent studies, using refined linkage disequilibrium methods to study several thousand alleles in the 3.9 million HapMap SNP data set (The International HapMap Consortium 2005; Hawks *et al.* 2007).

Several issues remain unresolved with these studies. The genes under study may be expressed in body tissues as well as the brain and hence the new variants may not have been selected with regard to brain function. If their most recent alleles are expressed within the brain, then there are numerous possibilities for their effect including brain size, cognition, personality, motor-sensory processing and susceptibility to neurological and psychological disorders. It remains a strong possibility, however, that the recent alleles of these genes indicate that the human brain has continued to evolve long after the emergence of *Homo sapiens*, and at a rapidly increased rate, likely under the strong influence of the cultural environment that humans themselves created within the late Pleistocene and early Holocene.

These studies suggest that the cultural environment has had a relatively recent impact on the evolution of the brain. The cultural environment also impacts the development of the brain within each individual. Epidemiological studies indicate that if a pregnant woman consumes substances such as alcohol and nicotine to excess, which may be a minimal quantity, it can have a deleterious impact on the developing of brain of her foetus. The consumption of these substances, as with any food, is conditioned by her cultural context which is, therefore, having a significant impact on her infant's brain.

Postnatal brain development is primarily constituted by two processes (Changeux 1985). One is the multiplication of glial cells, the key function of which is to insulate nerve cells with myelin which then proportionately increases the speed at which nerve impulses travel along axons. The other is the growth of dendrites, axons and in the number of synapses — the connections between neurons that form the circuitry

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of the brain and of which there are around 100 trillion in the adult brain. In these latter micro-structures lie the core processing capacities of human cognition, perception, action, etc.

At birth, a human neuron has on average approximately 2500 synapses (or connections with other neurons). By three years of age, each neuron has on average approximately 15,000 synapses. This peak at 3 years may be related to the fact that compared to other mammals, humans are born more than a year early in gestation. This early birth allows the newborn's skull to emerge from the mother's birth canal. This neural connectivity decreases from age three onward, so that by adulthood each neuron has on average 7000 synapses. Thus, brain maturation involves pruning of neural connections, with the early overgrowth reduced to the more efficient and active synapses and circuits. This is a process that has been described as neural Darwinism (Edelman 1987). In addition to such neural selectionism, connections also appear to be made progressively with neural activity directing the growth of new dendrites, axons and the formation of new synapses (Quartz & Sejnowski 1997).

Different regions of the brain mature at different rates (Gogtay *et al.* 2004). Measured by the ratio of grey matter (glia, vasculature, neurons) to white matter (axons), the frontal lobe matures in a back to front progression (moving from motor cortex forward to premotor and higher cognitive abilities), with the frontal pole maturing at the same time as the motor cortex. In the back of the brain, maturation begins in the primary sensory areas and spreads back through the parietal lobe, with the occipital lobe maturing at the same time as the sensory areas. The lateral temporal lobes mature last. This pattern of brain maturation appears consistent with developmental progression of cognitive, sensory and motor processes. Various sensory and motor abilities emerge early, followed by spatial orientation, speech, language and basic attention skills. Arriving relatively late are skills for executive function, higher attention and motor coordination. Furthermore, children with average intelligence show a thickening and then thinning of cortical thickness (from pruning) at approximately 7–8 years, while those of high intelligence show peak cortical thickness at 13 years, followed by a prolonged period of additional dynamic pruning (Shaw *et al.* 2006). This suggests that slower, delayed pruning of neural connections during a period of intense novel cultural activity is associated with neural structures of greater efficiency. The relative importance of this neural selectionism, and of constructivism (Quartz & Sejnowski 1997), remains unclear, but both processes are evidently influenced by the cultural context of the individual within whom the developing brain resides.

Evolutionary psychologists (e.g. Pinker 1997) argue that the significance of the cultural context is relatively slight, simply acting to fine-tune the brain. For instance, they will argue that all 'normal' brains will develop the circuitry of language, with the cultural context simply influencing the particular language that is acquired during a particular critical period of development. Similarly, they will stress other universally shared features of human cognition that will develop within the brain, provided the appropriate triggering stimuli are present. Other psychologists — cognitive constructivists (e.g. Karmiloff-Smith 1992) — will argue that the cultural context plays a much greater role in the ultimate neural circuitry and cognitive functioning of the brain.

While the overall stress on inheritance and environment may differ, all psychologists will agree that the cultural context plays a significant role in the development of the brain. By changing the cultural environment, each generation changes the brains of the next (Wexler 2006). Much of this occurs unintentionally, hence our description of the brain as an artefact of culture. However, when we deliberately seek to influence that developmental trajectory, such as by the provision of particular educational environments or dietary supplements, we are in effect turning the brain into a cultural artefact.

The brain as a cultural artefact

Our concern in this section is primarily with the extent to which the anatomy and function of the brain can be deliberately manipulated in much the same manner that one can mould a piece of clay or shape a nodule of stone. We have already indicated that this is the case with the brain of a developing infant; our interest is now primarily with the adult brain.

Several studies have found correlations between structural features of the brain and cultural activity, especially with regard to music. Schlaug *et al.* (1995) found that the size of the corpus callosum — the main band of interhemispheric axonal fibres that transfer and integrate information between the two hemispheres — is larger in musicians than non-musicians. This was later shown to be gender specific, applying to males but not females (Lee *et al.* 2003). Similarly, Hutchinson *et al.* (2003) found that male musicians have both absolutely and relatively larger cerebellums than non-musicians. In both of these studies there was a correlation between the volume of the brain structure

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and the intensity of musical training. Studying expert musicians, amateurs and non-musicians, other studies have reported brain areas of greater size or grey matter density in the medial portion of primary auditory cortex (Heschl's gyrus), inferior frontal gyrus and superior parietal cortex (Schneider *et al.* 2002; Amunts *et al.* 1997; Gaser & Schlaug 2003). Moreover, there is evidence for increases in white matter myelination in the corpus callosum, internal capsule, and arcuate fasiculus associated with duration of musical training in childhood and adolescence (Bengtsson *et al.* 2005).

This suggests that increases in structural volume, grey and white matter were direct consequences of the training itself — the anatomy of the brain being moulded by cultural activity: specifically, the somatosensory-motor, attentional and cognitive skills developed by training in music performance. It is possible, however, that those individuals who for entirely innate reasons had developed relatively larger versions of these brain structures were preferentially drawn to musical activity and were then able to achieve high levels of performance.

The best form of study to investigate these two interpretations is to randomly assign cognitive and genetically similar individuals (e.g. young identical twins) to different training and control conditions, and then to measure associated functional and structural brain and behaviour changes over time. This kind of study has not yet been conducted. However, researchers have begun to perform longitudinal studies of randomly selected adults learning new cultural skills. One such study has been undertaken in relation to juggling. Draganski *et al.* (2004) describe how a sample of adults learned to juggle over a three month period. Their brains were compared before and after, and with a group matched for age and sex and who did not learn juggling. The jugglers were found to have had a significant expansion in the quantity of grey matter in the bilateral mid-temporal area and in the left posterior intraparietal sulcus — areas of the brain used for the retention of visual-motion information. There was a close relationship between the extent of the grey matter expansion and the juggling performance. After a further three months during which the jugglers no longer juggled, the expanded grey matter was found to have decreased. This study demonstrated that, contrary to a long-held view, the anatomical structure of the adult human brain can be altered by environmentally induced demands, in this case from the cultural activity of juggling.

A similar conclusion arises from a study of the hippocampi of London taxi drivers (Maguire *et al.* 2000). The hippocampus is known to facilitate spatial memory in the form of navigation. Taxi drivers in London have to acquire and memorize a vast amount of spatial information to pass their licensing examinations — known as acquiring 'the knowledge'. Using magnetic resonance imaging (MRI) measures, Maguire *et al.* (2000) found that the posterior hippocampi of taxi drivers are larger than those of non-taxi drivers, and that there is a positive correlation with the amount of time spent as a taxi driver. While this could feasibly be explained by arguing that those individuals with an innately endowed large posterior hippocampus are preferentially drawn to activities such as taxi driving, a more likely explanation is that learning and deploying 'the knowledge' results in a structural change to the human brain.

The juggling and taxi-driving examples suggest that the differences amongst the brains of musicians, amateurs and non-musicians are more likely the consequence of musical practice than innate endowment. Such studies show how the anatomical structure of the adult brain can be changed by cultural activity in a manner that is directly comparable to how exercising in the gym can build muscle and turn the body into a cultural artefact.

A further example, which is particularly pertinent to archaeology but which only records changes in brain function rather than anatomy, is Stout & Chaminade's (2007) study of stone tool manufacture. They used positron emission tomography to collect functional brain imagery from six previously inexperienced subjects making Oldowan tools both before and after completing four weekly, one hour practice sessions. The initial brain scans indicated activity in the ventral premotor cortices and the rostral part of the intraparietal sulcus, areas homologous to those which support prehension and simple tool use in monkeys and humans. Following training, additional activity was evident in the ventral, lateral and dorsal higher-order visual areas within Brodmann Area (BA) 19 — a change in brain function arising from cultural activity. Both before and after training, there was no activation in the prefrontal cortices which are associated with executive function. This suggests that abstract conceptualization and planning were not required for such tool manufacture by Oldowan hominins.

Changing one's own brain

To explore these ideas further we undertook an exploratory study on one of our brains: we asked how the brain of an adult would change by participating in a form of unfamiliar cultural activity. For this we chose singing, because of our interests in musical

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Figure 1. *fMRI brain scan, Sheffield 14 June 2006. Mithen is positioned on the scanner below a mirror so that he can read the projected musical score during scanning.*

activity (Mithen 2005; Brown *et al.* 2004; 2006) and because the neuroscience of music has recently emerged as a surprisingly rich and impactful line of research. Our experiment was comparable to other experiments which we have undertaken with regard to archaeological research, whether the use of stone tools (Machin *et al.* 2007), roasting hazelnuts (Score & Mithen 2000) or growing of crops (Mithen *et al.* in press). All of those experiments were partly undertaken to gain further insights into the relevant issues by personal experience: what is it like to butcher an animal with a handaxe or to harvest wheat with a flint sickle? Such archaeological experiments have enabled us to develop a more informed and critical reading of relevant literature. In a similar manner, our study developed understanding of the brain as a cultural artefact and fostered an exchange of related archaeological and neuroscience views.

Our singing experiment was undertaken in collaboration with Pam Chilvers, a singing teacher (Mithen & Parsons 2008). We designed it as follows. A functional MRI brain scan (fMRI) would be undertaken during which Mithen would perform ten technical singing exercises designed to test component abilities of singing in pitch and rhythm, and would sing two passages from a selected song (John Rutter's *A Gaelic Blessing*). All of these were to be undertaken



Figure 2. *Singing lessons with Pam Chilvers, October 2006.*

by reading from musical scores. Mithen would then undertake singing lessons for one year, and have a second fMRI session identical to that of the first. Across the two sessions, we would compare the recorded singing performance and the fMRI measures of neural activity to identify changes in singing ability and their brain correlates. This analysis isolates neural changes with learning; the primary circuitry for singing cancels out when the common activity for the first and for second sessions are contrasted.

The fMRI scanning was conducted at the University of Sheffield, Department of Radiology, on a 3 Tesla Phillips Achieva scanner. The first scan occurred on the 14 June 2006 with each singing task being performed three times for thirty seconds while in the scanner, in alternation with rest periods (a baseline) (Fig. 1). Prior to this, Mithen had three singing lessons, the first singing undertaken since being at school more than 35 years ago. Those lessons had been to gain a sufficient ability at reading music to undertake the singing tasks and to make an initial evaluation of his singing ability. Mithen's singing was very poor, with difficulty in finding the correct pitch, inability to follow a rhythm, a pitch range less than an octave, and limited voice projection (Chilvers pers. comm.). Following the scan, Mithen had thirty more singing lessons evenly spaced throughout a year combined with regular practice (Fig. 2). These were designed to enhance his overall singing ability; in addition to *The Gaelic Blessing*, he learned *Lascia Ch'io Pianga*, an aria by Handel. These resulted in some improvements to singing performance during the year, such as in Mithen's ability to sustain and control pitch, convey a musical phrase, read musical scores, and project vol-

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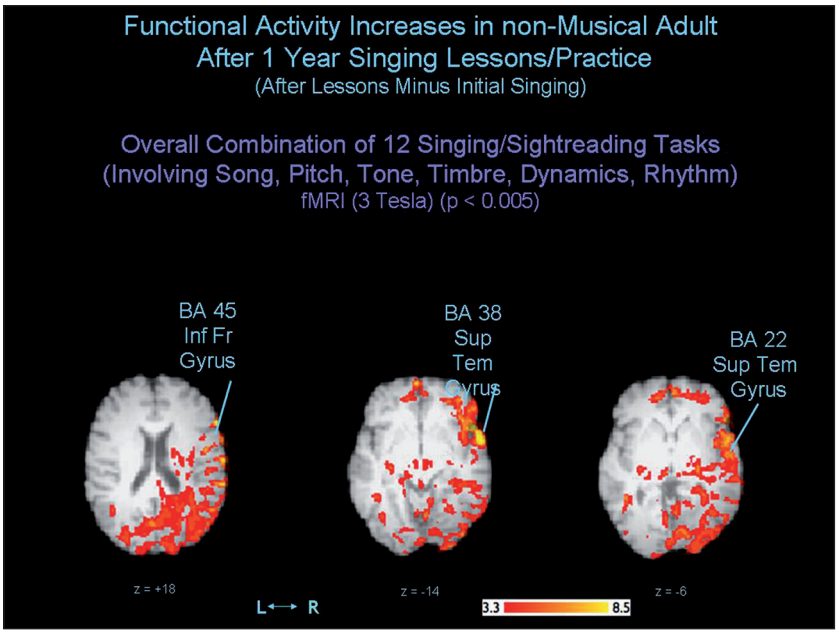


Figure 3. *Functional activity increases in Mithen's brain after one year of singing lessons and practice* (p < *0.005, corrected for multiple comparison).*

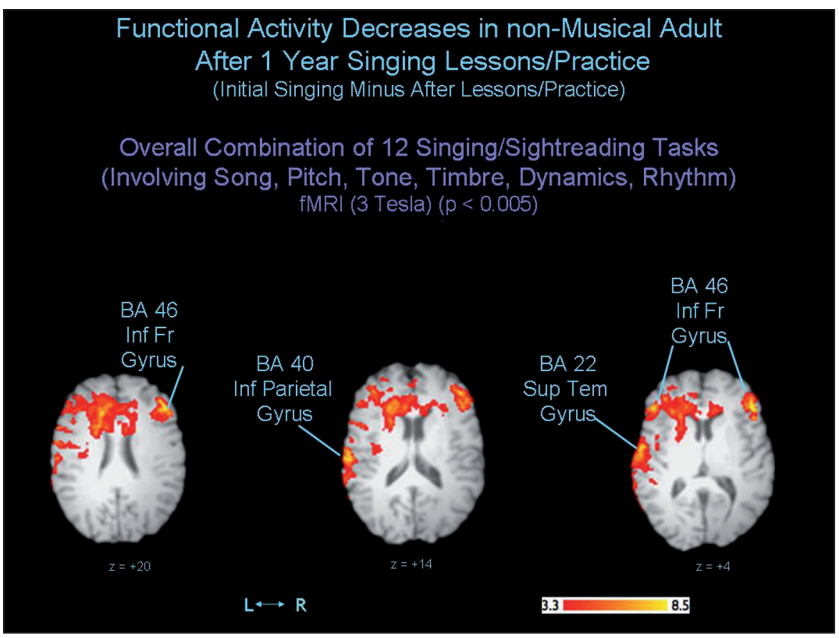


Figure 4. *Functional activity decreases in Mithen's brain after one year of singing lessons and practice* (p < *0.005, corrected for multiple comparison).*

ume. These improvements were evident in the second fMRI session which took place on 18 July 2007.

The first and second fMRI data (blood oxygenation level dependent measures) were compared by first averaging, for each session, the functional brain activity during all singing tasks (contrasted with rest baseline). The functional activity was superimposed onto the anatomical structural MRI image of Mithen's brain. Then we directly contrasted the two sessions to isolate increases and decreases in specific brain areas. The analysis methods were performed using FSL (FMRIB Software Library, Oxford University). As we were studying only a single individual who showed modest improvements in singing from a year's training, we knew we might not observe any significant change.

Figure 3 shows that significant increases of brain activity had occurred in the right inferior frontal gyrus (approximately BA 45), in the right pole of the temporal cortex (the planum polare, BA 38) and the right superior temporal gyrus (BA 22). These fit well with existing understanding about which parts of the brain are important for singing and for music in general. Our earlier studies have identified these areas with component processes of musical performance. These areas were active in prior studies of musicians singing (and playing piano) (Brown *et al.* 2004; 2006; Parsons *et al.* 2005). For example, the planum polare (BA 38), on the left and right side, has been implicated in the representation of tonality, melody and harmonic relations. Activity in the left or right inferior frontal cortex (BA 45, 44) has been associated with musical tasks such as generating melody and harmonization, as well as with sequencing gestures to metric beats or music (singing, finger tapping, dancing), and with perceiving musical coherence in instrumental passages. That these increases occur primarily in the right hemisphere of an adult non-musician is consistent with the hypothesis that changes in processing music and singing occur in the right hemisphere early in the development of skills, with higher levels of skill development associated with bilateral brain mechanisms.

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Figure 4 shows where significant decreases in brain activity had occurred. These are in areas associated with the auditory working memory (in the inferior prefrontal cortex, BA46), visual-spatial processing (in left parietal cortex, BA40) and the representation of verbal information (in left superior temporal cortex, BA22). These decreases may be a consequence of a reduced reliance on effortful, conscious verbal and spatial-temporal attentional strategies (i.e. the latter for learning to sight sing notes on the score).

The results from this study relate only to changes in brain function: i.e. how the activity in neural circuitry has been modified in conjunction with acquired cultural skill. We did not examine whether there were any observable structural changes in brain anatomy (such as density of dendritic fields, increases in white matter connectivity, etc.) It is also unclear whether they have been sustained or are temporary — as the extent of Mithen's singing has reduced since the second brain scan. This was an exploratory study and simply indicates that significant changes in neural activity can occur in the early stages of learning of singing in an adult. In relation to our current argument, this experiment provides further evidence that the brain can be considered as a cultural artefact.

Conclusion

Archaeologists of all periods need to acquaint themselves with the brain and its dialectical relationship with culture. We have argued this from the basis of evolutionary and developmental changes in brain anatomy and function that are a consequence of cultural activity. A comparable argument has been made by Daniel Lord Smail (2007) in his book entitled *On Deep History and the Brain*. His emphasis was on how cultural activity changes the chemistry of the brain, more specifically how it impacts on the flow of neurotransmitters such as dopamine, serotonin and oxytocin. Such changes can either be self directed, not only by extreme behaviours such as using pornography but simply by drinking tea or reading novels, or created by those in power, such as by creating environments of fear or by organizing theatrical and sporting spectacles. Without understanding the impact of such cultural behaviour on the brain, Smail argues, we will fail to gain an understanding of the past: historians need to become more scientifically literate, while biologists and physiologists have to become more historically minded and appreciate just how much our brains are products of society and culture.

The arguments that Smail has put forward, and those in the present article, challenge our notions of where the boundaries between biology and culture can be placed. The notion that the brain simply provides us with the capacity for culture and that its evolution and development are of interest only to those who study the Palaeolithic is no longer tenable. Archaeologists working in all periods have to come to terms with the brain as a cultural artefact.

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References

Amunts, K., G. Schlaug, L. Jancke, *et al.*, 1997. Motor cortex and hand motor skills: structural compliance in the human brain. *Human Brain Mapping* 5, 206–15.

Bengtsson, S.L., Z. Nagy, S. Skare, L. Forsman, H. Forssberg & F. Ullen, 2005. Extensive practicing has regionally specific effects on white matter development. *Nature Neuroscience* 8, 1148–50.

Bower, J.M. & L.M. Parsons, 2003. Rethinking the lesser brain. *Scientific American* 289, 50–57.

Brown, S. & L.M. Parsons, 2008. The neuroscience of dance. *Scientific American* 299, 78–83.

Brown, S., M.J. Martinez, D. Hodges, P.T. Fox & L.M. Parsons, 2004. The song system of the human brain. *Cognitive Brain Research* 20, 363–75.

Brown, S., M.J. Martinez & L.M. Parsons, 2006. Music and language side by side in the human brain: a PET study of generating melodic and sentences. *European Journal of Neuroscience* 23, 2791–803.

Changeux, J.-P., 1985. *Neuronal Man: the Biology of Mind.* Princeton (NJ): Princeton University Press.

Draganski, B., C. Gaser, V. Busch, G. Schuierer, U. Bogdahn

https://doi.org/10.1017/S0959774308000450 Published online by Cambridge University Press

& A. May, 2004. Changes in grey matter induced by training. *Nature* 427, 311–12.
Edelman, G., 1987. *Neural Darwinism: the Theory of Neuronal Group Selection.* New York (NY): Basic Books.
Evans, P.D., S.L. Gilbert, N. Mekel-Bobrov, *et al.*, 2005. Microephalin, a gene regulating brain size, continues to evolve adaptively in humans. *Science* 309, 1717–20.
Gaser, C. & G. Schlaug, 2003. Brain structures differ between musicians and non-musicians. *Journal of Neuroscience* 23, 9240–45.
Gogtay, N., J.N. Giedd, L. Lusk, *et al.*, 2004. Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences of the USA* 101, 8174–9.
Hawks, J., E.T. Wang, G.M. Cochran, H.C. Harpending & R.K. Moyzis, 2007. Recent acceleration of human adaptive evolution. *Proceedings of the National Academy of Sciences of the USA* 104, 20,753–8.
Hutchinson, S., L.H. Lee, N. Gaab & G. Schlaug, 2003. Cerebellar volume: gender and musicianship effects. *Cerebral Cortex* 13, 943–9.
The International HapMap Consortium, 2005. A haplotype map of the human genome. *Nature* 437, 1299–320.
Karmiloff-Smith, A., 1992. *Beyond Modularity: a Developmental Perspective on Cognitive Science.* Cambridge (MA): MIT Press.
Lee, D.J., Y. Chen & G. Schlaug, 2003. Corpus callosum: musician and gender effects. *Neuroreport* 14, 205–9.
Machin, A.J., R.T. Hosfield & S.J. Mithen, 2007. Why are some handaxes symmetrical? Testing the influence of handaxe morphology on butchery effectiveness. *Journal of Archaeological Science* 34, 883–93.
Maguire, E.A., D.G. Gadian, I.S. Johnsrude, *et al.*, 2000. Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences of the USA* 97, 4398–403.
Mekel-Bobrov, N., S.L. Gilbert, P.D. Evans, *et al.*, 2005. Ongoing adaptive evolution of ASPM, a brain size determinant in *Homo sapiens*. *Science* 309, 1720–22.
Mithen, S., 1996. *The Prehistory of the Mind*. London: Thames & Hudson.
Mithen, S., 2005. *The Singing Neanderthals.* London: Orion.
Mithen, S.J. & L.M. Parsons, 2008. The diva within. *New Scientist* 197, 38–9.
Mithen, S.J., E.L. Jenkins, K. Jamjoum, S. Numiut, S. Nortcliff & B. Finlayson, in press. Experimental crop growing to explore the development of phytoliths under different levels of irrigation. *World Archaeology.*
Parsons, L.M., 2003. Exploring the neuroanatomy of music, performance, perception and comprehension, in *The Cognitive Neuroscience of Music*, eds. R.J. Zatorre & I. Peretz. Oxford: Oxford University Press, 247–68.
Parsons, L.M., J. Sergent, D.A. Hidges & P.T. Fox, 2005. The brain basis of piano performance. *Neuropsychologia* 43, 199–215.
Pinker, S., 1997. *How the Mind Works.* London: Penguin.
Quartz, S. & T. Sejnowski, 1997. The neural basis of cognitive development: a constructivist manifesto. *Behavioral and Brain Sciences* 20, 537–96.
Rhodes, R., 1997. *Deadly Feasts: Tracking the Secrets of a Terrifying New Plague.* New York (NY): Simon & Schuster.
Schlaug, G., I. Jaencke, Y. Huang & H. Teinmetz, 1995. Increased corpus callosum size in musicians. *Neuropsychologia* 33, 1047–55.
Schneider, P., M. Scherg, H.G. Dosch, H.J. Specht, A. Gutschalk & A. Rupp, 2002. Morphology of Heschl's gyrus reflects enhanced activation in the auditory cortex of musicians. *Nature Neuroscience* 5, 688–94.
Score, D. & S.J. Mithen, 2000. The experimental roasting of hazelnuts, in *Hunter-Gatherer Landscape Archaeology: The Southern Hebrides Mesolithic Project 1988–1998,* ed. S. Mithen. (McDonald Institute Monographs.) Cambridge: McDonald Institute for Archaeological Research, 507–12.
Shaw, P., D. Greenstein, J. Lerch, *et al.*, 2006. Intellectual ability and cortical development in children and adolescent. *Nature* 440, 676–9.
Smail, L.M., 2007. *On Deep History and the Brain*. Berkeley (CA): University of California Press.
Sofaer, J., 2006. *The Body as Material Culture*. Cambridge: Cambridge University Press.
Stout, D. & T. Chaminade, 2007. The evolutionary neuroscience of tool making. *Neuropsychologia* 45, 1091–100.
Weaver, A.H., 2005. Reciprocal evolution of the cerebellum and neocortex in fossil humans. *Proceedings of the National Academy of Sciences of the USA* 102, 3576–80.
Wexler, B.E., 2006. *Brain and Culture: Neurobiology, Ideology and Social Change.* Cambridge (MA): MIT Press.

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