

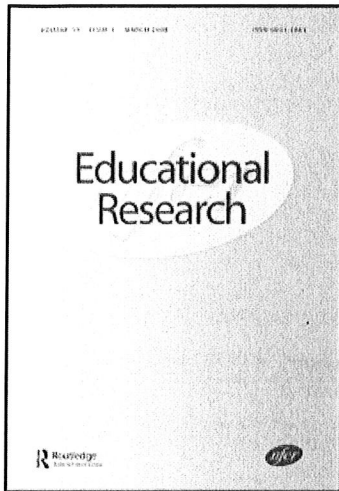
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## Neuromythologies in education

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*Background:* Many popular educational programmes claim to be ‘brain-based’, despite pleas from the neuroscience community that these neuromyths do not have a basis in scientific evidence about the brain.

*Purpose:* The main aim of this paper is to examine several of the most popular neuromyths in the light of the relevant neuroscientific and educational evidence. Examples of neuromyths include: 10% brain usage, left- and right-brained thinking, VAK learning styles and multiple intelligences

*Sources of evidence:* The basis for the argument put forward includes a literature review of relevant cognitive neuroscientific studies, often involving neuroimaging, together with several comprehensive education reviews of the brain-based approaches under scrutiny.

*Main argument:* The main elements of the argument are as follows. We use most of our brains most of the time, not some restricted 10% brain usage. This is because our brains are densely interconnected, and we exploit this interconnectivity to enable our primitively evolved primate brains to live in our complex modern human world. Although brain imaging delineates areas of higher (and lower) activation in response to particular tasks, thinking involves coordinated interconnectivity from both sides of the brain, not separate left- and right-brained thinking. High intelligence requires higher levels of inter-hemispheric and other connected activity. The brain’s interconnectivity includes the senses, especially vision and hearing. We do not learn by one sense alone, hence VAK learning styles do not reflect how our brains actually learn, nor the individual differences we observe in classrooms. Neuroimaging studies do not support multiple intelligences; in fact, the opposite is true. Through the activity of its frontal cortices, among other areas, the human brain seems to operate with general intelligence, applied to multiple areas of endeavour. Studies of educational effectiveness of applying any of these ideas in the classroom have failed to find any educational benefits.

*Conclusions:* The main conclusions arising from the argument are that teachers should seek independent scientific validation before adopting brain-based products in their classrooms. A more sceptical approach to educational panaceas could contribute to an enhanced professionalism of the field.

**Keywords:** neuromyths; brain-based; cognitive neuroscience; education

### Introduction

Neuromythologies are those popular accounts of brain functioning, which often appear within so-called ‘brain-based’ educational applications. They could be categorised into neuromyths where more is better: ‘If we can get more of the brain to “light up”, then learning will improve...’, and neuromyths where specificity is better: ‘If we concentrate

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teaching on the “lit-up” brain areas then learning will improve...’. Prominent examples of neuromythologies of the former include: the 10% myth, that we only use 10% of our brain; multiple intelligences; and Brain Gym. Prominent examples of neuromythologies of the latter include: left- and right-brained thinking; VAK (visual, auditory and kinaesthetic) learning styles; and water as brain food. Characteristically, the evidential basis of these schemes does not lie in cognitive neuroscience, but rather with the various enthusiastic promoters; in fact, sometimes the scientific evidence flatly contradicts the brain-based claims.

The assumption here is that educational practices which claim to be concomitant with the workings of the brain should, in fact, be so, at least to the extent that the scientific jury can ever be conclusive (Blakemore and Frith 2005). A counter-argument might be posed that the ultimate criterion is pragmatic, not evidential, and if it works in the classroom who cares if it seems scientifically untenable. For this author, basing education on scientific evidence is the hallmark of sound professional practice, and should be encouraged within the educational profession wherever possible. The counter-argument only serves to undermine the professionalism of teachers, and so should be resisted.

This is not to say that there is not a glimmer of truth embedded within various neuromyths. Usually their origins do lie in valid scientific research; it is just that the extrapolations go well beyond the data, especially in transfer out of the laboratory and into the classroom (Howard-Jones 2007). For example, there is plenty of evidence that cognitive function benefits from cardiovascular fitness; hence, general exercise is good for the brain in general (Blakemore and Frith 2005). But this does not mean that pressing particular spots on one’s body, as per Brain Gym, will enhance the activation of particular areas in the brain. As another example, there are undoubtedly individual differences in perceptual acuities which are modality based, and include visual, auditory and kinaesthetic sensations (although smell and taste are more notable), but this does not mean that learning is restricted to, or even necessarily associated with, one’s superior sense. All of us have areas of ability in which we perform better than others, especially as we grow older and spend more time on one rather than another. Consequently, a school curriculum which offers multiple opportunities is commendable, but this does not necessarily depend on there being multiple intelligences within each child which fortuitously map on to the various areas of curriculum. General cognitive ability could just as well play an important role in learning outcomes across the board.

The generation of such neuromythologies and possible reasons for their widespread acceptance has become a matter for investigation itself. In particular, the phenomenon of their widespread and largely uncritical acceptance in education raises several questions: why has this happened?; what might this suggest about the capacity for the education profession to engage in professional reflection on complex scientific evidence? And one cannot help but wonder about the extent to which political pressure for endless improvement in standardised test scores, publicised via school league tables, drives teachers to adopt a one-size-fits-all, brain-based life-raft when their daily classroom experience is replete with children’s individual differences.

To gather some data about these issues, Pickering and Howard-Jones (2007) surveyed nearly 200 teachers either attending an education and brain conference in the UK (one brain based, the other academic) or contributing to an OECD website internationally. All respondents were enthusiastic about the prospects of neuroscience informing teaching practice, particularly for pedagogy, but less so for curriculum design. Moreover, despite a prevailing ethos of pragmatism (notably with the brain-based conference attendees), it was generally conceded that the role of neuroscientists was to be professionally informative rather than prescriptive. This, in turn, points to the critical necessity for a mutually

comprehensible language with which neuroscientists and educators can engage in a genuine interdisciplinary dialogue.

The American Nobel Laureate physicist Richard Feynman, in one of his more famous graduation addresses at Caltech, warned his audience of young science graduates about 'cargo cult science' (Feynman 1974). His point was that, while it might accord with 'human nature' to engage in wishful thinking, good scientists have to learn not to fool themselves. Feynman's warning could well be applied to the myriad 'brain-based' strategies that pervade current educational thinking. Whereas it is commonly stated in such schemes that the brain is the most complex object in the universe (although how this could possibly be verified remains unexplained), this assumption is then completely ignored in proposing a pedagogy based on the simplest of analyses – e.g., in the brain there are two hemispheres, left and right, therefore there are two kinds of thinking: of-the-left-brain and of-the-right-brain, and therefore there are only two kinds of teaching necessary: for-the-left-brain and for-the-right-brain. Not a very exciting universe where the most complex object has only two states! And not, fortunately, the universe in which we exist, where the complexity of the human brain has been the focus of intense investigation for over a century, but particularly over the past two decades, thanks to the invention of neuroimaging technologies.

The resulting neuroimages – brains with brightly coloured areas – are disarmingly simple, and seem to fit with a commonsense view of the brain as having localised specialist functions which enable us to do the various things we do. But such apparent simplicity is generated out of considerable complexity. In functional magnetic resonance imaging (fMRI), for example, the images are the end-result of many years' work on understanding the quantum mechanics of nuclear magnetic resonance phenomena, the development of the engineering of superconducting magnets, the application of inverse fast Fourier transforms to large data sets and the refinement of high-speed computing hardware and software to analyse large data sets across multiple parameters. The neuroimaging picture is undoubtedly worth the proverbial thousand words, but the scientist's words can be quite different from those of the layperson.

A crucial point that most of the media overlook, or ignore, is that neuroimaging data are statistical. The coloured blobs on brain maps representing areas of significant activation (so-called 'lighting up') are like the peaks of sub-oceanic mountains which rise above sea level, in neuroimaging, how much or how little activation (sea level) to reveal being determined by the researcher in setting a suitable level of statistical threshold. In fact, the most challenging aspect of most neuroimaging experimental design is to determine suitable control conditions to highlight a particular area of experimental interest and thus avoid showing how most of the brain is involved in most cognitive tasks. So, in a classroom it would be quite silly to think that only a small portion of pupils' brains are involved in a task, just because a small area of brain activity was reported in a neuroimaging study of a similar task (Geake 2006). Neuroscience is a laboratory-based endeavour. Even with the best of intentions, extrapolations from the lab to the classroom need to be made with considerable caution (Howard-Jones 2007). As Nobel Laureate Charles Sherrington (1938, 181) warned in Oxford some 70 years ago: 'To suppose the roof-brain consists of point to point centres identified each with a particular item of intelligent concrete behaviour is a scheme over simplified and to be abandoned.' In other words, we have to be very wary of oversimplifications of the neuro-level of description in seeking applications at the cognitive or behavioural levels.

The central characteristic of brain function which generates its complexity is neural functional interconnectivity. There are common brain functions for all acts of intelligence,

especially those involved in school learning (Geake in press). These interconnected brain functions (and implicated brain areas) include:

- Working memory (lateral frontal cortex);
- Long-term memory (hippocampus and other cortical areas);
- Decision-making (orbitofrontal cortex);
- Emotional mediation (limbic subcortex and associated frontal areas);
- Sequencing of symbolic representation (fusiform gyrus and temporal lobes);
- Conceptual interrelationships (parietal lobe);
- Conceptual and motor rehearsal (cerebellum).

This parallel interconnected functioning is occurring all the time our brains are alive. Importantly, these neural contributions to intelligence are necessary for all school subjects, and all other aspects of cognition. Creative thinking would not be possible without our extensive neural interconnectivity (Geake and Dobson 2005). Moreover, there are no individual modules in the brain which correspond directly to the school curriculum (Geake 2006). Cerebral interconnectivity is necessary for all domain-specific learning, from music to maths to history to French as a second language. Neuromyths typically ignore such interconnectivity in their pursuit of simplicity. Steve Mithen (2005) argues that it was a characteristic of the Neanderthal brain that it was not well interconnected. This could explain the curious stasis of Neanderthal culture over several hundred thousand years, and the even more curious fact that Neanderthal culture was rapidly out-competed by our physically less robust Cro-Magnon forebears, whose brains, Mithen argues, had evolved to become well interconnected.

### Multiple intelligences

Highly evolved cerebral interconnectedness has implications for any brain-based justification of the widely promoted model of multiple intelligences (MI). Gardner (1993) divided human cognitive abilities into seven intelligences: logic-mathematics, verbal, interpersonal, spatial, music, movement and intrapersonal. Some 2500 years earlier, Plato recommended that a balanced curriculum have the following six subjects: logic, rhetoric, arithmetic, geometry-astronomy, music and dance-physical. For philosopher-kings, additionally, *meditation* was recommended. Clearly MI is nothing new: Gardner has just recycled Plato. But although such a curriculum scheme is long-standing, it doesn't mean that our brains think about these areas completely independently from one another. Each MI requires sensory information processing, memory, language, and so on. Rather, this just demonstrates Sherrington's point that the way the brain goes about dividing its labours is quite separate from how we see such divisions on the outside, so to speak. In other words, there are no multiple intelligences, but rather, it is argued, multiple applications of the same multifaceted intelligence.

Whereas undoubtedly there are large individual differences in subject-specific abilities, the evidence which conflicts with a multiple intelligences interpretation of brain function is that these subject-specific abilities are positively correlated, as shown by Carroll (1993) in his large meta-analysis. Such a pervasive correlation between different abilities is conceptualised as general intelligence, *g*. The existence of *g* not only suggests that the same brain modules are likely to be involved in many different abilities, but that their functional connectivity is of paramount importance. In fact, the main thrust of research in cognitive neuroscience in the next decade will be the mapping of functional connectivity,

that is how functional modules transfer information, anatomically, bio-chemically, bio-electrically, rhythmically, synchronistically, and so on. A recent study along these lines sought evidence for neural correlates of general intelligence – i.e., where and how does the brain generate measures of general intelligence? Duncan et al. (2000) found a common brain involvement, in the frontal cortex of adult subjects, on both spatial and verbal IQ tests. A further meta-analysis of 20 neuroimaging studies involving language, logic, mathematics and memory showed that the same frontal cortical areas were involved (Duncan 2001). It seems unlikely that these intelligences are independent if the same part of the brain is common to all. This point is elaborated in a recent critique of MI (Waterhouse 2006, 213).

The human brain is unlikely to function via Gardner's multiple intelligences. Taken together the evidence for the intercorrelations of subskills of IQ measures, the evidence for a shared set of genes associated with mathematics, reading, and *g*, and the evidence for shared and overlapping 'what is it?' and 'where is it?' neural processing pathways, and shared neural pathways for language, music, motor skills, and emotions suggest that it is unlikely that each of Gardner's intelligences could operate 'via a different set of neural mechanisms' [as Gardner claims].

To explain how those same pathways support high-level general intelligence across so many different cognitive areas, Duncan (2001, 824) suggested that: 'neurons in selected frontal regions adapt their properties to code information of relevance to current behaviour, pruning away ... all that is currently task-irrelevant.' So, underlying our specific abilities is adaptive brain functioning. In support of this idea of an adapting brain, Dehaene and his colleagues have proposed a dynamic model of brain functioning in which these frontal adaptive neurons coordinate the myriad inputs from our perceptual modules from all over the brain, and continually assess the relative importance of these inputs such that from time to time, a thought becomes conscious; it literally 'comes to mind' (Dehaene, Kerszberg, and Changeux 1998). It could be predicted, then, that deliberate attempts to restrict intelligence within classrooms according to MI theory would not promote children's learning, and it could be noted in passing that one of the 'independent consultants' who advocates brain-based learning strategies acknowledges teachers' frustration with the lack of long-term impact of applying MI theory (Beere 2006).

### 10% usage

None of the above implies that *g* is all that there is to intelligence – quite the opposite. With its population age-norming, IQ might be a convenient surrogate for intelligence in the laboratory, but not even the most resolute empiricist would claim that IQ captures all of the variance in cognitive abilities. Rather, intelligence in all its manifestations illustrates the underlying dynamic complexity of its generative neural processes, with emphasis on 'dynamic'. There is overwhelming evidence that the brain is perpetually busy, and that even when any of our brain cells are not involved in processing some information, they still fire randomly. As an organ which has evolved not to know what is going to happen next, such constant activity keeps our brain in a state of readiness. Consequently, the neuromyth that 'We only use 10% of our brains' could not be more in error. The absurdity has been pointed out by Beyerstein (2004): evolution does not produce excess, much less 90% excess. In the millions of studies of the brain, no one has ever found an unused portion of the brain!

It is unfortunate that teachers are constantly subjected to such pervasive nonsense about the brain, so it is worth pausing to investigate the various sources of the 10% myth

(Nyhus and Sobel 2003). It seems to have begun with an Italian neuro-surgeon c.1890 who removed scoops of brains of psychiatric patients to see if there were any differences in their reported behaviours. The myth received an unexpected boost c.1920 during a radio interview with Albert Einstein, when the physicist used the 10% figure to implore us to think more. The myth received its widest circulation before the Second World War when some American advertisers of home-help manuals re-invented the 10% figure in order to convince customers that they were not very smart. Odd, then, that it has been so enthusiastically adopted by wishful-thinking educationists at the end of the twentieth century. It would be nice if the brains of our students had all this spare educable capacity. To be sure, the plasticity of young (and even older) brains should never be underestimated. But what plasticity requires is a dynamically engaged brain, with all neurons firing. To put it bluntly, if you are only using 10% of your brain, then you are in a vegetative state so close to death that you should hope (not that you could) that your relatives will pull out the plug of the life support machine!

### **Left- and right-brained thinking**

Another pervasive example of over-simplification has been the misinterpretation of laterality studies to produce so-called 'left- and right-brained thinking'. Historically, the original studies were of split-brain patients: patients who had the major communication tract between the two brain hemispheres, the corpus callosum, surgically severed in an attempt to reduce life-threatening epilepsy. It was found that the separate hemispheres of these patients could separately process different types of information, but only the left hemisphere processing was reported by the patients. Unfortunately, the caveat that the researchers who carried out these studies back in the 1970s did emphasise – i.e., that these patients had abnormal brains – was largely ignored. For normal people, as Singh and O'Boyle (2004, 671) point out:

the brain does not consist of two hemispheres operating in isolation. In fact, the different cognitive specialties of the LH and RH are so well integrated that they seldom cause significant processing conflicts ... hemispheric specialisation ... consists of a dynamic interactive partnership between the two.

Creative thinking, in particular, requires the interaction of both hemispheric specialists, neither one can operate in isolation from the other:

Since the right hemisphere and the left hemisphere are massively interconnected (through the corpus callosum), it is not only possible, but also highly likely, that the creative person can iterate back and forth between these specialized modes to arrive at a practical solution to a real problem. If the right hemisphere were somehow disconnected from the left and confined to its own specialized thinking modes, it might be relegated to only 'soft' fantasy solutions, pipe dreams or weird ideas that would be difficult, if not impossible, to fully implement in the real world. The left brain helps keep the right brain on track. (Herrmann 1998, <http://www.sciam.com>)

This, then, has important implications for the misguided 'right-brain' promotion of creative thinking in the school classroom. Goswami (2004) draws attention to a recent OECD report in which left brain/right brain learning is the most troubling of several neuromyths – a sort of anti-intellectual virus which spreads among lay people as misinformation about what neuroscience can offer education. This is not to say that there isn't abundant good evidence that much brain functioning is modular, and that many higher cognitive functions, such as language production, are critically reliant on modules which are usually found in one or other hemisphere, such as Broca's Area (BA), usually

found in the left frontal cortex. But there are notable differences between individuals as to where these modules are located. In about 5% of right-handed males, BA is found in the right frontal cortex, and in a higher number of females, the principle function of BA, language production, is found in both the left and right frontal cortices. In left-handed people, only 60% have BA functions on the left, with the rest having their language production involving frontal areas on both sides or on the right (Kolb and Wishaw 1990). An implication of this for neuroscience research is that practically all subjects in neuroimaging studies are screened for extreme right-handedness – it is a way of maximising the probability that the group map has contributions from all subjects (that is, their functional modules involved in the study will be in much the same place in the different individual's brains). Consequently, with a nice circularity, the data which show that language production is on the left comes almost exclusively from subjects who've been chosen to have their language production areas on the left.

Thus the left- and right-brain thinking myth seems to have arisen from misapplying lab studies which show that the semantic system is left-lateralised (language information processing in the left hemisphere; graphic and emotional information processing in the right hemisphere) by ignoring several important caveats. First, the left-lateralisation is in fact a statistically significant bias, not an absolute. Even in left-lateralised individuals, language processing does stimulate some right hemisphere activation. Second, the subjects for such studies are extremely right-handed. As language researchers are at pains to point out: 'It is dangerous to suppose that language processing only occurs in the left hemisphere of all people' (Thierry, Giraud, and Price 2003, 506). The largest interconnection to transmit information in the brain is the corpus callosum, the thick band of fibres which connects the two hemispheres. It seems that the left and right sides of our brains cannot help but pass all information between them. In fact, there is some evidence that constrictions in the corpus callosum could be predictive of deficiencies in reading abilities (Fine 2005), which obviously could not occur if language processing was an exclusively left hemisphere activity.

It would be neat if all cognitive functioning was simply lateralised, and towards such a schema some commentators have suggested that perhaps there are stylistic differences between left and right hemispheric functions, with the left mediating detail, while the holistic right focuses on the bigger picture. For example, using EEG to describe the time course of activations identified by fMRI, Jung-Beeman et al. (2004) found that the insight or 'aha' moment of problem solution elicits increased neural activity in the right hemisphere's temporal lobe. Jung-Beeman et al. (2004) suggest that the this right hemisphere function facilitates a coarse-level integration of information from distant relational sources, in contrast to the finer-level information processing characteristic of its left hemisphere homologue. However, researchers in music cognition disagree (Peretz 2003). Even regarding the left hemisphere (metaphorically if not literally) as a verbal processor, music, as non-verbal information *par excellence*, is not exclusively processed in the right, but in both hemispheres (Peretz 2003). Moreover, neuroimaging studies have shown that the location and extent of various areas of the brain involved with music perception and production shift and grow with musical experience (Parsons 2003). In fact, there is a strong evolutionary argument that music plays a crucial role in promoting the growth of the inter-module connections which underpin cognitive development in infants and young children (Cross 1999).

Consequently, for the many reasons noted above, leading neuroscientists have been calling on the neuroscience community to shift their interpretative focus of brain function from modularisation to interaction. As Hellige (2000, 206) pleads: 'Having learned so



much about hemispheric differences . . . it is now time to put the brain back together again.' Or as Walsh and Pascual-Leone (2003, 206) summarise: 'Human brain function and behaviour seem best explained on the basis of functional connectivity between brain structures rather than on the basis of localization of a given function to a specific brain structure.'

### **VAK learning styles**

This emphasis on connectedness rather than separateness of brain functions has important implications for education (Geake 2004). The multi-sensory pedagogies, which experienced teachers know to be effective, are supported by fMRI research. The work of Calvert, Campbell and Brammer (2000), on imaging brain sites of cross-modal binding in human subjects, seems relevant. Bimodal processing of congruent information has a supra-additive effect (e.g., simultaneously seeing and hearing the same information works better than first just seeing and then hearing it). These findings are consistent with observed behaviour. Much good pedagogy in the early years of schooling is based on coincident bimodal information processing, especially sight and sound, or sight and speech, as demonstrated by every early years teacher pointing to the words of the story as she reads them aloud.

However, such 'natural' pedagogy is threatened by the promulgation of learning styles. The notion that individual differences in academic abilities can be partly attributed to individual learning styles has considerable intuitive appeal if we are to judge by the number of learning style models or inventories that have been devised – 170 at the last count, and rising (Coffield et al. 2004). The myriad ways that approaches to learning can seem to be partitioned, labelled and measured seems to know no bounds. The disappointing outcome of all of this endeavour is that, overall, the evidence consistently shows that modifying a teaching approach to cater for differences in learning styles does not result in any improvement in learning outcomes (Coffield et al. 2004).

Despite the lack of positive evidence, the education community has been swamped by claims for a learning style model based on the sensory modalities: visual, auditory and kinaesthetic (VAK) (Dunn, Dunn and Price 1984). The idea is that children can be tested to ascertain which is their dominant learning style, V, A or K, and then taught accordingly. Some schools have even gone so far as to label children with V, A and K shirts, presumably because these purported differences are no longer obvious in the classroom. The implicit assumption here is that the information gained through one sensory modality is processed in the brain to be learned independently from information gained through another sensory modality. There is plenty of evidence from a plethora of cross-modal investigations as to why such an assumption is wrong. What is possibly more insidious is that focusing on one sensory modality flies in the face of the brain's natural interconnectivity. VAK might, if it has any effect at all, be actually harming the academic prospects of the children so inflicted.

A simple demonstration of the ineffectiveness of VAK as a model of cognition comes from asking 5-year-olds to distinguish different sized groups of dots where the groups are too large for counting (Gilmore, McCarthy, and Spike 2007). So long as the group sizes are not almost equal, young children can do this quite reliably. Now, what happens when one group is replaced by as many sounds played too rapidly for counting? There is no change in accuracy! Going from a V versus V version of the task to a V versus A version makes no difference to task performance. The reason is that input modalities in the brain are interlinked: visual with auditory; visual with motor; motor with auditory; visual with

taste; and so on. There are well-adapted evolutionary reasons for this. Out on the savannah as a pre-hominid hunter-gatherer, coordinating sight and sound makes all the difference between *detecting* dinner and *being* dinner. As Sherrington (1938, 217) noted:

The naïve observer would have expected evolution in its course to have supplied us with more various sense organs for ampler perception of the world . . . Not new senses but better liaison between the old senses is what the developing nervous system has in this respect stood for.

To emphasise the cross-modal nature of sensory experience, Kayser (2007) writes that: 'the brain sees with its ears and touch, and hears with its eyes.' Moreover, as primates, we are predominantly processors of visual information. This is true even for congenitally blind children who instantiate Braille not in the kinaesthetic areas of their brains, but in those parts of their visual cortices that sighted children dedicate to learning written language. Moreover, unsighted people create the same mental spatial maps of their physical reality as sighted people do (Kriegseis et al. in press). Obviously the information to create spatial maps by blind people comes from auditory and tactile inputs, but it gets used as though it was visual. Similarly, people who after losing their hearing get a cochlear implant find that they are suddenly much more dependent on visual speech, such as cues for segmentation and formats, to conduct conversation (Thomas and Pilling in press). Wright (2007) points out just how interconnected our daily neural processes must be. Eating does not engage just taste, but smell, tactile (inside the mouth), auditory and visual sensations. Learning a language, and the practice of it, requires the coordinated use of visual, auditory and kinaesthetic modalities, in addition to memory, emotion, will, thinking and imagination:

To an anatomist this implies the need for an immense number of neural connections between many parts of the brain. In particular, there must be numerous links between the primary auditory cortex (in the temporal lobe), the primary proprioceptive-tactile cortex (in the parietal lobe) and the primary visual cortex (in the occipital lobe). There is indeed such a neural concourse, in the parieto-temporo-occipital 'association' cortex in each cerebral hemisphere. (Wright 2007, 275)

Input information is abstracted to be processed and learnt, mostly unconsciously, through the brain's interconnectivity (Dehaene, Kerszberg, and Changeux 1998). Actually, we don't even create sensory perception in our sensory cortices:

For a long time it was thought that the primary sensory areas are the substrate of our perception. . . . these zones simply generate representational maps of the sensorial information . . . although these respond to stimuli, they are not responsible for . . . perceptions . . . Perceptual experience occurs in certain zones of the frontal lobes [where] neurons combine sensory information with memory information. (Trujillo 2006, M9)

Literally following a VAK regime in real classrooms would lead to all sorts of ridiculous paradoxes: what does a teacher do with: the V and K 'learners' in a music lesson/ the A and K 'learners' at an art lesson/ the V and A 'learners' in a craft practical lesson? The images of blindfolds and corks in mouths are all too reminiscent of *Tommy*, the rock opera by The Who. As Sharp, Byrne and Bowker (in press) elaborate, VAK trivialises the complexity of learning, and in doing so, threatens the professionalism of educators. Fortunately, many teachers have not been taken in. Ironically, VAK has become, in the hands of practitioners, a recipe for a mixed-modality pedagogy where lessons have explicit presentations of material in V, A and K modes. Teachers quickly observed that their pupils' so-called learning styles were not stable, that the expressions of

V-, A- and K-ness varied with the demands of the lessons, as they should (Geake 2006). As with other learning-style inventories, research has shown that there is no improvement of learning outcomes with VAK above teacher enthusiasm, where 'attempts to focus on learning styles were wasted effort' (Kratzig and Arbuthnott 2006).

We might speculate in passing why do VAK and other 'learning styles' seem so attractive? I wonder if two aspects of folk psychology, where we seem to learn differently from each other, and we have five senses, have created folk neuroscience: the working of our brains directly reflects our folk psychology. Of course, if our brains were that simple, we wouldn't be here today!

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