outcome of interest being whether young people were participating in any form of education in October 2006 and October 2007. The results after taking account of background variables including Key Stage 3 attainment are shown in Table 3 and Figure 3. The results after taking account of Key Stage 4 attainment are shown in Table 4 and Figure 4. The findings with respect to actual destinations are in line with those described earlier with respect to aspirations. Before taking account of the background characteristics of young people there is a clear difference in the probability of those entered for different tiers remaining in education post-16. However, once the influence of background characteristics is taken into account this difference is greatly reduced. Furthermore, as shown in Table 4 and Figure 4, once we account for the achievement of pupils at Key Stage 4 there is essentially no difference between the educational destinations of those who were entered for the lower tier and those entered for the higher tier.

Summary and caveats

The analysis presented here has explored the link between entry tier in Maths and English GCSE and future educational aspirations as measured within the Longitudinal Study of Young People in England (LSYPE). The analysis shows that any differences in aspirations or, indeed, chances of actually continuing in post-compulsory education can be entirely explained by the background characteristics of young people and in particular their educational ability as measured by their level of achievement at Key Stage 4. Whilst it could be argued that taking account of achievement at Key Stage 4 is inappropriate (as this could itself be affected by entry tier), our analysis has also shown that even taking account of achievement at Key Stage 3 is sufficient to explain much of the difference between higher and lower tier students.

It should be noted that this analysis is based on somewhat old data; the young people being studied completed their GCSEs in 2006. Furthermore, because information about entry tier is only available from particular exam boards, analysis is largely restricted to pupils taking Maths and English with AQA rather than with any other exam boards. Thus our analysis implicitly assumes that the impact of tiering will be similar across different exam boards.

Nevertheless, despite the need to restrict to candidates entering English and Maths to particular exam boards, we have successfully been able to compare the educational aspirations of several thousand higher and lower tier candidates. Once differences in the characteristics of these pupils are accounted for, we have seen remarkable similarity in their educational aspirations. This provides a clear empirical challenge to the statement that being placed in a lower tier examination will lead to demotivation and disillusionment. How teachers and schools should decide upon the most appropriate tier for their candidates remains an open question. However, it is clear that this decision can be made without fear that entering students for a lower tier will have wide reaching consequences beyond the individual GCSE subject.

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Education and neuroscience

Vikas Dhawan Research Division

If we value the pursuit of knowledge, we must be free to follow wherever that search may lead us. Adlai E. Stevenson Jr. (1952)

Introduction

This study was aimed at exploring how recent developments in neuroscience (the study of the structure and functioning of the brain) might affect the fields of education and test development in the future.

The study investigated some of the potential areas of application as well as limitations of neuroscience in education. A brief summary of the application of neuroscience in some other areas is also given. These are marketing and advertising, health, psychology and politics.

The main findings of this study were:

- There is a growing interest in the media, commercial organisations and the education sector for anything related to neuroscience.
- Various universities and academic institutions have started centres for research in neuroscience and education including Cambridge, Oxford, Bristol, University College London (UCL), Birkbeck, Harvard and Stanford.
- The field of health and medicine is leading the research in neuroscience which is being used in other fields.
- Neuroscience applications are in great demand in consumer marketing and advertising.
- Considerable research is being carried out in understanding learning disabilities (such as dyslexia and dyscalculia) using neuroscience.

- New classroom-teaching approaches based on neuroscience are becoming increasingly popular.
- Caution needs to be observed on claims made for applications of neuroscience – not all activity is scientifically valid and there are many 'neuromyths' floating around (e.g. we use only 10% of our brain).
- The techniques used in mapping the activity of brain (such as scanning) are expensive and cumbersome at this stage and therefore not suitable for large scale testing.
- The applicability of neuroscience for developing or validating educational assessments at present appears limited.
- More neuroscience-based applications are likely to emerge in the near future especially as various governments are committing to research in this field – the USA has announced investment of $3 billion over 10 years in neuroscience research and the European Commission has recently awarded €1 billion to the Human Brain Project under its Future and Emerging Technologies initiative.
- Educational authorities and awarding organisations should keep themselves abreast of how neuroscience might lead to innovative teaching and test-development practices.

What is neuroscience?

Neuroscience implies the study of the working of the brain. This field has been growing significantly in recent years. Understanding of how the human brain works is being increasingly applied to various fields such as health, psychology, education, marketing, politics and law. In all such applications the objective is to provide solutions based on the underlying causes of why and how human beings function the way they do. Deciphering the brain would indeed be the 'holy grail' in designing solutions in all walks of life. It could minimise the dependence on individual biases such as judgement and perception by making available a more reliable source of information instead – the functioning of the brain. For instance, if we have a precise understanding of how learning difficulties manifest in the brain there is a better chance of providing more targeted solutions. Similarly, we might be able to get a better picture of the psychological state of an individual by enhancing our understanding of how different behaviours are represented in the brain. Neuroscience might also allow us to develop educational tests that tap the skills that we intend to assess in a more targeted and effective manner.

Neuroscientists use the term 'mapping' to study the structure and functioning of the brain. A major project to map the brain was launched by the National Institutes of Health in the USA in 2009 (Connectome, 2013). The project aims to prepare a network map of the brain by using images of the brain and relate it with behavioural tests. Data and results from this project have now been made freely available to the scientific community for further research. USA President Barack Obama has recently announced plans to invest $3 billion in neuroscience research over a period of ten years (TES, 2013; The New York Times, 2013; BRAIN Initiative, 2013). The project is known as the BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies), also referred to as the Brain Activity Map project. It is aimed at building a comprehensive activity map of the brain – similar to what the Human Genome Project (1990–2003) did for genetics and came with a price tag of $3.8 billion. The European Commission has recently awarded €1 billion to the Human Brain Project under its Future and Emerging Technologies initiative. (Human Brain Project, 2013; Europa, 2013).

Over the next decade the project will aim to develop a large scale information and communications technology (ICT) infrastructure specifically for understanding the brain.

Brain mapping techniques

The major techniques used in brain mapping (Mapping Techniques, 2013a; 2013b) are:

- Computer axial tomography (CAT) scan: X-rays of structures of the brain from different angles.
- Electroencephalography (EEG): measures brain activity using detectors implanted in the brain or worn on a cap.
- Functional Magnetic Resonance Imaging (fMRI): shows images of brain activity while subjects work on various tasks.
- Magnetoencephalography (MEG): records brain activity by using electrical currents occurring naturally in the brain.
- Positron emission tomography (PET) scan: produces three-dimensional images of radioactive markers in the brain.

The techniques are meant to capture changes in neural activity due to specific demands placed on the brain by various tasks. The participants might either be healthy individuals or those suffering from a disorder, depending on the study. Out of the techniques mentioned above, fMRI and EEG are being extensively used by researchers to study brain activity.

Figure 1 shows an MRI scanning machine. The participant lies inside the scanner and is given audio or visual input.

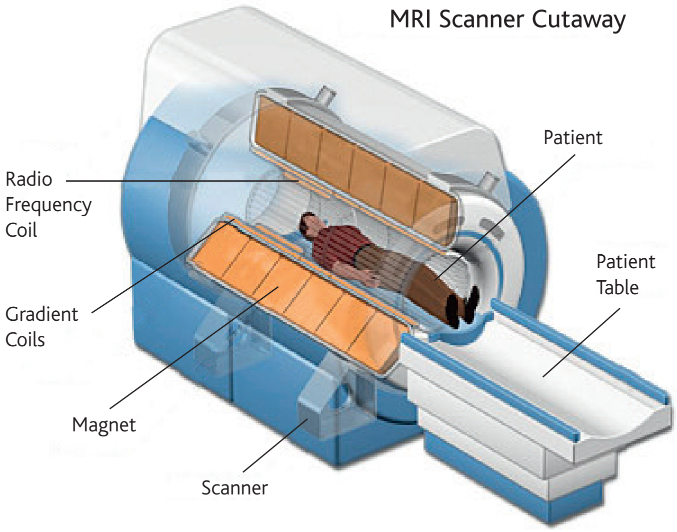

Figure 1: Scanner used for fMRI studies (Magnet Lab, 2013).
Image courtesy of Magnet Lab – National High Magnetic Laboratory, Florida State University.

Figure 2 gives an example of fMRI output. The images have been taken from a study which compared children aged 11 on a task of writing a letter (Todd *et al*., 2011). The figure shows the difference in the activity patterns in the brains of children who were classified as good writers and poor writers.

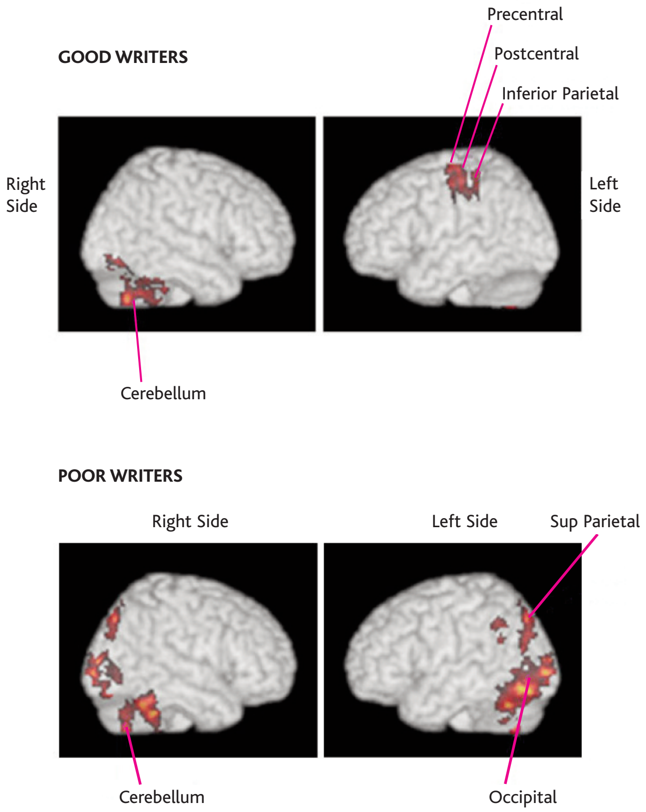

Figure 2: Example of fMRI scan images of brain: comparison of brain activity in children classified as good and poor writers (Todd *et al*., 2011).
Image courtesy of Springer©, Part of Springer Science+Business Media

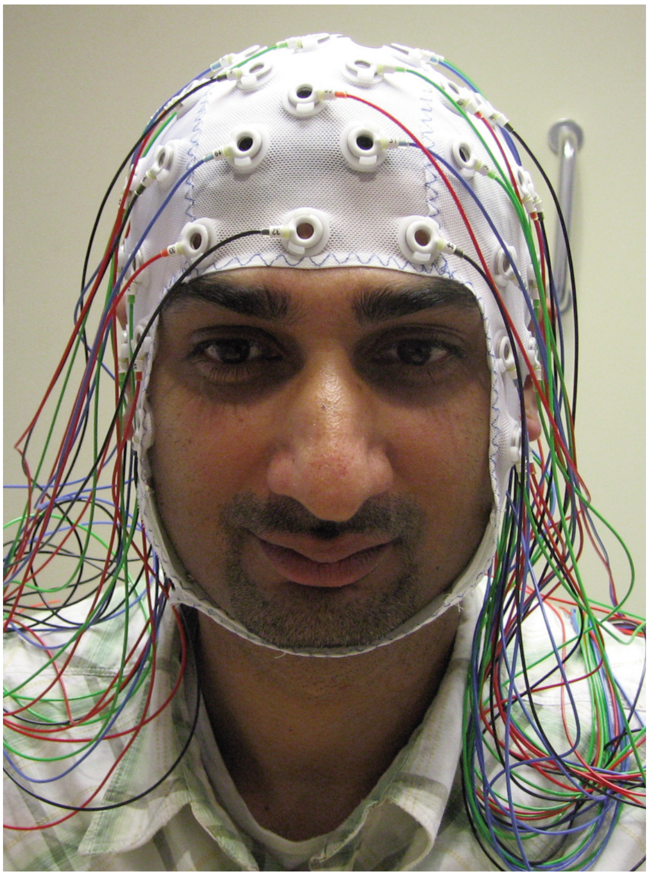

Figure 3: Example of an EEG recording.
Image courtesy of the National Institute for Health (NIH) Research: Nottingham Hearing Biomedical Research Unit.

Figure 3 gives an example of the EEG technique. The participant is required to wear a cap on their skull which is then fitted with electrodes, which can take up to an hour. The electrical activity of the brain is recorded according to the study requirements – while engaged in some activity or in a resting state.

Applications of neuroscience

There has been huge interest recently in the application of neuroscience to various fields. The flurry of activity and media interest has given rise to many new terms such as neuromarketing, neuroeconomics, neuroaesthetics, neurotheology, neurolaw, neueroanthropology and neuropolitics (Legrenzi, Umilta and Anderson, 2011).

Marketing

One of the most commercially intensive applications of neuroscience is neuromarketing (also called consumer neuroscience). It involves studying which products/packaging/ideas 'appeal' to the brain and devising marketing strategies accordingly. Techniques such as fMRI and EEG are used along with biometric measures such as eye movements, heartbeat and skin response, coupled with interviews/questionnaires to understand the subconscious preferences of consumers. A large number of market research organisations, including the well-known ones such as Ipsos, Gallup and Nielsen, now offer a neuroscience component in their portfolio of research tools. Major companies such as Google, HP, Microsoft and Coca-Cola are known to use neuroscience and biometric measures for devising their marketing strategies. According to one UK-based estimate, more than 10 per cent of prime time TV advertisements have been developed using neuromarketing techniques (Guardian, 2012).

Some of the findings claimed by NeuroFocus, probably one of the world's leading neuromarketing firms (now a part of Neilsen), are:

- People prefer items with rounded edges than those with sharp corners;
- Mannequins and photos with missing heads turn consumers off;
- Men typically respond to a product's features whereas women are more interested in getting a deal.

(ABC News, 2011).

They also claim to have noticed some other gender differences (Neurorelay, 2012). For example, for insurance products, women reacted much more strongly than men to the character of the spokesperson, while men reacted to the price. In light-hearted adverts for snack foods, men reacted to slapstick humour, while women ignored it. In automotive adverts, men were interested only in the performance of the vehicle whereas women were interested in storage capacity and safety features. In spite of the widespread use of neuromarketing, the actual applications are not frequently published and it appears that companies prefer to keep them shrouded. Some of the applications designed by NeuroFocus for its clients are given in Figure 4.

Interestingly, film producers also seem to have started using neuroscience in film-making and marketing. For instance, it is reported that the trailers for the popular film, *Avatar*, were designed using viewer responses to different trailer scenes and sequences (Neurocinema, 2011).

In all these applications it is not clear if similar results could have been obtained by using only questionnaires and interviews without the need for the neuroscience component. The neuroscience experiments are

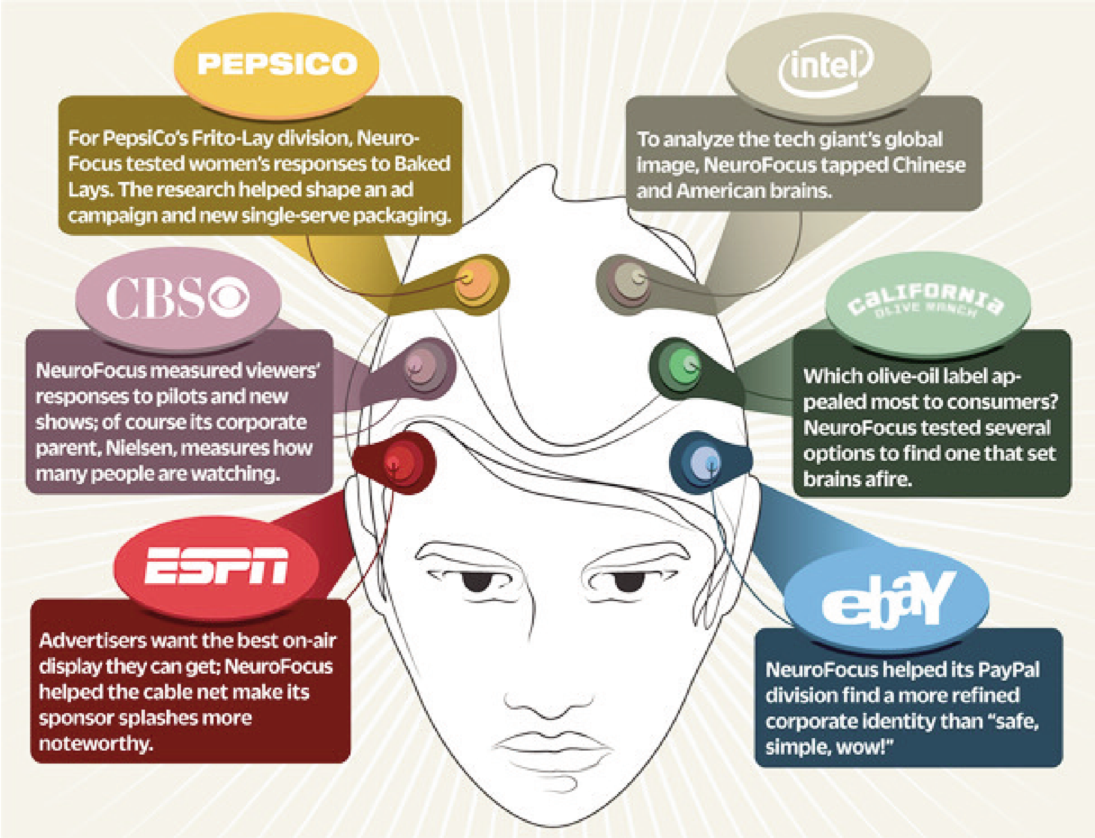

Figure 4: Examples of neuromarketing by NeuroFocus (Fast Company, 2011).
Image courtesy of SUPEREXPRESSO.

normally very expensive and their use would be beneficial only if they can provide additional evidence compared to the traditional methods such as interviews and focus groups.

Politics

Another area where neuroscience is being used is politics and law. It is well known that the 2012 Obama presidential campaign was heavily data-driven and used insights from behavioural economics and neuroscience to influence voters and to improve voter turnout (New York Times, 2012). Recent books such as The Victory Lab: The Secret Science of Winning Campaigns (Issenberg, 2012) and The political brain: The role of emotion in deciding the fate of the nation (Westen, 2007) also highlight this trend of how knowledge about human decision-making and the increasing power of analytics is being applied to political marketing.

The following USA-based study gives an example of using neuroscience research in this field. The study investigated if political awareness could be distinctly represented in the brain. Differences in brain activity were found between college students who were politically knowledgeable about Democrats and Republicans against those who did not know much about national politics (Schreiber, 2007 cited in Fowler and Schreiber, 2008). Figure 5 (Part A) shows that there were differences in the fMRI scans of those who were politically aware against those classified as political novices when asked questions about national politics. Part B in the figure shows the level of activation of specific brain regions for the two groups.

Health

The major developments in neuroscience emanate from the field of health and medicine. The Medical Research Council (MRC) Cognition and Brain Sciences Unit (CBU) in Cambridge conducts research in fundamental human cognitive processes such as attention, language, memory, and emotion using a combination of behavioural experiments, neuroimaging and computer modelling. The CBU works in close collaboration with the University of Cambridge and the local Addenbrooke's hospital.

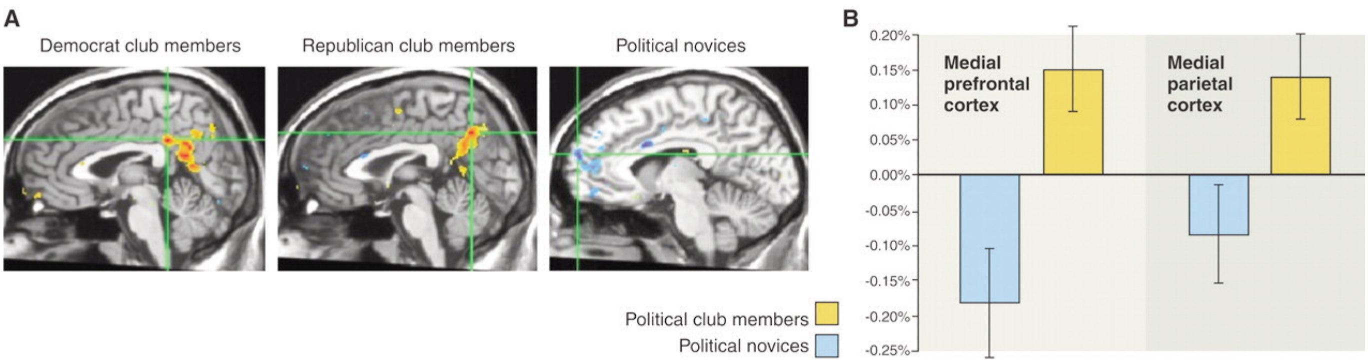

Figure 5: Difference in brain activity between politically knowledgeable against politically novice college students in the USA (Fowler and Schreiber, 2008).
Image courtesy of the authors.

The Center for Interdisciplinary Brain Sciences Research (CIBSR) at the Stanford University School of Medicine is a good example of multidisciplinary research. Its website states that the centre "is dedicated to research that will improve the lives and well-being of individuals with disorders of the brain and improve knowledge of healthy brain and behavioral development." CIBSR (2013).

The Center, which brings together experts from the fields of psychiatry, neurology, psychology, computer science, biostatistics and genetics, has developed a battery of assessment tools for measuring neurological and behavioural functions. The suite of assessments called the NIH[1] Toolbox measures motor, cognitive, sensory and emotional functions. It is available online, royalty-free and can be used by researchers and clinicians. The idea was to develop a 'common currency' or 'gold standards' against which individual performances can be compared across different neurological research studies. Education and psychology researchers might find this resource useful for their work in various domains such as cognitive psychology, emotional intelligence, marking and judgement processes and, also, impact of new modes of assessment such as computer-based tests – on both participants as well as judges. The NIH Toolbox could help provide a more targeted insight into understanding the level of stress and cognitive workload on markers in various modes of assessment, paper-based against computer-based.

Psychology

The assessment of personality traits could become more robust if a neurological basis of the traits can be established. Currently, most personality assessments are self-report measures, (that is, the participants answer statements about themselves and the responses are then used to estimate their personality profiles). Such self-report measures are susceptible to individual bias and social impression management. Using neuroscience techniques might help us gain a more uncluttered insight into personality and behaviour. DeYoung *et al*. (2010) found that four of the Big-Five[2] personality traits varied with the volume of different brain regions. The participants (n=116) were administered the self-report version of the Revised NEO Personality inventory (NEO-PI-R) (Costa and McCrae, 1992) which is based on the Big-Five model, followed by MRI scans. It was reported that E*xtraversion* co-varied with the brain region involved in processing reward information, N*euroticism* with regions associated with threat, punishment and negative affect, A*greeableness* with regions that process information about the intentions and mental states of other individuals and C*onscientiousness* with the region involved in planning and voluntary control of behaviour. No significant evidence was found for O*penness*. Figure 6 shows the association of different areas of brain with the personality traits. Research such as this could be used to develop more effective personality assessments.

An example of the application of neuroscience to personality assessment is the PRISM Brain Mapping© tool (Prism, 2013). It is an online personality assessment claimed to be based on neuroscience and can be used to identify the behavioural preferences that directly relate to personal relationships and work performance. The role of the instrument, as advertised, is "to explain behaviour in terms of the activities of the brain – how it marshals its billions of individual nerve cells to produce behaviour, and how those cells are influenced by the environment". We need to note here that questionnaires might not be different regardless of the technique used – traditional personality assessment or neuroscience. The insights gained into the personality of individuals using these two methodologies might also be similar to each other.

Education and neuroscience

A new area of research that has been gaining an increasing amount of interest is educational neuroscience which, as the name suggests, involves using neuroscience techniques in the field of education and learning. Another popular name which is being used to denote this field is Mind, Brain and Education (MBE). The field of educational neuroscience is vast and multi-disciplinary with perhaps no clear definition as yet. Szücs and Goswami (2007) define it as: "the combination of cognitive neuroscience and behavioral methods to investigate the development of mental representations"[4].

Most of the studies in this area involve using brain-scanning techniques, including fMRI and EEG, the results of which are validated against behavioural or educational assessments.

Educational neuroscience is still an emerging area of research. It has a wide remit at present with not very well defined boundaries. A report by the Royal Society which investigated the implications of neuroscience in education (Brain Waves, 2011) states that:

> *Education is about enhancing learning, and neuroscience is about understanding the mental processes involved in learning. The common ground suggests a future in which educational practice can be transformed by science, just as medical practice was transformed by science about a century ago*. (Page v)

The aim is to understand how learning behaviour is manifested in the brain so as to improve how we practice teaching or learning or assessment activities.

Research in this area is being carried out at various institutions such as CIBSR-Stanford, the Centre for Neuroscience in Education (CNE)-Cambridge and UCL. The CNE Director, Professor Goswami, states that:

> *… the tools of cognitive neuroscience offer various possibilities to education, including the early diagnosis of special educational needs, the monitoring and comparison of the effects of different kinds of educational input on learning, and an increased understanding of individual differences in learning and the best ways to suit input to learner.* (Goswami, 2004, page 6)

The CIBSR-Stanford is also examining relationships between brain and behaviour to predict future learning difficulties in children so that early interventions could be developed.

Neuroscience has given rise to many theories about learning behaviours and classroom teaching strategies, not all of which are completely valid. Some of them may be false or incomplete or exaggerated and such misconceptions are known as 'neuromyths', a term coined by the Organisation for Economic Co-operation and Development (OECD) report on understanding the brain with

1. The National Institutes of Health (NIH) is a part of the USA Department of Health and Human Services and is the nation's medical research agency. NIH is made up of 27 Institutes and Centers, each with a specific research agenda.
2. The Big-Five model of personality assessment is a well-known model of personality (Rust and Golombok, 1999). Its five factors - Extraversion, Agreeableness, Openness to experience, Neuroticism and Conscientiousness are widely accepted to encompass most other behaviours.
3. In Figure 6, the lighter colour signifies a larger effect size, and the darker colour signifies a smaller effect.
4. The authors describe mental representation as: "the activity of neural networks of the brain which code information in the form of electrochemical activity."

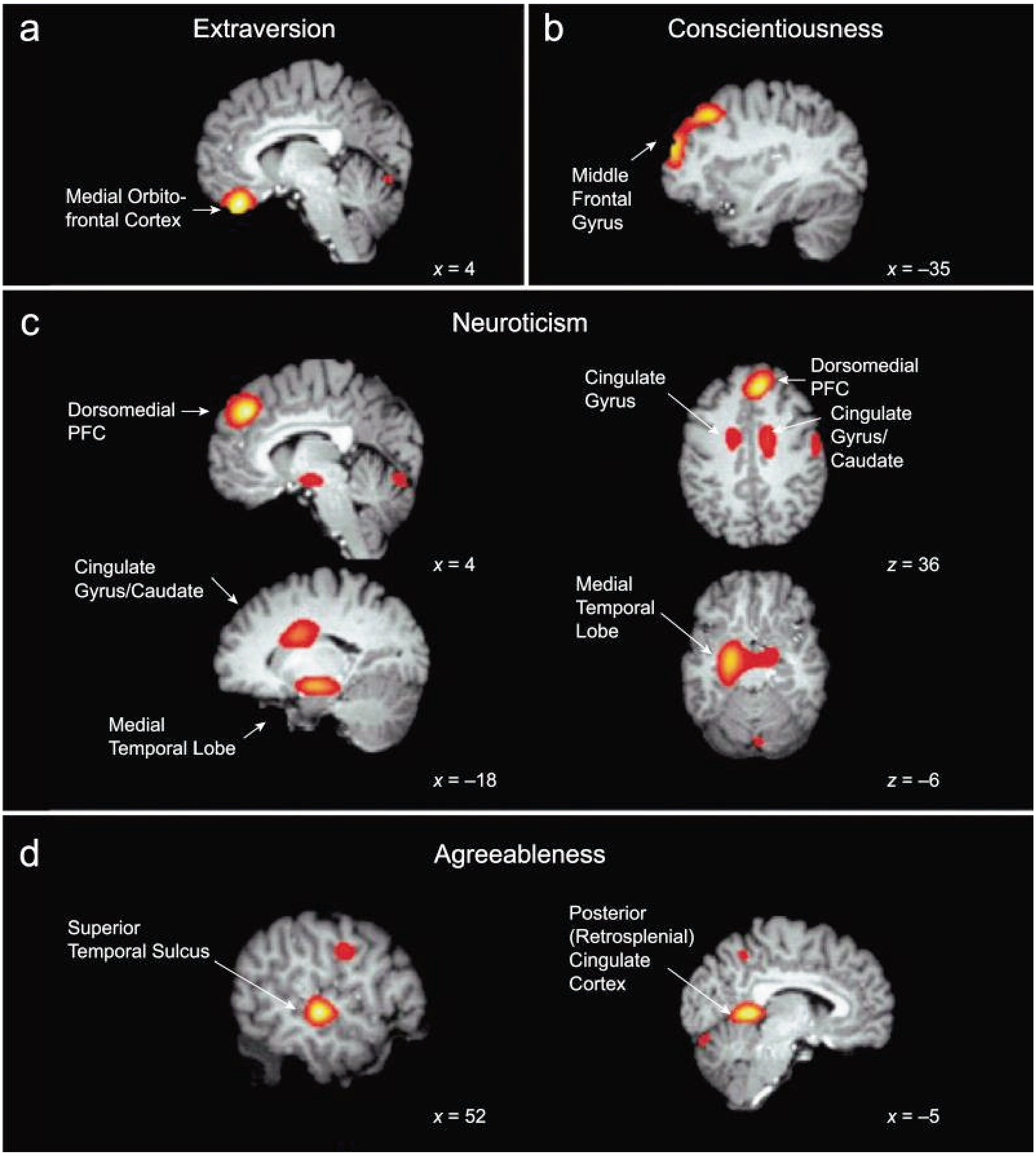

Figure 6[3]: Brain regions in which local volume was significantly associated with (a) Extraversion, (b) Conscientiousness, (c) Neuroticism, and (d) Agreeableness, as hypothesized in DeYoung *et al*. (2010). *Image courtesy of SAGE Publications.*

respect to learning (OECD, 2002). Some of the well-known myths are:

- We have either a left-brain or a right-brain thinking style
- We use only 10 per cent of our brain
- There are critical periods for learning certain tasks which cannot be learnt when that age period is over.

The myths can be difficult to dispel once they become popular. OECD (2007) points out that these misconceptions "often have their origins in some element of sound science, which makes identifying and refuting them more difficult".

A detailed review of some of the neuromyths is given in Beyerstein (1999), Geake (2008) and Goswami (2006).

An important characteristic that needs to be mentioned here is the ability of the brain to form new connections between neurons in response to new learning or environment. This characteristic is known as 'Brain Plasticity' or 'Neuroplasticity' and can occur during adult life as well. It can be defined as the ability of the brain to mould itself in response to an external sensory input or internal events which may include the effects of our own thoughts or visual imagery, hormones, genes and following brain injury (Anderson and Sala, 2012). This points to the possibility of developing new behaviours and skills later on in life and could have implications for life-long learning.

Findings from neuroscience could help in test development by giving a better insight into the underlying constructs we assess and by providing us with tools to develop better tests. We might be able to use the understanding of the brain to tap into the specific skills we intend to assess and therefore prepare tests with relatively higher validity. For instance, if brain imaging techniques can help us to establish whether a question of numerical reasoning is in fact assessing numerical reasoning, as we have defined it, and not some other skill, it can provide a significant contribution in assessing the validity of test questions. At present it appears that the most visible area of educational assessment where neuroscience is being used is the diagnosis of learning difficulties such as dyslexia and dyscalculia. The growing understanding of such learning difficulties will inevitably lead to a better understanding of skills such as language and numerical cognition which perhaps could be used in test development at some stage. An example of how neuroscience is being applied to understand dyscalculia and mathematical skills is given in the following section.

How neuroscience can help – Dyscalculia and Mathematics

This example draws heavily on Butterworth, Varma and Laurillard (2011), Butterworth and Laurillard (2010) and Szücs, Devine, Soltesz, Nobes and Gabriel (2013).

Developmental dyscalculia refers to the existence of a severe disability in learning arithmetic. It has roughly the same prevalence as dyslexia but has not received as much attention. Usually low achievement on mathematical achievement tests is used as a criterion for identifying dyscalculia. However, this approach may not necessarily identify the underlying neurological reasons and therefore may lead to insufficient remedial actions.

An understanding of how mathematical ability is represented in the brain would be very helpful for designing remedial actions for dyscalculia and for Mathematics education in general. Neuroscientists are working on understanding how mathematical skills and dyscalculia can be explained through neuro-imaging research.

One area of research (Butterworth *et al*., ibid.) suggests that dyscalculia is caused by a disorder in the way the brain represents magnitude. Neuroscientists have been able to identify areas of the brain associated with mathematical skills, such as learning new arithmetical facts (frontal lobes and the intra-parietal sulci – IPS), using previously learned facts and in retrieving facts from memory (left angular gyrus) (Ischebeck, Zamarian, Schocke and Delazer, 2009). Various experiments have shown a reduced activation in these regions for children with dyscalculia (Mussolini *et al*., 2010). The identification of the region where almost all arithmetical abilities and numerical processes are mapped (parietal lobes) can significantly help understand the basis of mathematical skills or their lack thereof. Dyscalculics show poor performance on numerosity tasks such as counting the number of dots or making number comparisons, which may suggest that dyscalculia is characterised by impairment in magnitude representation. An illustration of these two numerosity tasks is given in Figure 7.

Neuroscience experiments have shown the areas in the brain which get activated while performing such numerosity tasks. A difference in activation of these areas in normal functioning brains and those affected by dyscalculia is shown in Figure 8. The research suggests that the pedagogic interventions to help dyscalculic children should, therefore, attempt to make the individuals develop the ability to process the numerosities.

An alternate focus of research (Szücs *et al*., 2013) suggests that the magnitude representation function of the brain might not be sufficient to explain dyscalculia and that impairment of other functions such as visuo-spatial short term memory and working memory along with inhibitory functions[5] might lead to dyscalculia. They recommend that various theories, along with behavioural research, need to be tested to gain sound understanding of mathematical skills.

Teachers make an attempt to improve the performance of their students on mathematical tasks. However these students might be those having low numeracy skills and not necessarily have dyscalculia. The assessment of students is usually based on curriculum-based tests which may not necessarily differentiate between dyscalculia and general low numeracy. Neuroscience evidence, on the other hand, can provide a more targeted approach for assessment and remedial action which is largely independent of learners' social and educational circumstances (Landerl, Bevan and Butterworth, 2004; Butterworth *et al*., 2010).

The classical remedial measures require trained special education needs (SEN) teachers and considerable time, both of which are limited resources. Computer adaptive software based on neuroscience that

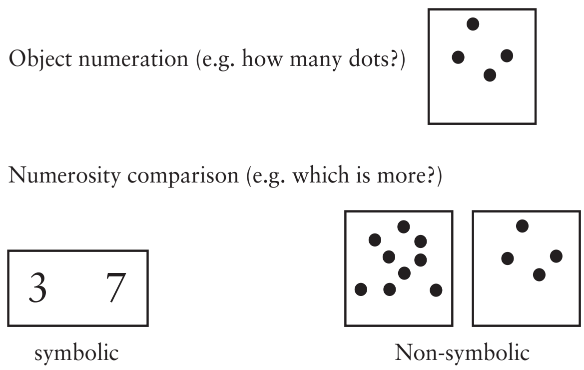

Fig. 3 Numerosity tasks on the enumeration of dot arrays and the comparison of digits and of dot arrays.

Figure 7: Example of numerosity tasks (Butterworth and Laurillard, 2010).
Image courtesy of the authors.

allows learners to explore the meaning of numbers can provide an optimum solution. Examples of two such software are mentioned below.

The *Number Race* game (Wilson, Revkin, Cohen, D., Cohen, L., and Dehaene, 2006) targets the area of the brain that supports early arithmetic to improve the precision in this skill. The learners are required to select the larger of the two arrays of dots. The software adapts to the performance of the learner, making the difference between the arrays smaller as their performance improves and provides feedback as to which is correct. Another game, *Graphogame-Maths*, targets the area of the brain known for representing and manipulating sets. Candidates are required to identify the link between the number of objects in the sets and their verbal numeric label and are given feedback about the correct answer. Some studies report some improvement in performance of children in several tasks after training which could mean an improvement in their numerical cognition (Wilson *et al*., 2006 and Räsänen, Salminen, Wilson, Aunio, and Dehaene, 2009). More such numeracy games are available from Numeracy Games (2013).

The private sector is becoming increasingly active in the area of brain-training software. According to an estimate, the market for such software

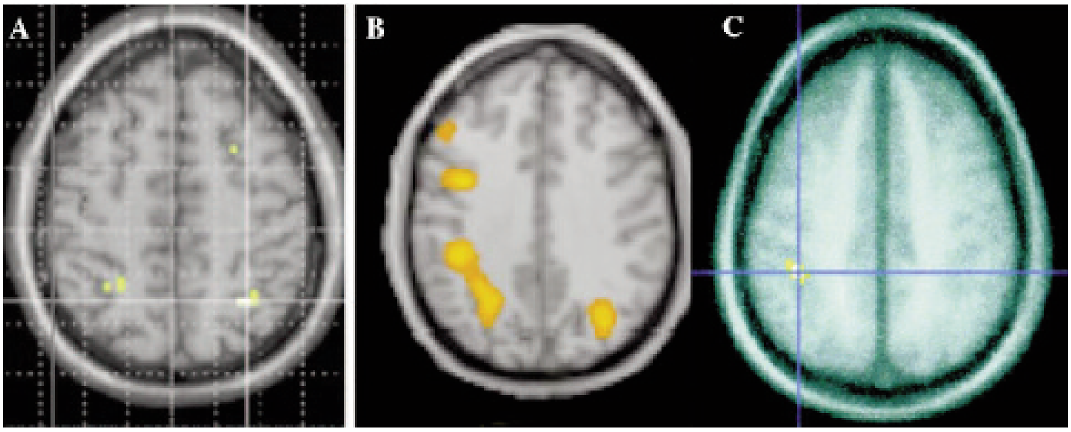

Fig. 2
Normal and atypical adult brain areas for bilateral number processing in the intraparietal sulcus.
a The *highlighted parts* show the areas that are normally activated in numerosity comparison tasks (Castelli *et al*., 2006).
b The *highlighted parts* show the networks normally activated for arithmetical calculation, which include the numerosity processing areas (Zago *et al*., 2001).
c The *highlight* indicates the part that is found to be structurally abnormal in adolescent dyscalculics (Isacs *et al*., 2001).

Figure 8: Comparison of brain activation in normal individual and those affected by dyscalculia (Butterworth and Laurillard, 2010).
Image courtesy of the authors.

in 2012 was roughly £1 billion which is expected to rise to £6 billion by 2020 (TES, 2013). However, it is important to note that such products may or may not be valid in scientific terms and might raise some ethical concerns and have unknown side effects.

Some examples were shown earlier to give an idea of how neuroscience might be used in education. Goswami (2004) notes that while some of the studies confirm what was already known from behavioural studies, new insights are also being gained such as "a way of distinguishing between different cognitive theories (e.g., whether dyslexia has a visual basis or a linguistic basis in children)." The use of neuroscience has two implications here – firstly, to complement traditional research and confirm what is already known and secondly, to give us an insight into what has hitherto been unknown. The latter holds some immensely exciting possibilities for the future.

Discussion

Knowledge of how our brains work will allow us to better understand human behaviour and cognition. Neuroscience holds the potential to enable us to provide more targeted solutions, be it in medicine or education. In recent years there has been a significant interest in applying neuroscience to various fields. After the surge of information and communication technologies, neuroscience, by allowing us to see beyond what has been observable, may well lead us to the next phase in human development history.

However, we need to be cautious of the fact that, at present, a great deal of attention being given to this field is driven by commercial reasons. The consumer marketing companies, in particular, are looking to exploit neuroscience research – not all of which may withstand scientific scrutiny. Similarly, a large number of software development companies have launched products (such as educational training and psychological tests) based on what is claimed as neuroscience evidence. It may be difficult to establish the authenticity of such products.

The techniques used for mapping brain activity (such as MRI scans) are currently very expensive. This is one of the reasons why the sample size in most neuroscience studies is small, which could affect general conclusions. The scanning machines are not very convenient for the participants.

5. Inhibitory functions refer to, for example, the ability to withhold a response or block out distracting stimuli.

They require lying down inside huge scanners or wearing caps knitted with detectors which require a long time to set up. Testing young children is even more difficult. In addition, a large number of studies are based on mapping the areas of brain which get activated when a certain task is performed. However, different areas of the brain might get activated due to different reasons (such as movement of a body part) and not necessarily the activity being monitored.

Continued research in health as well as learning disabilities will lead to applications in education as well. Some of the most important benefits of neuroscience in understanding and improving individual performance are likely to be derived from increasing understanding of how functions such as memory, attention span and reward systems work in the brain. As various teaching and learning strategies based on neuroscience start becoming popular we will have to watch out for the neuromyths which can be difficult to dislodge once they enter the popular culture. Products/methodologies based on neuroscience can be evaluated based on:

- do they provide any additional utility – over and above the current ones,
- are they scientifically reliable and valid (doing what they purport to do)

  and
- do they justify the higher costs as compared to traditional approaches?

The use of neuroscience in test development is limited by the fact that currently there isn't ample understanding of the relationship of neural signals with high level concepts such as ability and skills. The neuroscientific understanding of such concepts is still at a nascent stage. So, the development of educational tests and examination questions *purely* based on neuroscience is, perhaps, a bridge too far. However, the knowledge base in this area is expanding rapidly which could be applied in test development. For instance, the growing understanding of different strategies used by students to answer examination questions could help validate the constructs used in the tests. The most important question for a test developer is: Does an examination question measure what it is intended to measure? If neuroscience can provide an answer to this question, more accurately than what we already know, it will be a tremendous contribution to the field of assessment. As neuroscientists expand their knowledge of how different skills and behaviours are represented in the brain, we can expect neuroscience applications in educational assessment in the near future. It is also worth mentioning that test development is not a standalone activity. It is informed by various factors which are more likely to be influenced by neuroscience evidence in the immediate future than question writing itself. Such factors include teaching, curriculum, use of technology and political and social environment.

Huge investments are being made in neuroscience research in the US and Europe by governments and academic institutions. We can expect some high level research outcomes in the following years. The on-going improvement in scanning machines will also make research easier and more accessible. However, for the time being it appears that the commercial sector will continue to lead in using neuroscience.

Educational authorities and awarding organisations will need to keep themselves abreast of how developments such as neuroscience might have an impact on their operations. The prime objective of this study has therefore been to briefly encapsulate the association of neuroscience and education so as to ensure future readiness. Not having the answers now does not mean that we will not have them in the future; nor should we stop looking for them.

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Book announcement: Validity in Educational and Psychological Assessment

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Introduction

For almost one hundred years, divergent views on the concept of validity have proliferated. Even today, the meaning of validity is heavily contested. Despite a century of accumulated scholarship, new definitions of validity continue to be proposed, and new 'types' of validity continue to be invented (see Newton and Shaw, 2013). Yet, against the backdrop of an evolving measurement and testing landscape and the increased use of assessments across scientific, social, psychological and educational settings, validity has remained "the paramount concept in the field of testing." (Fast and Hebbler, 2004, p.i).

Validity is universally regarded as the hallmark of quality for educational and psychological measurement. But what does quality mean in this context? And to what exactly does the concept of validity actually apply? What does it mean to claim validity? And how can a claim to validity be substantiated? In a book entitled *Validity in Educational and Psychological Assessment*, due to be published in the UK by SAGE in March 2014, we explore answers to these fundamental questions.

Validity in Educational and Psychological Assessment adopts an historical perspective, providing a narrative through which to understand the evolution of validity theory from the nineteenth century to the present day. We describe the history of validity in five broad phases, mapped to the periods between:

1. the mid-1800s and 1920: gestation
2. 1921 and 1951: crystallisation
3. 1952 and 1974: fragmentation
4. 1975 and 1999: (re)unification
5. 2000 and 2012: deconstruction.

We explain how each of these phases can be characterised by different answers to the question at the heart of any validation exercise: how much and what kind of evidence and analysis is required to substantiate a claim of validity?