Research insight
February 2014

Fresh thinking in learning and development Part 1 of 3

Neuroscience and learning

WORK WORKFORCE WORKPLACE

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Fresh thinking in learning and development

Part 1

Neuroscience and learning

Contents

This report was written by Dr Paul Howard-Jones, University of Bristol, with Dr John McGurk, CIPD.

Background

This report forms part of stage two of research launched in 2012 to challenge tried and tested models of insight and diagnosis such as Myers-Briggs, learning styles and other such approaches, and build fresh insight for L&D. Through our 2012 *Learning and Talent Development* survey, conducted in partnership with Cornerstone OnDemand, we identified extensive use of traditional techniques and low awareness of emerging practice such as neuroscience, cognition and wider cognitive processes such as intuition and thinking skills. We outlined our survey findings in our 2012 report *From Steady State to Ready State: A need for fresh thinking in learning and talent development?* and set out to develop newer insight. These new insights are critical, in our view, to developing curiosity, the driving behaviour of L&D professionals. This new series of reports, written with key experts, allows us to tap into the insight potential of new areas. The intention is that this will help build the capability which helps L&D build its role at the centre of organisational learning.

These three research insight reports cover:

- neuroscience and learning
- cognition, decision and expertise
- insight and intuition.

This is the first in the series and it addresses neuroscience and learning.

Acknowledgements

The CIPD wishes to thank our community of learning and development practitioners who made this series possible by completing our 2012 survey and allowing us to tap into both the steady and ready states of L&D practice. We also wish to thank those practitioners who joined our winter 2013 webinars and who participated in the first webinar delivered by Dr Paul Howard-Jones. We want to thank Mike Morrison of RapidBI and Martin Couzins of LearnPatch for facilitating those webinars and helping facilitate delivery of some of the insights we used in this report. Finally, thanks are owed to Dr Paul Howard-Jones for providing us with his expertise and giving us real insight into neuroscience and learning.

About the author

Dr Paul Howard-Jones is a reader in neuroscience and education at the Graduate School of Education, University of Bristol. He researches at the interface of neuroscience with educational theory, practice and policy, publishing in all associated areas. His scientific research combines neurocomputational modelling with functional brain imaging to explore the relationship between reward and learning, and he is applying this knowledge in the development of educational learning games. He is the author of *Introducing Neuroeducational Research* (published by Routledge in 2010 and translated into several languages) and leads the MSc in Neuroscience and Education at Bristol. He was a member of the UK's Royal Society working group on neuroscience and education that published its report in 2011. In a previous life he worked as a school teacher, a trainer of teachers and an inspector of schools.

Executive summary

In the CIPD's report *From Steady State to Ready State: A need for fresh thinking in learning and talent development?* (2012) we identified the need to lift our awareness as a learning community of the insights that could be obtained from areas such as neuroscience, cognitive science and decision research. We also highlighted some emerging areas of social science insight which could feed new thinking. We identified neuroscience as a compelling source of fresh insight in learning and development. In our 2012 *Learning and Talent Development* survey we identified quite low levels of awareness of key neuroscience areas relevant to learning, such as brain plasticity, myellination and memory and recall. Only around 10% of respondents were aware of such issues, for example. So, neuroscience gives us a range of powerful insights into human learning and its supporting processes. But it can also mislead us if not understood with care and precision. This report will highlight ways in which neuroscience can help us understand key learning issues, in particular how we can help people and organisations to:

- maximise learning at any age and respond optimally to our world
- interact with technology such as video games and learn how we can harvest such technology for new learning opportunities
- work creatively and help processes of innovation happen more effectively
- use exercise to generate positive effects on learning as a positive side effect
- understand how key basic learning skills such as numeracy and language are built and how they support the development of spatial and visuomotor skills necessary for certain roles and tasks
- understand the importance of stimulants, sleep and rest on effective learning.

With all of this promise comes some peril. The glib and often superficial way neuroscience is presented in popular accounts or the way its insights are loosely interpolated by even the most attentive and conscientious non-scientists have led to many misapprehensions:

- undue faith and a lack of scepticism about the overuse of neuroscientific explanation in a whole range of fields, including learning
- the rise of neuromyths, which wrongly prescribe our understanding of neuroscience and its usefulness, such as the left-brain/right-brain confusion, the idea that we use only 10% of our brain, and questionable instructions on brain stimulus such as rubbing body parts to 'wake up' the brain: though used more in school environments such processes have found their way into workplace learning
- confusion between the brain (the physical and biological matter and its electro-chemical operation) and the mind (feelings, thoughts and desires); that confusion can be exacerbated by explanations that assume they are unrelated or the same thing
- a lack of expert scientific input into discussions about learning leading to non-expert speculation on issues such as thinking styles, learning preferences and the like.

This report helps us to understand how learning can be informed by neuroscience. It is detailed and informative and it is also richly referenced. The problem with much neuroscience commentary is that it is not written by experts. Real expertise is crucial in such a nuanced and highly specialised field. Dr Howard-Jones researches at the very intersection between neuroscience and education and is renowned for it. Here he brings his unique perspective and his expert judgement to help L&D engage with the possibilities his compelling scientific field affords.

Dr John McGurk, CIPD

1 Neuroscience and education – a new field of insight for learning and HR

There is a new field of enterprise and enquiry emerging at the interface of neuroscience and education. It has been called a variety of different names, including 'neuro-education', 'educational neuroscience', and 'brain, mind and education'. These names may reflect some diversity in approach, but all the research is inspired by one common idea: burgeoning scientific insights about the brain can inform the ways in which we teach and learn (see Figure 1).

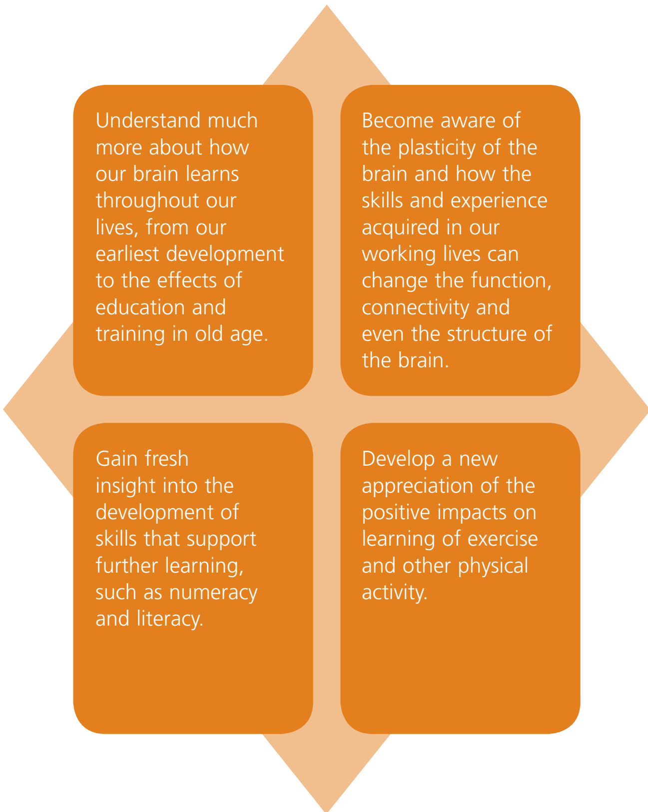
Insights from neuroscience mean we are also beginning to understand how to harness the learning potential of new technologies involving gaming, connectivity and simulation.

But, in the eagerness of many to apply neuroscientific concepts to learning, there have been some false starts. A number of neuromyths, such as right-brain/left-brain learning and the idea that we use only 10% of our brain, continue to circulate. Coupled with confusion about 'spaced learning' and the failure of many of the favoured models of L&D to be supported in neuroscience research, it's clear that we need to be more mindful about how we gather insights into the science of learning.

Our brains build our learning, learning builds our brains

Everyone knows we need our brains to learn and sometimes we can even blame any difficulties we face when learning on our brains.

Figure 1: The promise of neuroscience for learning



However, our brains impose no clearly defined biological limit on our learning potential. Moreover, we can change and develop our brains through learning:

- Understanding the nature of brain development has helped economists to challenge the idea that assumes we have an innate fixed ability.
- Such research supports the idea that investment in learning improves our ability to learn more and emphasises the importance of considering when we invest, as well as what we invest in (Heckman 2000).

'Much of the building of our brains comes through the use of skills and experience, which can happen at any age.'

Below we develop some of the insight which arises from this research. You will learn that the brains of cabbies and jugglers give us an understanding of brain plasticity. You will learn that neuroscience and education have been 'talking' to each other for two decades, and that we now know a lot more about how people count, write and think as a result. Furthermore, neuroscience helps us understand more about learning issues such as creativity, caffeine and the impact of gaming. We will also know how exercise can really help to fuel our thinking and improve our performance. All of this is increasingly relevant to workplace L&D.

What you can learn about lifelong learning from a child, your cabbie and from juggling

Evidence for the effectiveness of some early childhood interventions is sometimes misinterpreted to mean our brains are fully formed by the time we are three years old (Howard-Jones et al 2012). However, more recent economic research drawing on neuroscience supports the economic value of education and training well beyond infancy, while emphasising that returns may depend on the type of skills invested in (Cunha et al 2010). Our brains are certainly more 'plastic' when we are younger, but their connectivity, function and even structure can change dramatically in response to learning throughout our lives.

Much of the building of our brains comes through the use of skills and experience, which can happen at any age. One celebrated study of brain plasticity reported on the effects of professional experience amongst London taxi drivers (Maguire et al 2000, Woollett et al 2009). Their *posterior hippocampus*, a region associated with the type of visual-spatial memory processing required to navigate around a large city, was shown to increase with the number of years' experience the taxi drivers had accrued. Our ability to detect small but important changes in the structure of the brain over shorter periods is limited by present technology, but a study of the effects of adults attending a juggling course showed detectable changes in brain structure in just over three months (Draganski et al 2004). The plasticity of the brain is in sharp contrast with the common belief that our brains define a limit to our achievements – a belief that can, of course, be self-fulfilling. Indeed, in a study of adolescents, it was found that understanding about concepts such as plasticity improved both self-concept and achievement (Blackwell et al 2007).

London cabbies have a big hippocampus linked to navigating the complex layout of London.

Although our development arises from an interaction of our genes with the environment, the brain's plasticity demonstrates very clearly that our genes only partly determine our progress. External environmental factors strongly influence how our brains are constructed and an important external factor, perhaps the most important for many of us, is our education. That includes opportunities for training that present themselves throughout our working lives.

It all begins in the classroom: the decade of the brain

When the 1990s was designated the 'Decade of the Brain' in the US, it helped usher in a host of educational programmes that claimed a brain basis with little genuine input from scientists, such as the infamous 'brain buttons' whereby school children are told to simultaneously stimulate their neckbones and rub their tummies in order to increase blood flow to the brain (Dekker et al 2012). Unsurprisingly, the outcome was a mushrooming of unscientific brain-based entrepreneurs spreading neuromyths, rather than a new research-based approach to learning.

By the start of the next decade, however, fresh impetus towards genuine progress was provided by a small number of neuroscientists who began persistent efforts to advance neuroscience insights in the field of education.

In the UK in 2000, neuroscience researchers Sarah-Jayne Blakemore and Uta Frith were commissioned by the Teaching and Learning Research Programme (TLRP) to carry out a review of neuroscientific findings relevant to educators (Blakemore and Frith 2000). This review attacked a number of neuromyths, including those concerning sensitive periods, and highlighted some new areas of potential interest to educators, such as the role of sleep in learning. We'll address more neuromyths and misapprehensions later in this report.

But first, a number of insights from neuroscience have special relevance for education and translate into the workplace. There is a raging policy debate at the moment about child development and much of our appreciation of adult learning comes from this area of neuroscience.

2 Some key neuroscience insights for workplace learning

'A recent study of teenage learners showed a daily 30-minute exercise break improved their on-task attention during lessons within the week…'

We covered a few key areas in our 2012 report on how neuroscience can help learning; here we will look at several nuggets of neuroscience-based insight which can help develop learning in organisations. They are not particular to L&D – they help everyone in the organisation think about learning as an area for everyone.

Reading, writing and counting

Basic skills are critical to workplace learning. As our economy becomes more knowledge-based and as people are required to use words and numbers more regularly, even for basic jobs, it helps L&D, at least at a basic level, to know something about the processes by which people learn these key skills. Over the last five to ten years we have witnessed something of a step-change in neuro-education. Examples include identification of 'number sense' (a non-symbolic representation of quantity) as an important foundation of mathematical development and associated with a specific brain region called the *intraparietal sulcus* (Cantlon et al 2006). As we learn to count, our number sense integrates with our early ability to exactly represent small numbers (1 to 4) to 'bootstrap' our detailed understanding of numbers. That process can often go wrong as people encounter difficulties at school. While this problem would be easy to dismiss as the fault of primary schools, the need to engage at least with the need for this and with other learning difficulties such as dyslexia and poor literacy skills is increasingly important. This is especially the case when with programmes such as the CIPD's Learning to Work initiative we are rightly seeking to bring more of the young and long-term unemployed into the workplace. The skills required for many jobs are increasing and the skills of L&D practitioners also need to keep up. Union learning representatives (ULRs) have been at the forefront of supporting this kind of basic learning and, as is shown by the CIPD's 2013 *Learning and Talent Development* survey report, produced in partnership with Cornerstone OnDemand, this has been well received.

Getting in the swim: learning, well-being and exercise

Neuroscience is also shedding light in other areas of education, providing insight into the link between exercise and learning (Hillman et al 2008) and prompting re-examination of teenage behaviour (Blakemore 2008). Perhaps as importantly, it is now established scientists who are promoting neuroscience as having educational value (for example Blakemore and Frith 2005, De Jong et al 2009, Goswami 2004). Neuroscientists appear increasingly willing to involve themselves with exploring the implications of their work for 'real world' learning and, in 2007, the first issue of the journal *Mind, Brain and Education* was published, featuring articles by world-renowned neuroscientists and practising teachers.

At the same time, behavioural evidence of the beneficial effects of exercise on cognitive function is being augmented by neuroscience studies that are revealing the underlying processes (Hillman et al 2008). One study of healthy adults revealed increased levels of brain-derived neurotrophic factor (BDNF) after two three-minute sprints (Winter et al 2007). When compared with sedentary or moderate exercise conditions, participants showed a 20% increase in the speed of recall for words they learned immediately following their intense exercise. BDNF plays an important role in synaptic plasticity. It is an essential contributor to the process of long-term potentiation (LTP) – a process essential to the changes in neural connectivity considered to underlie learning. In this human study by Winter et al, data was based on peripheral measurements of these chemicals in blood samples, but this finding is consistent with non-human studies showing that BDNF in the brain mediates the positive effects of exercise on cognition (Vaynman et al 2004). Based on this scientific understanding of the processes, we can conclude that the benefits of exercise for learning derive from its aerobic content.

That suggests that the content of short exercise breaks during learning might be inspired by the types of aerobic exercise aimed at physical fitness. Indeed, a recent study of teenage learners showed a daily 30-minute exercise break improved their on-task attention during lessons within the week, while a brief five-minute exercise break did not (Kubesch et al 2009). Having identified some key learning issues around neuroscience, let us now look at how evidence from that area can sometimes misinform how we manage learning. This critical reflection is vital before we go on to unlock the enriching insights that neuroscience can bring to workplace learning.

Learning and the rewards of uncertainty

One of the biggest debates in management is the rightful place of reward. Decades-old research has shown, for example, that paying children to do something takes the fun out of the task and that artists working on commissioned paintings have less motivation than those working on a canvas which is yet to be sold (see Pink 2009 for a summary). Research at Bristol University confirmed children’s preference for uncertain reward in a learning task and, in a study with adults, demonstrated how it increased the emotional response to learning (Howard-Jones and Demetriou 2009). Researchers also studied how the points available for recalling the answer to a question were related to whether the answer was successfully recalled. It was found that an estimate of dopamine levels (not the number of points at stake) predicted whether newly learned information was recalled (Howard-Jones et al 2011). Further brain imaging research (Howard-Jones et al 2010) and work with educators and developers has now produced software informed by our understanding of the brain, and that helps turn almost any PowerPoint-based training session into an engaging game in which all learners compete together in teams. Learners respond to multiple-choice questions (either by putting their hand up or by using any Internet-connected device) in return for escalating numbers of points. However, winning requires both learning and luck and this creates a roller-coaster ride of emotion that supports learning. It also generates the type of motivational talk more often observed in sport, including the attribution of loss to bad luck and gains to skill. This is an exciting future avenue of neuroscientific research which can impact learning in the future.

This is one of the first examples of how experts from neuroscience, education and technology have worked together to provide resources and techniques suitable for training and talent development. It is important to emphasise, however, that the concepts involved here should continue to be (and are) the subject of ongoing research, because there is still so much we do not know. For example, although it’s established that the response of the brain to reward can enhance memory and learning, the exact processes by which this occurs are still to be determined. As we learn more about these processes, so both the concepts and their application in learning and training can be advanced.

3 Neuroscience, learning and development

'Neuroscience has helped identify the processes by which sharing ideas can help us be more creative.'

We now discuss some insights and research findings which should help L&D practitioners to understand the learning process better and frame their interventions accordingly. They include:

- innovation and creativity
- the impact of stimulants and sleep on learning states
- how the brain interacts with and is affected by technology, including electronic gaming and social technology.

Creativity and the innovative brain

Creativity and innovation are key 'employability' skills valued well beyond the creative industries (IBM 2010), but a lack of understanding of their cognitive processes has hampered efforts to teach and transfer the thinking skills involved. Neuroimaging of the creative brain is generating images that extend our understanding of the underlying processes and is also helping to demystify and 'concretise' creativity as a concept.

Functional magnetic resonance imaging (fMRI) has also been used to investigate a popular strategy for fostering creativity that works even when we are working independently: incorporating elements which are not related to each other into a creative outcome.

Creativity allows the combining of old knowledge to create new ideas relevant to the problem being solved, and it often occurs when we work together and exchange our thoughts. Neuroscience has helped identify the processes by which sharing ideas can help us be more creative. When we are trying to think of new ideas on our own, we must work hard at suppressing those within our immediate attention in order to avoid *fixating* upon them, as we search for original and novel associations instead. That is why working independently to create new ideas is associated with deactivation of a region of the brain associated with the automatic processing of whatever's in front of us. But it seems we don't have to do this so much when we work as a team; there is less deactivation (that is, more activation) of this region when working with other people, and this brain response is linked to a greater number of ideas available to each team member (Fink et al 2010).

Separately, a brain imaging study investigating the generation of stories from words that were unrelated, showed that such strategies can increase the brain activity associated with creative effort, supporting their likely effectiveness in fostering longer-term creative ability (Howard-Jones et al 2005). New technology to measure neural activity can also be used to stimulate creativity more directly by providing neurofeedback. This is the monitoring of one's own brain activity, usually carried out with a view to influencing it. Recent work investigating electroencephalography (EEG) neurofeedback concluded that it helped improve the performance ability of music students. Elite music students studying at a conservatoire received training using neurofeedback and improvements in their musical performance were highly correlated with their ability to progressively influence neural signals associated with attention and relaxation (Gruzelier and Egner 2004). Similar results have been found for dancers (Raymond et al 2005). Current theories about the operation of neurofeedback in this context suggest it may have potential benefit in a broad variety of areas (Gruzelier 2009).

The nurtured brain: stimulants and sleep

Though caffeine is classed as a stimulant, its tendency to suppress the cognitive function of habitual users is less well publicised. It influences our physiology and behaviour through blocking the action of *adenosine*, an inhibitory neurotransmitter. *Adenosine* is produced naturally by the body and its levels increase with each hour of wakefulness until we sleep, decreasing neural firing rates and inhibiting neurotransmitter release in a number of key brain regions.

Caffeine interrupts this action but, with regular consumption of caffeine, what are known as *counter-regulatory* changes occur in the adenosine system. These result in adverse effects when caffeine is withdrawn. Thus, when faced with cognitive tests at breakfast time, coffee drinkers appear unable to perform as well as non-caffeine users until after they have had their usual dose. There are clear links between ingesting caffeine and daytime sleepiness, and these effects are generally underestimated by the public and even by physicians (Roehrs and Roth 2008). Caffeine's effects on daytime sleepiness can derive directly from its suppression of cognitive function but also from caffeine's effect upon disrupting night-time sleep.

Avoiding sleep disruption, whether it is caused by caffeine or any other factor, is important for learning because, as well as ensuring we are fully alert to learn the next day, sleep also helps us retain what we have learned the day before. Due to this nightly consolidation process, our sleeping brains reproduce similar activities as those characterising whatever we experienced in our preceding hours of wakefulness (Maquet et al 2000). As well as helping us remember what we learned yesterday, sleep also helps us prepare to learn more and use what we know to generate insights (Wagner et al 2004).

Regular and sufficient sleep is thus essential for the brain to learn efficiently. There are many causes of sleep disruption other than caffeine, including the use of technology. Activities involving close bright screens are able to delay the brain's production of the hormone *melatonin* and so interrupt sleep-cycles in ways that, for example, a TV screen does not (Higuchi et al 2003, 2005). However, more important than the brightness of the screen is how the technology is being used, with the effect of playing late-night computer games influencing both objective and subjective measures of sleep quality. The impact on well-being of the various ways in which we use technology is another area where neuroscience is helping to provide insight.

The wired brain: neuroscience and the design, use and impact of technology

The future impact of neuroscience on learning may be greatest when it becomes combined with technology.

Computer-based cognitive training (or so-called 'brain training') has chiefly been found to improve performance on the training itself, rather than transferring to everyday application (Owen et al 2010). One important exception, however, is the training of working memory. Working memory describes our ability to hold information in our attention. It is a major constraint on our ability to learn new concepts and a good predictor of our professional and academic achievement. When young adults undertook a 19-day computer-based training programme that focused on developing working memory for 30 minutes a day, it was found that not only their working memory improved but also their fluid intelligence, that is, their ability to solve problems in new situations (Jaeggi et al 2008).

A convincing range of such results have led scientists to conclude that working memory can be trained (Klingberg 2010) and changes to prefrontal activations associated with working memory training have been identified (Olesen et al 2004). This bodes well for those wishing to develop more effective 'brain training' games – although so far the commercial response to these exciting developments has been slow.

How games seriously build skills

While the impact of computer-based brain training on other types of cognitive function has disappointed, off-the-shelf action video games have shown themselves surprisingly effective at developing a range of cognitive skills. They appear able to enhance performance on many visuomotor tasks, switching of visual attention, suppression of visual distraction, inference of an action's probable outcome and even contrast sensitivity (which is the primary factor limiting sight) (Caplovitz and Kastner 2009, Castel et al 2005, *'Games work by promoting an emotional response to learning based on uncertain reward.'*

Dye and Bavelier 2010, Dye et al 2009, Green and Bavelier 2003, 2006a, 2006b, Green et al 2010, Li et al 2009).

Unlike most attempts by scientists to devise bespoke software, these improvements transfer beyond the training task itself. Indeed, evidence for the transfer of these skills is bolstered by examples of action game training that has contributed to real-world expertise. An early study by Gopher et al (1994) showed ten hours of video game experience (designed specifically to study cognitive training) improved the subsequent flight performance of cadets. Following this work, video game training was incorporated into the regular training programme of the Israeli Air Force. (An echo of this finding can be found in recent informal reports that gamers make better drone pilots, see Smith (2010)). In a study of laparoscopic surgery, it was found that surgeons who had played video games in the past and were playing video games currently made 37% and 32% fewer errors (respectively) during examination of their surgical skills (Rosser et al 2007).

These results join several other studies showing individuals with previous regular engagement with video games have better video-endoscopic surgical skills (Grantcharov et al 2003, Tsai and Heinrichs 1994). Recent developments in video game technology may strengthen this relationship. For example, skill on a Nintendo Wii, with its motion sensing interface, has been shown to be a good predictor of laparoscopic skill (Badurdeen et al 2010).

This is a useful counterpoint to the unevidenced critiques of gaming which usually dominate. For L&D it is a new horizon which can help practitioners to engage learners. Such findings are encouraging some neuroscientists to suggest that video game technology may prove a promising method to *'take the brakes off adult plasticity'* (Bavelier et al 2010).

Indeed, neuroscience is already helping unravel some of the mysteries around games and providing a principled basis for the 'gamification' of learning. The ability of computer games to intensely engage their players may derive from the rapid schedule of uncertain rewards they present to the player and the potential of such a schedule to stimulate the reward system in the midbrain (Howard-Jones et al 2011). Indeed, the level of midbrain stimulation has been described by one study as comparable with that generated by ingestion of methylphenidate (Ritalin) or some amphetamines (Weinstein 2010). This stimulation of the brain's reward system is important because it can make learning more likely to occur

Surgeons with a history of playing video games made 37% fewer errors in tests of their surgical skills.

(Adcock 2006). The mechanisms by which this occurs are still the subject of research, but it is thought that increased uptake of midbrain dopamine can enhance *cortical synaptoplasticity* – that is, the process of changing connection strengths between neurons, which is also considered to be the basis of learning (Shohamy and Adcock 2010). This may help explain why computer games can be such effective teachers. Much of that impact is bound up with how games and other immersive experiences can stimulate the reward and pleasure centres of the brain. Games work by promoting an emotional response to learning based on uncertain reward.

The tools and traps of neuroscience

Neuroscience is a complex and interdisciplinary area of scientific research. Neuroscientists use complex statistical methods to interpret the brain images they create. Neuroscience is an area of deep expertise but the techniques of neuroscience are becoming more available to non-expert individuals outside the discipline. Tools such as functional magnetic resonance imaging (fMRI), electroencephalography (EEG) and magnetoencephalography (MEG) all help see images related to people's brain activity, but the results need to be interpreted with care and precision. Brain images often appear to suggest only small regions being activated, but these are the regions whose activity has exceeded a statistical threshold set by the experimenter. Rather than having brain regions exclusively dedicated to love, creativity or any other complex set of processes, these processes are distributed across many regions of the brain. In the box below we describe some research which should provide a cautionary tale for those seeking to engage with neuroscience.

> Adults who were naive about neuroscience were assigned to two groups and presented with good and bad explanations for psychological phenomena. One group were given irrelevant neuroscience in their explanations, and this group rated the bad explanations as good (Weisberg et al 2008). That tells us that neuroscience explanation can make poor research or dodgy conclusions look superficially compelling. So it is important to recognise that neuroscience can be used spuriously by non-experts. When we have that in mind we can use it as a source of insight while being continually mindful of how we frame its use.

Conclusion and practice pointers

- Concepts from neuroscience will increasingly impact on approaches taken to L&D.
- A basic understanding of neuroscience can help protect against proliferating neuromyths that undermine the effectiveness of L&D.
- Neuroscience is producing many insights with genuine relevance for L&D. Rather than being directly applied to L&D programmes, they are an exciting new source of evidence to be used alongside other perspectives in the ongoing development and evaluation of new approaches to L&D.
- In the future, the greatest impact of advances in neuroscience on L&D may arise in combination with advances in digital technology, especially through gaming.
- We should see neuroscience as a new area of insights to be carefully combined with those from other perspectives, rather than a silver bullet solution to all the issues within L&D.
- Practitioners can engage better with neuroscience by beginning to:

  – develop an understanding of some of the key concepts by accessing at least some of the material we have outlined
  – understand some of the key issues around early-years education which are the foundation for much neuroscience insight
  – take on board issues such as brain plasticity and the neuroscience of memory, retention and spatial skills
  – integrate into learning an appreciation of the role of both stimulants and sleep
  – be mindful and critical when apprising neuroscience insight with a view to the expertise of the authors, their willingness to work with experts and how their insights have been publicised; at least triangulate by seeing what neuroscientists are saying about such findings
  – understand the impact of neuroscience on creativity by developing approaches that break through fixation and tap the ability of groups to think differently
  – gain an understanding of the impact of gaming upon learning, as we predict that game-enriched learning will be a major aspect of learning and development in the very near future; key facts such as the research on pilots and surgeons, for example, show how games build skills
  – understand how learning is partly shaped by the uncertainty of rewards and build upon that insight.

Neuroscience has been around for a long time but its integration into learning is fairly new. Our survey research shows low awareness of this and other emerging areas of insight such as cognitive science, behavioural economics and decision science. Combined together these offer a new lens for both thought and practice. This report on neuroscience provides the foundation to build upon. In most cases our insight can be built through experimenting with some of the key insights we have outlined here. Insight can be enriched through reading on whatever medium and by accessing key publications such as *New Scientist* and *Scientific American Mind* regularly. We can also build insight by connecting and discussing with other professionals and tapping into the expertise of people like Dr Howard-Jones.

Dr John McGurk, CIPD

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