Title	Neuroscience and education: Promises and pitfalls
Author(s)	Kerry Lee
Source	*Asia Pacific Journal of Education, 23*(2), 109-119
Published by	Taylor & Francis

Running head: NEUROSCIENCE AND EDUCATION

This is an uncorrected preprint.
The published version can be obtained from the author or from
DOI:
10.1080/0218879030230202

Neuroscience and education: promises and pitfalls

Kerry Lee
National Institute of Education,
Nanyang Technological University

Abstract

Recent findings on the anatomical, physiological, and functional properties of the brain have stimulated debates on whether such findings provide meaningful contribution to education. In this article, I examined one aspect of the interface between neuroscience and education: "brain-compatible" strategies. Although some of these strategies such as providing a balanced diet in a child's early years are based on sound empirical data, others are based on shakier grounds. In particular, strategies regarding environmental enrichment and stress reduction in the classroom are based on questionable interpretation of the data. Because research in neuroscience is still in its infancy, it is not surprising some early attempts in translating research to practice involve a degree of over-generalisation. At this stage, it may be more beneficial to focus on neuroscience findings that relate to educationally relevant processes. Attention, learning, and memory are all fundamental processes studied in both disciplines. Research in neuroscience offers not only additional knowledge about such processes but also tools and methods that will allow us to refine our theories and, eventually, practice.

Neuroscience and education: promises and pitfalls

Recent advances in neuroscience have generated some debates on their relevance to education (e.g., Byrnes & Fox, 1998; Bruer, 1999). This article provides a selective review of the interface between the two disciplines. In particular, I examined several strategies that have been recommended as being "brain-compatible". Although some of these strategies are likely to be efficacious, others are based on controversial or over-generalisation of the original findings. Several areas in which neuroscience can make meaningful contributions to education are also discussed.

What is neuroscience?

Broadly defined, neuroscience is the study of the anatomical, physiological, and functional properties of the brain. In the 1990s alone, over 10000 research articles on various aspects of neuroscience were published (2002). A sub-discipline, cognitive neuroscience, focuses on the neural bases of cognition and behaviour. In terms of relevance to education, many of these studies focused on the identification of brain structures and functions involved in the learning process, e.g., attention, reading, and language (for review, see Cabeza & Nyberg, 2000). Others focused on the neural bases of learning and remembrance (Squire & Kandel, 1999).

Although sharing a common lineage, the focus of cognitive neuroscience differs from that of cognitive or behavioural psychology. Relationships between brain and behaviour can be studied using one of three approaches: mental, cognitive, and neural (Best, 1999). Cognitive psychology is largely concerned with the mental and cognitive approaches. The mental approach focuses on processes and experiences that are open to conscious self-examination. The cognitive approach focuses on both conscious and unconscious processes. In contrast, cognitive neuroscience focuses on the neurological bases of conscious and unconscious processes. In addition, the two disciplines differ in methodology and explanatory framework. Cognitive psychology relies on behavioural measures such as reaction time, accuracy of response, and analyses of errors. Explanations tend to be abstract and involve theoretical constructs. Although many of the same tools and theories are used in cognitive neuroscience research, it is characterised by the use of biomedical techniques, e.g., functional brain imaging, biochemical assays,

and genetic manipulation. Explanations tend to be couched in biological terms and focused on the anatomical and physiological properties of the brain.

Brain compatible education

The term brain compatible teaching first appeared in the education literature in the late 1970s (Hart, 1978; Fagan, 1979). The emphasis then was on the implications of brain hemisphericity, growth spurts, and learning styles. Initial excitement surrounding the identification of functional specialisation in the brain led to some exaggerated claims. For example, it is sometimes claimed that the average person uses only 10% of his or her brain or that the educational system teaches only to the left brain. Recent findings from functional brain imaging show that many different parts of the brain – and certainly more than 10% -- are activated when we engage in daily activities such as reading (Cabeza et al., 2000). Interests in brain compatible teaching faded in the late 1980s. With the recent explosion in neuroscience research, there is now renewed interest in the area.

A review of several practitioners' guides (e.g., Jensen, 1998; Sylwester, 1998) resulted in a list of commonly recommended brain compatible strategies. For the sake of brevity, many strategies that were based on obvious misinterpretations or that had no recognisable linkages to either neuroscience or the behavioural sciences were excluded from the list.

1) Provide parents with information regarding the importance of balanced diet in the early years of life when neural growth is rapid.
2) Schedule classes and school-based activities in accordance to developmental differences in sleep requirements and biological rhythms.
3) Rather than teaching facts and figures in isolation, embed them in a meaningful context.
4) To maximise attention, provide choice and novelty in the learning process,
5) Present material in a multi-modal fashion; integrate the learning of skills with the learning of academic subjects; integrate arts, music, and physical activities into the curriculum.
6) Provide an enriched environment that with challenges and feedback.
7) Minimise threats but engage and stimulate pupils emotionally as a part of instructions

Some of these strategies and recommendations are practicable and are potentially efficacious. For example, recent research showed that a 20 minutes nap in the early afternoon resulted in improved affect

and performance for young adults (Hayashi, Watanabe, & Hori, 1999; Hayashi, Ito, & Hori, 1999). If this finding generalises to adolescents and younger children, it has important implications for the scheduling of school timetables. For students attending full day schooling, one way to take advantage of this finding is to schedule a longer lunch break and to designate areas within the school where students can rest. Similarly, recommendations regarding nutrition are based on well-established data. In particular, both prenatal and postnatal nutritional deprivation can result in delays in brain development (Shonkoff & Phillips, 2000). Their precise effects depend on the severity and timing of deprivation. Deficiency in the third trimester, for example, tends to affect the development of glial cells, which provide physical and structural support to nerve cells in the central nervous system. Postnatal deficiency tends to result in reduction in brain size.

Other strategies are more closely linked to well-established cognitive behavioural findings than recent findings in neuroscience. Take, for example, the recommendation to embed information in a meaningful context. Research on verbal learning dating back to the 1930s showed that increases in meaningfulness result in increases in accuracy of recollection (McGeoch, 1930), and speed of learning (Underwood & Richardson, 1956). The recommendation to present material in a multi-modal fashion also has a long history. Cicero in the first century BC described the use of mnemonic techniques, e.g., the method of loci, to remember lists of verbal material. Even then, it was understood that verbal information can be remembered more accurately if they are translated into a systematic pictorial equivalence. More recently, Paivio (1969) explained such findings using the dual coding theory. He suggested that information is stored in two separate long-term memory system: one responsible for verbal, the other for non-verbal information. By translating verbal information into its non-verbal equivalence and learning both, chances of later retrieval is increased; as access to the original information can be obtained from either the verbal or the non-verbal store. Although subsequent studies have cast doubt on the validity of the dual coding explanation (Schwartz & Reisberg, 1991), the basic finding regarding the efficacy of imagery techniques remains robust.

One serious concern regarding some of these recommendations is that they are based on controversial interpretation of the data. In the next part of this article, I focus on two issues: critical periods and the effects of stress.

Critical periods & environmental enrichment

Some commentators argue for the use of environmental enrichment during the early childhood years to ensure optimal development. These early years are sometimes referred to as critical or sensitive periods. Proponents argue that environmental input during these early years is critical to later development. So much so that certain abilities can develop only during this period. Without appropriate environmental input, permanent disability is likely to result. The works of Wiesel and Hubel (1965; 1963) are often cited to support the critical periods hypothesis. In a series of studies, Wiesel and Hubel sutured one eye of kittens from soon after birth to about three months of age. When their eyes were reopened some months later, majority of cells in the visual cortex connected to the sutured eye failed to respond. A repetition of the procedure using adult cats did not result in such disabilities. Although these findings point to the importance of early environmental exposure, subsequent findings show that a critical period hypothesis cannot be sustained. Using a similar procedure, Olson and Freeman (1978) showed early deprivation did not result in permanent disability. Using intensive training and forced exposure to the target stimuli, they were able to demonstrate partial recovery of functions. These findings suggest that the critical period hypothesis should be revised to one that specifies periods of sensitivity, during which development can occur most readily.

In relation to issues of optimal development, a question of interest to educator is whether early enrichment results in better developmental outcome than a normal environment. Findings from Greenough and his colleagues are often cited in support of enrichment. In their studies (Turner & Greenough, 1985; Camel, Withers, & Greenough, 1986; Fuchs, Montemayor, & Greenough, 2001), they examined the effect of environmental complexity on neurological development. Rats were raised in enriched versus standard laboratory conditions. Results showed the enriched environments resulted in greater synaptic density or more dendritic branching in the rats' visual and temporal cortex than did the standard laboratory environments. A study conducted with middle-aged rats showed similar results (Green, Greenough, & Schlumpf, 1983). More recently, Young, During, and their colleagues (Young, Lawlor, Leone, Dragunow, & During, 1999) found environmental enrichment reduced cell death associated with normal aging by 45% in rats' hippocampus. The same environment also protected against the effect of a neurotoxin that induced seizures in rats raised in a control, non-enriched environment.

Do these findings show early enrichment results in superior brain development? According to Bruer (1999), the evidence is more equivocal than it seems and recommendations for early enrichment are based on questionable interpretations. He argued that a complex or enriched environment for laboratory rats is very different from the kind of enriched childhood environment advocated by their proponents. In Camel, Withers, and Greenough (1986), the super-enriched environment consisted of two cages: one contained water and the other food. The cages were connected by a maze containing barriers that changed daily. In contrast, rats in the standard laboratory environments were housed in individual cages with minimal toys. In Young's (1999) experiment, the standard laboratory housing for rats was enriched with running wheels, balls, and a choice of food. Rats in the standard condition had no toys and no choice in food supply. Bruer argued that in such experiments, the enriched environments were more stimulating only in comparison to the standard environments. In term of ecological validity, the enriched -- not the standard -- environment is more naturalistic. Stimuli equivalent to different mazes, toys, and food sources are likely to be encountered by a rat living in the wild. In contrast, the standard laboratory environment represents a level of stimulus deprivation unlikely to be found in most naturalistic environments. As such, the effects demonstrated by these experiments are less associated with enrichment as they are with deprivation.

Alternatively, it can be argued that if minimal enhancement such as the provision of toys can reverse the effect of deprivation, better enhancement should provide even better outcome. This extrapolation rests on the assumption that there is a linear relationship between enhancement and performance (Byrnes & Fox, 1998). Data from other domains of investigation show that relationships between environmental manipulation and performance are not always linear. Yerkes and Dodson (1908), for example, manipulated physiological arousal by manipulating the length of a submerged tubing that rats had to swim through to obtain rewards. They found an inverted U-shaped relationship between arousal and performance. Performance was at optimal when arousal was at a moderate level. In comparison, performance deteriorated when arousal was either too low or too high.

This critique is not meant to downgrade the importance of environmental effects. Both the behavioural sciences and cognitive neuroscience provide clear data on the danger of deprivation. However, conditions required for enhanced brain development have not been studied extensively. Much

of the behavioural research on human enrichment programmes recruited populations with a history of deprivation, e.g., the HeadStart programme. There is little data on the effect of enhancement on children with a "normal" upbringing. One question that needs to be overcome is what constitutes enriched environments. At present, enrichment is often defined in terms of differences with standard conditions, e.g., more toys, more choices. When a manipulation fails to result in behavioural or neurological improvement, it is easy to discard it as being insufficiently enriching. In this way, the definition of enrichment becomes circular; the only way to verify whether an environment is enriching is to examine its outcome. Within such a paradigm, it is possible to examine whether specific environmental manipulation results in an improvement in the dependent measure. However, whether environmental enrichment per se results in improvement can never be verified because no matter how enriching an environment is, there are always even more enriching conditions.

Stress and Emotion

Some commentators suggest that classrooms should not be stressful and pupils should be engaged emotionally to achieve optimal learning. The validity of this recommendation depends on how stress and emotions are understood. Cognitive-behavioural research shows that stress could have either a facilitative or a detrimental effect on learning. One of the key differentiating variables is the stage at which it is experienced. Under a high level of stress at acquisition, e.g. as induced by medical procedures, memory for the stress inducing event is more accurate than those experienced in non-stressful conditions (e.g., Goodman, Hirschman, Hepps, & Rudy, 1991). However, events that occurred prior to or after the onset of stress, and information peripheral to the stress inducing event are more difficult to remember (Christianson, 1992). Although stress at acquisition is generally associated with better remembrance, the opposite is true for stress experienced at retrieval. Using the courtroom as a stress inducing environment, Saywitz and Nathanson (1993) found impaired memory performance in children questioned in a courtroom rather than in a classroom. Research on the neurobiological effects of stress suggests these findings may be caused by the effect of epinephrine. Epinephrine is a hormone released by the adrenal glands when the body is at stress. Animal studies showed that memory for procedural information acquired immediately before administration of epinephrine is enhanced (McGaugh, 1995).

Several aspects of these findings are important for the educational setting. First, findings on the effect of stress at acquisition are not consistent with that recommended strategies. Findings from both behavioural and neurobiological studies suggest that stress at acquisition has a facilitative effect on later remembrance. Second, the level of stress used in most studies is unlikely to be experienced on a regular basis in most classrooms. In Goodman, Quas, Batterman, Riddlesberger, et al. (1994), for example, children underwent a urethral catheterisation as part of their prescribed medical treatment. A catheter was inserted into the urethra and children had to urinate in front of the medical staff; the procedure involved both physical discomfort and social embarrassment. Third, the facilitative effect of stress comes at a cost to long-term memory functioning. Although stress has a short-term facilitative effect on information acquisition, long-term exposure to stress is associated with deficits in memory that involves the hippocampus: a brain region believed to be involved in explicit memory and the processing of relational information. Bremner (1999) examined hippocampal functions in Vietnam veterans and child abuse survivors who experienced prolonged and high levels of stress. Results showed that both groups of patients exhibited reduced volume in their hippocampus. For the Vietnam veteran, this reduction in volume was correlated with deficits in their performances on neuropsychological tests. This pattern of findings is consistent with laboratory studies showing that both long-term exposure to stress or injection of corticosterone – a hormone produced in response to stress – resulted in neuronal damage; specifically dendritic atrophy and loss of synapses in the hippocampus of rats (e.g., Sousa, Lukoyanov, Madeira, Almeida, & Paula-Barbosa, 2000).

How can neuroscience contribute to education?

The previous section shows caution is needed in drawing classroom applications from cognitive neuroscience findings. Bruer (1999) argued that neuroscience is "a bridge too far" for education. He argued that development in neuroscience is still at a stage that has little direct application for educational practices. Although it is certainly true that neuroscience is still at an early developmental stage, ignorance of the neural bases of cognition will also likely prevent us from developing a full understanding of learning related processes. There are several areas where neuroscience can contribute to education.

1) Regardless of content area, education is about giving children optimal experiences to develop affectively, cognitively, and physically. Learning, memory, and motivation are fundamental processes

that are involved in every stage of such development. Because brain activities are necessarily involved in every instance of such processes, basic research on their neuroanatomical and neurophysiological bases will provide new insight on educational issues.

2) Byrnes and Fox (1998) argued that findings from cognitive neuroscience can serve to define parameters for educational theories. Because cognition must necessarily involve the brain, cognitive processes or constructs that cannot be supported by the brain will have no correspondence in reality. For example, Gardner (1983) proposed a symbolic and domain-specific view of intelligence with eight specific abilities: linguistic, logical-mathematical, visual/spatial, kinaesthetic, musical, interpersonal, intrapersonal, naturalist. His theory stipulated a broader definition of intelligence than that specified in traditional theories, which usually defines intelligence as either a generalised cognitive ability and/or a small number of domain-specific abilities. Cognitive neuroscience can help clarify the validity of Gardner's theory by examining the brain structures activated by tasks measuring the eight domain-specific abilities. Involvement of the same structures will lend support to the generalised ability position, whereas activation of separate structures will give weight to Gardner's conceptualisation. The available data are equivocal and the lack of standardised tasks to measure individual differences in the eight proposed intelligence renders it difficult to compare across studies. At present, it is clear there are specialised brain areas responsible for cognitive abilities that were developed early in the evolutionary timeframe, e.g., Broca's and Wernickes' areas for language processing, the motor strip for motor skills. For higher cognitive abilities such as mathematics or music, the data is more equivocal. Comparisons of musical versus linguistic processing identified both similarities and differences: depending on whether one focuses on the semantic/melodic or the syntactic/harmonic aspects of processing (Besson M & Schön D, 2001). In a recent review, performance of many everyday cognitive functions, e.g. problem solving, memory encoding and retrieval, were found to activate similar parts of the brain, with degree of similarity being determined by the precise nature of the tasks (see Cabeza et al., 2000; Gabrieli, 1998). These findings show that rigorous operationalisation of cognitive processes is vital if one is interested in locating their neural correlates. When one refers to cognitive processes in general terms, such as linguistic or musical processing, one will find many of the same neural structures being involved. However, as Besson and

Schön demonstrated, more precise identification of causal sub-components will often reveal a high degree of modularity.

3) Brain imaging techniques, e.g., electroencephalogram and functional magnetic resonance imaging fMRI, can be used to supplement behavioural measures of intervention effects. One example is a recent study on an intervention programme for dyslexia. In addition to behavioural measures, Berninger and her colleagues (Berninger & Corina, 1998; Richards et al., 2000) measured brain lactate metabolism in control versus dyslexic children using fMRI. Before intervention, children were scanned during the performance of a phonological task. Dyslexic children showed higher lactate levels than did the controls. After intervention, children were tested once again using both imaging and behavioural measures. Dyslexic children showed improvement in the behavioural aspect of reading and exhibited similar lactate levels as did the controls. By demonstrating a physiological correlate to the behavioural improvement, this finding provides not only data on the efficacy of intervention but also data on the probable mechanisms responsible for improvement.

4) One of the aims of education is to identify individual differences in abilities and to maximise each child's talents. A key to this approach is assessment. To cater to children of different abilities, educators have to be able to identify those abilities. At present, decisions regarding such abilities are made with formal examinations and cognitive-behavioural measures such as intelligence tests. Neuroscience and neuropsychology in particular offer additional information and tools for these critical decisions. From neuropsychology, there are behavioural tests that offer more discriminating measures of children's abilities, e.g., Wisconsin Card Sorting Test for measuring strategy formation and usage. Although most of these tests were designed to measure cognitive disabilities, some recent studies have used them to measure individual differences amongst normal children. Bull, Johnston, & Roy (1999), for example, showed the Wisconsin Card Sorting Test provided better prediction to mathematical abilities than did conventional measures of intelligence.

Conclusions

Even at this early stage, neuroscience can provide a meaningful contribution to education. Apart from the more obvious linkages related to treatment of learning disabilities, several areas were identified in this article. Regarding brain compatible education, the history of neuroscience is short and it is perhaps

unreasonable to expect such early findings to be directly applicable to the classroom setting. Yet, commentators have attempted to draw this link. Although admirable, it should be noted that such applications are often based on experimental paradigms that are distant from classroom situations. Because the association between applications and the science upon which they are based is tenuous, the two are often linked by a good deal of speculation and broad generalisation. As with other adoption of emerging technologies: users beware.

References

American Psychological Association (2002). PsychINFO [Computer database]. Washington, DC: APA.

Berninger, V. W. & Corina, D. (1998). Making cognitive neuroscience educationally relevant: Creating bidirectional collaborations between educational psychology and cognitive neuroscience. *Educational Psychology Review, 10,* 343-354.

Besson M & Schön D (2001). Comparison between language and music. *Annual New York Academy Science, 930,* 232-258.

Best, J. B. (1999). *Cognitive Psychology*. (5 ed.) Belmont, CA: Wadsworth.

Bremner, J. D. (1999). Does stress damage the brain? *Biological Psychiatry, 45,* 797-805.

Bruer, J. T. (1999). Education and the brain: a bridge too far. *Educational Researcher, 26,* 4-16.

Bull, R., Johnston, R. S., & Roy, J. A. (1999). Exploring the roles of the visual-spatial sketch pad and central executive in children's arithmetical skills: Views from cognition and developmental neuropsychology. *Developmental Neuropsychology, 15,* 421-442.

Byrnes, J. P. & Fox, N. A. (1998). The educational relevance of research in cognitive neuroscience. *Educational Psychology Review, 10,* 297-342.

Cabeza, R. & Nyberg, L. (2000). Imaging cognition II: An empirical review of 275 PET and fMRI studies. *Journal of Cognitive Neuroscience, 12,* 1-47.

Camel, J. E., Withers, G. S., & Greenough, W. T. (1986). Persistence of visual cortex dendritic alterations induced by postweaning exposure to a "superenriched" environment in rats. *Behavioral Neuroscience, 100(6)*, 810-813.

Christianson, S. A. (1992). Emotional stress and eyewitness memory: A critical review. *Psychological Bulletin, 112,* 284-309.

Fagan, E. R. (1979). Brain Hemispheres: Panacea 2001? *Clearing-House, 52,* 407-410.

Fuchs, J. L., Montemayor, M., & Greenough, W. T. (2001). Effect of environmental complexity on size of the superior colliculus. *Behavioral & Neural Biology, 54,* 198-203.

Gabrieli, J. D. E. (1998). Cognitive neuroscience of human memory. *Annual Review of Psychology, 49,* 87-115.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences.* New York, NY: Basic Books.

Goodman, G. S., Hirschman, J. E., Hepps, D., & Rudy, L. (1991). Children's memory for stressful events. *Merrill Palmer Quarterly, 37,* 109-157.

Goodman, G. S., Quas, J. A., Batterman Faunce, J. M., Riddlesberger, M. M., & et al. (1994). Predictors of accurate and inaccurate memories of traumatic events experienced in childhood. Special Issue: The recovered memory/false memory debate. *Consciousness and Cognition: An International Journal, 3,* 269-294.

Green, E. J., Greenough, W. T., & Schlumpf, B. E. (1983). Effects of complex or isolated environments on cortical dendrites of middle-aged rats. *Brain Research, 264,* 233-240.

Hart, L. A. (1978). Brain-Compatible Teaching. *Today's-Education, 67,* 42-45.

Hayashi, M., Ito, S., & Hori, T. (1999). The effects of a 20-min nap at noon on sleepiness, performance and EEG activity. *International.Journal of Psychophysiology, 32,* 173-180.

Hayashi, M., Watanabe, M., & Hori, T. (1999). The effects of a 20 min nap in the mid-afternoon on mood, performance and EEG activity. *Clinical.Neurophysiology, 110,* 272-279.

Jensen, E. (1998). *Teaching with the brain in mind.* Alexandria, Va.: Association for Supervision and Curriculum Development.

McGaugh, J. L. (1995). Emotional activation, neuromodulatory systems, and memory. In D.L.Schacter (Ed.), *Memory Disortion* (pp. 255-273). Cambridge, MA: Harvard University Press.

McGeoch, J. A. (1930). The influence of associative value upon the difficulty of nonsense-syllable lists. *Journal of Genetic Psychology, 37,* 421-426.

Olson, C. R. & Freeman, R. D. (1978). Monocular deprivation and recovery during sensitive period in kittens. *Journal of Neurophysiology, 41,* 65-74.

Paivio, A. (1969). Mental imagery in associative learning and memory. *Psychological Review, 76,* 241-263.

Richards, T. L., Corina, D., Serafini, S., Steury, K., Echelard, D. R., Dager, S. R., Marro, K., Abbott, R. D., Maravilla, K. R., & Berninger, V. W. (2000). Effects of a phonologically driven treatment for dyslexia on lactate levels measured by proton MR spectroscopic imaging. *AJNR American Journal of Neuroradiology, 21,* 916-922.

Saywitz, K. J. & Nathanson, R. (1993). Children's testimony and their perceptions of stress in and out of the courtroom. *Child Abuse and Neglect, 17,* 613-622.

Schwartz, B. & Reisberg, D. (1991). *Learning and Memory.* New York: NY: Norton.

Shonkoff, J. P. & Phillips, D. A. (2000). *From Neurons to Neighborhoods: The Science of Early Childhood Development.* Washington, DC.: National Academy Press.

Sousa, N., Lukoyanov, N. V., Madeira, M. D., Almeida, O. F., & Paula-Barbosa, M. M. (2000). Reorganization of the morphology of hippocampal neurites and synapses after stress-induced damage correlates with behavioral improvement. *Neuroscience, 97,* 253-266.

Squire, L. R. & Kandel, E. R. (1999). *Memory: From Mind to Molecules.* New York: Scientific American Library.

Sylwester, R. (1998). *Student brains school issues.* Arlington Heights, IL: Skylight Training and Publishing.

Turner, A. M. & Greenough, W. T. (1985). Differential rearing effects on rat visual cortex synapses: I. Synaptic and neuronal density and synapses per neuron. *Brain Research, 329,* 195-203.

Underwood, B. J. & Richardson, J. (1956). The influence of meaningfulness, intralist similarity, and serial position on retention. *Journal of Experimental Psychology, 52,* 119-126.

Wiesel, T. N. & Hubel, D. H. (1963). Single-cell responses in striate cortex of kittens deprived of vision in one eye. *Journal of Neurophysiology, 26,* 1002-1017.

Wiesel, T. N. & Hubel, D. H. (1965). Comparison of the effects of unilateral and bilateral eye closure on cortical unit responses in kittens. *Journal of Neurophysiology, 28,* 1029-1040.

Yerkes, R. M. & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology of Psychology, 18,* 495-523.

Young, D., Lawlor, P. A., Leone, P., Dragunow, M., & During, M. J. (1999). Environmental enrichment inhibits spontaneous apoptosis, prevents seizures and is neuroprotective. *Nature Medicine, 5,* 448-453.

Author Note

Correspondence concerning this article should be addressed to Kerry Lee, Psychological Studies Academic Group, National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, Singapore 637616. Electronic mail should be directed to klee@nie.edu.sg. Thanks to Susanna Bay for research assistance and David Hung for his comments and insight.