Translating Across Methodologies: Neuroscience and Education

George Aranda

Deakin University

George.aranda@deakin.edu.au

Educational Neuroscience is an emerging scientific field that seeks to bring together a number of disciplines with the aim to explore the interactions between biological processes and education. Neuroscience has already provided insights into neural mechanisms related to reading, numerical cognition, attention and related disorders. Further research may provide insight to neural 'learning markers', that identify processes not observable behaviourally, and early identification of potential learning difficulties. But to explore more complex processes, such as replicating classroom environments; learning over longer periods; incorporating sociocultural influences – new research methodologies will need to be created. This paper will explore the underpinnings of Educational Neuroscience and the methodological challenges faced by this emerging field.

Educational Neuroscience

Educational Neuroscience (also known as Mind Brain and Education and Neuroeducation (Petitto & Dunbar, 2004)) is an emerging field. It is seen to come out of allied research fields such as Educational Psychology, Cognitive Neuroscience and Neuroscience. *Educational Psychology* refers to a branch of psychology, which focuses on teaching and learning methods and cognitive development in an educational setting. *Cognitive Neuroscience* is a scientific field, which seeks to identify and examine the neural substrates underlying cognition. *Neuroscience* is field of biology that examines the functioning of the brain at a cellular level. Educational Neuroscience has been put forward as a transdisciplinary field that can bring together a varied group of researchers with interests in education, learning, teaching, the brain and policy (Petitto & Dunbar, 2004). Its aim is to generate research that will provide a new account of teaching and learning that can inform education.

This field has already achieved some success with the assessment, treatment and educational interventions of psychological learning disorders such as attention deficit and hyperactivity disorders and autism, and atypical language disorders such as dyslexia (Petitto & Dunbar, 2004).

Figure 1.0 highlights the idea of the emergence of Educational Neuroscience (analogous to Mind, Brain and Education Science), from the fields of psychology, education and neuroscience. It is the interaction between each of these disciplines which will allow this emerging field to inform educational practice and theory.

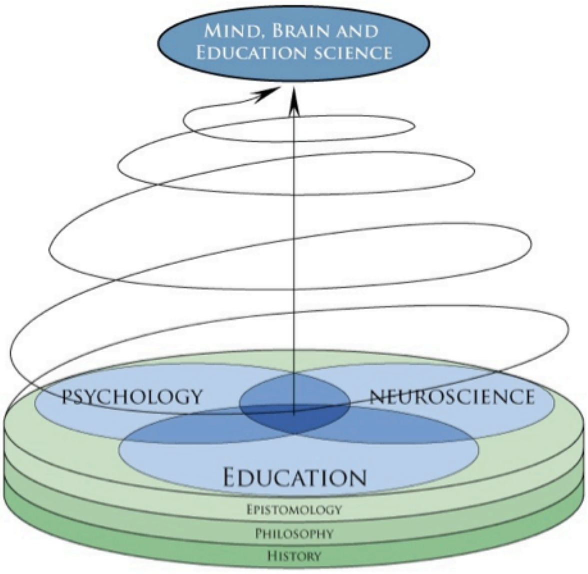


Figure 1.0 Source: Tokuhama-Espinosa, 2010

This paper is being written in conjunction with Russell Tytler's (2013) paper which focuses on a the new Australian Research Council Project – the Science of Learning Research Centre: http://www.slrc.org.au/ (accessed, 10th December, 2013)

> SLRC is a Special Research Initiative of the Australian Research Council. In the Centre researchers in education, neuroscience and cognitive psychology are working together with teachers to understand the learning process. – Science of Learning Research Centre (2013)

This centre is the result of a collaboration between seven Australian universities and the Australian Council for Educational Research (ACER) and includes 25 chief investigators. They are seeking ways in which education and neuroscience can inform each other. For the purposes of this paper, I will focusing on two techniques that are predominantly used in cognitive neuroscience and would be indispensible in Educational Neuroscience.

Functional Magnetic Resonance Imaging (fMRI) is a technique that has been used in cognitive neuroscience over the last 20 years. Magnetic Resonance Imaging is an imaging technology that allows scanning of the body with millimeter precision. The *functional* aspect of fMRI is this ability to examine what is going on within the brain over regular intervals while participants are engaged in cognitively demanding tasks within the scanner. This repeated measurement of brain activity allows researchers to examine what parts of the brain are involved with particular cognitively demanding tasks (Huettel, Song & McCarthy, 2009).

Electroencephalography (EEG) is a second technique that is commonly used in cognitive neuroscience. EEG is a technique that records electrical activity from the brain, measured using electrodes attached to the scalp. Similar to fMRI it measures changes in the brain activity while a participant is engaged in a cognitively demanding task (Kandel, Schwartz & Jessel, 2000)

Both techniques have their own pros and cons. fMRI has lower temporal resolution as it is only able to measure changes in metabolic brain activity over a period of seconds (Huettel et al., 2009), however, it has high spatial resolution and is able to measure changes in brain activity to the millimeter level. EEG, on the other hand, has a high temporal resolution and is able to continuously measure changes in electrical brain activity down to milliseconds. However, it suffers from indirectly measuring electrical activity from the brain, where the signal passes through skin and skull, reducing its spatial resolution. (Kandel et al., 2000)

Both techniques have their limitations. Both require repeated measures where a participant is required to go through a task repeatedly so that the minute changes can be recorded. Both techniques record tiny changes in brain activity and require repeated measurement so that when averages of brain activity are performed, consistent activity (such as the brain's consistent response to stimuli) can be distinguished and interpreted, while the brain's normal background noise (brain activity not related to the stimuli) is greatly reduced. This averaging is important, so that researchers can be confident that what they have recorded is a measured effect and not due to chance.

Example. Below are images from the author's PhD dissertation (Aranda, 2008). The thesis examined the electrical brain activity of individuals diagnosed with schizophrenia when matching faces based on their identity of emotional expression. In condition one, participants decided whether two faces were the same or different based on their depicted identity, and in condition two they viewed exactly the same faces and made the same decision based on the depicted emotion. Table 1 demonstrates the two overarching categories, identity (vertical axis) and emotion (horizontal axis) and the various subcategories that were used.

Table 1
Examples of the four types of face-pairs (Ekman faces, from Aranda, 2008)

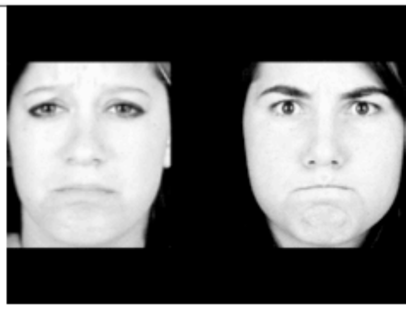
		Identity	
		Same Identity	Different Identity
Emotion	Same Emotion		
	Different Emotion		

Figure 2 below illustrates how the face-pairs were used in the EEG experiment. Face-pairs were presented on-screen for 3000 ms with an equiluminant image (grey squares) in between each face-pair for 1000 ms. The equiluminant images were used to minimize differences in electrical brain activity based on changes in the brightness of the images. To obtain sufficient electrical brain activity that could be used in statistical analyses, 80 face-pairs were presented in each condition.

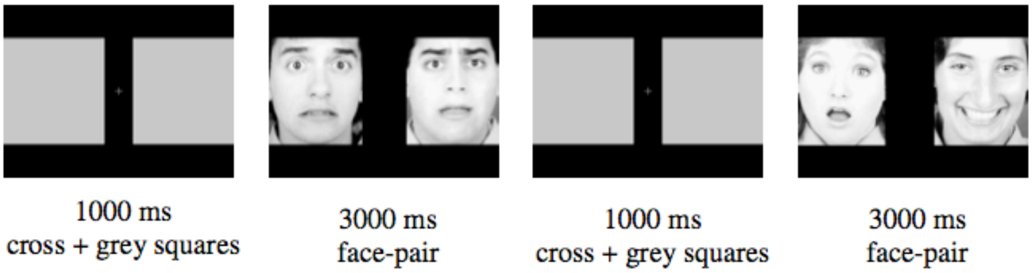


Figure 2: Summary of Task Presentation (from Aranda, 2008)

The above highlights that cognitive neuroscience paradigms are constrained by 1) the need to use repeated measures to collect sufficient data that can be statistically analysed; 2) that the presentation of stimuli needs to be consistently presented (although the stimuli can be presented in other modalities such as auditory or taste); 3) that the presentation of the stimuli in the experiment focuses on removing as much extraneous information as possible. This provides a challenge in an education environment where information extraneous to the task is ever present.

Neuromyths

One area that may benefit from an interface between neuroscience and education is neuromyths. Neuromyths may be defined as irresponsible extrapolations of neuroscience findings applied into the field of education (OECD, 2007) Sometimes these extrapolations are taken so far beyond their original context that they unrecognizable.

Such neuromyths would include:

Left Vs Right Brained: The idea that people have characteristic ways of processing the world depending on which hemisphere of the brain they predominantly use. Originally based on ideas of hemisphericity from language and visuospatial research in the 60s. However, more modern thinking suggests much greater interaction of the hemispheres on many tasks (OECD, 2007).

Critical Periods: The idea that there are critical periods in life where one must learn something, e.g. language, outside of which a level of the skill will never be realized. Subsequent research has demonstrated that high-level learning can occur outside these periods (OECD, 2007).

Enriched Environments: The idea that providing highly enriched environments to young children before the age of three will promote learning. This research was originally conducted in the visual system of kittens and monkeys up to the age of three. However, this three-year period is considered adolescence in monkeys and it is unclear whether this is consistent with three years in humans or continues into human adolescence (OECD, 2007).

Synaptogenesis: Related to Enriched Environments, it is the idea that there is a great growth of dendrites and synaptic connections in the first three years of life. At this age we have more neurons than at any other time of life before *synaptic pruning* occurs and the number of neurons is reduced to more adult levels. It is seen as important to have learning during this period before pruning occurs. However, it is unclear how synaptogenesis relates to learning and whether learning at this time will eventuate in greater learning at later time periods (Bruer, 1997)

Female Vs Male Brains: The idea that male and female brains are fundamentally different is intuitively appealing. It may also seem true when considering cognitive profiles about how boys and girls think differently. But when applied to learning, there is no evidence that boys and girls learn differently at a neural level (OECD, 2007)

One potentially important role for Educational Neuroscience would be to examine the claims of neuromyths, such as those listed above. It would be possible to develop methods by which to test the above claims and provide evidence to the validity (or lack thereof) of the techniques or interventions in school settings.

Example of Educational Neuroscience: Bilingualism

For Educational Neuroscience to play an important role in education, research needs to be designed that will provide useful information that can be applied at an organizational and curricular level. A two-way street between education and neuroscience needs to be developed where both fields are mutually informed by the research.

One purpose of Educational Neuroscience is to apply cognitive neuroscience and educational psychology methods to tackle issues relevant to education. One example has been discussed by Pettito & Dunbar (2004), which addressed the long-held view that exposing children to a second language 'too early' would be detrimental to their learning in their majority language (e.g. English within the United States). This is consistent with educational policy within US schools where second languages are taught in secondary school. However, in some US states in the 2000s, such a Massachusetts, this was extended, and public-school classes were conducted in English-only. This was significant in that Spanish was therefore withheld from young children from Spanish-speaking homes.

In line with the idea of teaching a second language too early, parents often choose to have their child learn one of the family's languages at school in the belief that it is better to firmly establish one language, avoiding the confusion of learning two languages at an early age. They worry that learning two languages at the same time would mean their child is less proficient in either of the languages compared to monolingual speakers (Petitto & Dunbar, 2004)

Educational Psychology Evidence

Part of the reason for this choice regarding language learning at an early age is the notion as to whether children have a *fused* representation of language, where they don't differentiate between the languages being spoken to them until around the age of three years old. This is supported by the notion that there is a protracted language development compared to monolingual peers, as they sort out the two input languages. In contrast, there is evidence that children do differentiate between the languages spoken to them early in life, although the exact age at when his happens is unclear. (Petitto & Dunbar, 2004)

Over a number of studies, it was reported that bilingual exposure below the age of five was important for the development and mastery of both languages; that bilingual children exposed to both languages achieved milestones in both languages at the same time as monolingual peers; that monolingual children between two and nine years of age can achieve the fundamentals of the second language within the first year of exposure (Petitto & Dunbar, 2004).

Together, these studies indicate that the introduction of a second language does not 'contaminate' the learning and development of the first language.

Brain Imaging of Monolinguals and Bilinguals

Brain studies were conducted to examine what regions of the brain were involved with processing different languages in bilingual adults who had been exposed to language before the age of five or after. Using fMRI scanning, it was reported that those who had learned the two languages before the age of five processed both languages in overlapping language areas within the left-hemisphere of the brain, which was consistent with the language regions universally observed with monolinguals (Petitto, Kovelman, Baker & Grafton (in press), cited by Petitto & Dunbar, 2004). They were highly competent in both languages on classic behavioural language tasks. However, late-exposed bilinguals demonstrated different areas of brain activity broadly across the frontal regions of the brain. The authors concluded that the regions involved were consistent with working memory and inhibitory regions of the frontal lobe. Behavioural measures indicated that late-bilinguals frequently exhibited more cognitive effort. These findings suggest that those who learn a second language later in life use different strategies compared to those who learn their second language before the age of five.

The involvement of brain imaging allowed the authors to more directly examine which parts of the brain were involved in bilingual processing of language and how the functioning of those parts was different based on what age of speaker was when they started learning the second language. It allowed the authors to make interpretations that went beyond what was observable by behavioural measures alone and could also be supported by previous neuroscience research.

Educational Neuroscience Implications for Policy

Returning to the earlier idea that learning a second language early might be detrimental to the primary language, the results of educational psychology and cognitive neuroscience studies indicate that the learning of a second language early should not be considered harmful.

> "Our findings suggest that early bilingualism offers no disadvantage; on the contrary, young bilinguals may be afforded a linguistic and cognitive advantage." (Petitto & Dunbar, 2004)

Based on this evidence, it would seem appropriate to re-examine the policy of teaching English-only classes at public schools in the US, a policy that was introduced in Massachusetts in 2002 and continues to this day.

Isn't it Obvious?

It does seem that what emerges from some neuroscientific research based on brain imaging techniques tells us what we already know, or the tasks investigated are simple compared with the learning of complex knowledge or skills required in school. (Mason, 2009)

The initial results that come from neuroimaging studies might seem basic and irrelevant to education at the moment. But it's important to acknowledge that they *should* replicate findings and be consistent with current knowledge. It is necessary for new techniques and technology to confirm what we already know. It is only as we build on the body of knowledge that we already understand that we can develop new methodologies and techniques that can move us into the future, and the unknown.

Theory to Method

Educational Neuroscience is proposed to be a discipline that emerges from Educational Psychology, Cognitive Neuroscience and Neuroscience. But is it a "bridge too far"? Bruer (1997) questions whether we need neuroscience to inform us about learning and whether the claims made by neuroscientists can help educational practice in any meaningful way.

Educational Neuroscience does have some way to go to provide meaningful information to education, but the two disciplines can inform each other. Education can provide instances, contexts, ideas and assumptions that would benefit from examination via new tools and methodologies that educational psychology and cognitive neuroscience can provide. On the other hand, these new tools and methodologies can confirm what we might already know and provide new ways of thinking that had not been previously considered or were even possible to know. These new answers and questions can then inform educational policy and teaching processes in the classroom (Mason, 2009). While Educational Neuroscience has some way to go legitimatizing itself as a discipline, it provides a fresh new perspective on education and new challenges to educational psychology and cognitive neuroscience that are of a level of complexity beyond what it has typically worked on in the past. Both fields can benefit from this interface and be enriched by the relationship.

References

Aranda, G. (2008) *Functional Brain Electrical Activity Imaging during Affective Facial Processing in People with Schizophrenia* (Unpublished doctoral dissertation). Swinburne University of Technology, Melbourne, Australia.

Bruer, J. (1997) Education and the Brain: A Bridge Too Far, *Educational Researcher*, 26, 8, 4-16.

Huettel, S. A.; Song, A. W.; McCarthy, G. (2009), *Functional Magnetic Resonance Imaging* (2 ed.), Massachusetts: Sinauer

Kandel, E., Schwartz, J. & Jessell, T. (2000) *Principles of Neural Science* (4 ed.), McGraw-Hill Medical.

Mason, L. (2009) Bridging neuroscience and education: A two-way path is possible. *Cortex, 45,* 548-549.

OECD (2007), *Understanding the Brain: The Birth of a Learning Science*, OECD Publishing. doi: 10.1787/9789264029132-en

Petitto, L., & Dunbar, K. (2004) New findings from Educational Neuroscience on Bilingual Brains, Scientific Brains and the educated mind. In Fischer, K.; Katzir, T. *Building Usable Knowledge in Mind, Brain & Education*. Cambridge University Press.

Science of Learning Research Centre (2013) *Science of Learning Research Centre Homepage* http://www.slrc.org.au/ (accessed, 10th December, 2013)

Tytler, R. (2013) Aligning socio-cultural, classroom perspectives on learning with neuroscience perspectives and findings. 2013 Deakin Symposium: Contemporary Approaches to Research in Mathematics, Science, Health and Environmental Education, Deakin University, Melbourne, Australia.

Tokuhama-Espinosa, T. (2010). *Mind, brain, and education science: A comprehensive guide to the new brain-based teaching*. New York: Norton.