Educational Philosophy and Theory, Vol. 43, Nos. 1–2, 2011
doi: 10.1111/j.1469-5812.2010.00705.x

Connecting Education and Cognitive Neuroscience: Where will the journey take us?

DANIEL ANSARI[1], DONNA COCH[2] & BERT DE SMEDT[1,3]
[1]*Department of Psychology, University of Western Ontario, Canada*
[2]*Department of Education, Dartmouth College, USA*
[3]*Department of Educational Sciences, Katholieke Universiteit Leuven, Belgium*

Abstract 1

••.

Keywords: ••.

Introduction

There has been tremendous growth in the scientific study of the human brain over the last 15 years, and a concomitant excitement surrounding new findings about how the brain works. The burgeoning availability of non-invasive tools and techniques used to measure brain function during cognitive tasks led to the creation of the field of Cognitive Neuroscience in the early 1990s, and the continuous development of such tools has supported the remarkable growth of this field since then. Broadly speaking, the aim of Cognitive Neuroscience is to elucidate how the brain enables the mind (Gazzaniga, 2002). In other words, the goal of Cognitive Neuroscience is to constrain cognitive, psychological theories with neuroscientific data, thereby shaping such theories to be more biologically plausible. Throughout the 'Decade of the Brain' in the 1990s and into the 21st century, cognitive neuroscience research has been widely popularized, with colorful brain images filling the 'Science and Nature' sections of daily newspapers frequently.

Recently, research in cognitive neuroscience has attracted the attention of educationalists. Naturally, people interested in learning and education might want to know how results from relevant cognitive neuroscience research could be applied in the classroom. Given that the brain is the 'organ of learning' it seems logical that knowledge about how the brain works should be able to inform education. Indeed, there is a growing body of cognitive neuroscience research in areas that are of potential key interest to education, such as research on the neural correlates of reading (e.g. Pugh *et al.*, 1996; Turkeltaub *et al.*, 2003) and mathematics and number processing (e.g. Dehaene *et al.*, 2003; Dehaene *et al.*, 1999). Such research has generated great hopes amongst some for a revolution in education in which results from the neuroscience laboratory positively

Published by Blackwell Publishing, 9600 Garsington Road, Oxford, OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA

transform the classroom. In fact, a number of journal publications have reviewed and discussed evidence from cognitive neuroscience that might be relevant to education (Ansari & Coch, 2006; Blakemore & Frith, 2005; Goswami, 2004, 2006; Posner & Rothbart, 2005; Stern, 2005). Further evidence for the growth in excitement surrounding the potential connection between neuroscience and education is the creation of a new international society for Mind, Brain, and Education (http://www.imbes.org/) accompanied by the launch of a peer-reviewed journal of the same name. Of course, the present special issue is further testament to growth in the emerging field of Mind, Brain, and Education.

These are certainly exciting times, in which the potential for real and meaningful connections between education and cognitive neuroscience is strong and widely supported (although cf. Bruer, 1997). However, in the context of this wave of excitement surrounding such potential connections, a number of questions have been left largely unconsidered in a systematic fashion: exactly how will cognitive neuroscience inform education, and how will education inform cognitive neuroscience? At what levels will such connections be most fruitful, in terms of generating useable knowledge? What practical changes need to be undertaken in order to support such sustainable connections? What will be the roles of cognitive neuroscientists, educators, funding agencies, and policy makers in this endeavor? How will existing philosophical boundaries between so-called 'applied' (i.e. in the real world of the classroom) and 'basic' (i.e. in the controlled world of the laboratory) research be overcome?

We discuss some of these critical questions in the present paper. We feel that careful consideration of these issues is necessary in order to facilitate and sustain connections between education and cognitive neuroscience. We contend that without concerted thinking about *how* to build bridges and maintain them, the very idea that cognitive neuroscience and education can interact to improve education will become just another educational fad, a footnote in the history of the movement towards research-based education. In considering these critical questions, we also discuss the potential future of the emerging field of Mind, Brain, and Education—where this journey will take us—and some important constraints that should guide us along the way.

How Might Cognitive Neuroscience Inform Education?

According to one perspective, the ideal connection between education and cognitive neuroscience would be as follows: cognitive neuroscientists would conduct experiments and then educators would directly apply the results of this research in their teaching; there would be a seamless flow from the laboratory to the classroom. Indeed, there are frequently calls for such direct links and the enterprise of Mind, Brain, and Education is considered by some to have failed if such links cannot be achieved. At a recent conference one of us was asked what he would tell teachers to do on the basis of his research results. When he answered that he would like to first hear from teachers what *they* thought about the results and how *they* thought the findings might or might not be informative, there was visible disappointment on behalf of the questioner that a straightforward recipe derived from the research was not forthcoming. Here is an example of a philosophical divide that has plagued the history of education as a science; as Condliffe Lagemann notes: 'When educational scholarship was professionalized, it was viewed with contempt by noneducationalists; when it was discipline-based, it was shunned by students, who had wanted "recipes for practice"' (2000, p. 179).

We contend that such expectations for silver bullets, for research-based 'fixes' of educational problems, for easy-to-follow 'recipes for practice' based on cognitive neuroscience findings, are bound to be disappointed quickly; moreover, we argue that such expectations are unrealistic and threaten to erode efforts to forge useful connections between education and neuroscience. Indeed, there exists a growing industry of so-called 'brain-based learning' products that propose pedagogical approaches and introduce tools and teaching techniques that claim to be based on neuroscientific data. However, close inspection of these claims for a direct connection between particular 'brain-based' tools and teaching approaches reveals very loose and often factually incorrect links.

We do not believe that this sort of approach is the most fruitful for creating a sustainable science of Mind, Brain, and Education that mutually benefits education and cognitive neuroscience. Instead, we believe that the real potential lies in systematic interactions between cognitive neuroscientists and educators to arrive at common questions and a common language, rather than in the direct route from research to its application. The history of 'applied' research shows that the implementation of research results to solve problems is often very indirect and rarely straightforward. This is especially the case in Education, a field in which there has been much resistance to the potential influence of scientific, quantitative research (Lagemann, 2000). We expect that developing the field of Mind, Brain, and Education and the collaborations at the core of the field will require a journey much more complex than the direct route from the neuroscience laboratory to the classroom.

In light of this, the question that leads this section (how might cognitive neuroscience inform education?) is limiting inherently, as it contains the implicit assumption of a one-way link between education and neuroscience. Such unidirectionality is either implicitly or explicitly stated in discussions about education and neuroscience too often. We believe that instead of asking what neuroscience can do for education it should be asked how education and neuroscience might inform *each other*; that is, it is our explicit assumption that Mind, Brain, and Education should be framed in terms of interactions and based on mutually beneficial dialogue among participants with knowledge of child development, learning, and teaching. This will also ensure that no knowledge hierarchy is created in which educators are simply the recipients of information generated by neuroscientists. There is often a perception that scientists will tell educators what they should do; such a patronizing approach will be avoided if the types of collaborations we propose are realized.

As we have previously articulated (Ansari & Coch, 2006; Coch & Ansari, 2009), we argue that it is crucial for training in aspects of cognitive neuroscience to become a fundamental part of teacher education, while at the same time graduate students in cognitive neuroscience should be exposed to educational issues. We believe that such instructional components will help teachers to gain a fuller understanding of child development and the biological constraints placed on learning processes as well as research methodologies; similarly, cognitive neuroscientists investigating subjects that have potential educational relevance will be familiar with pedagogical issues surrounding their subject matter as well as with the related 'burning' questions being asked by educators and the constraints of the classroom learning environment. For example, educators might discuss with cognitive neuroscientists the different strategies that they have observed children using to solve a particular problem, or allow cognitive neuroscientists to observe children using various strategies in the classroom environment, thus providing an avenue to potentially bring some of the rich and deep descriptions of classroom learning into the neuroscience realm. This all will facilitate the generation of new interdisciplinary researchers fluent in the languages of education and cognitive neuroscience. In turn, this will result in collaborations from which new research questions will emerge that are closely aligned with both the traditional basic science interests of the cognitive neuroscientist and the applied issues encountered by teachers in their classrooms.

What Needs to Happen for Education and Neuroscience to Interact?

There are a number of practical issues that need to be addressed before interactions between educators and neuroscientists of the sort described above can become a reality. Here we focus on the teacher preparation issue mentioned above as an example. We believe that teacher education programs need to integrate courses on cognitive neuroscience into their curricula, or integrate cognitive neuroscience methods and findings into their current courses. Such courses should provide not only a basic introduction to structural and functional brain development as well as the brain mechanisms subserving core domains of cognitive functions such as the typical and atypical development of reading and mathematical skills, but also discuss wider topics of relevance to education such as the effects of culture on brain function. Of course, such courses should not be focused solely on results from brain imaging studies, but should also discuss evidence from behavioral research; by definition, Cognitive Neuroscience is an interdisciplinary science that draws on results from cognitive psychology, neuroscience, sociology, and anthropology to generate a better understanding of the brain bases of cognitive processes. In order to understand and better support human learning and development in their students, teachers need to know what science has discovered about learning and development at multiple levels of analysis, from multiple perspectives.

Teacher training should also introduce aspiring teachers to research methodologies, the strengths and limitations of behavioral methods and methods that measure brain activity, as well as the uses and misuses of scientific data in popular publications. Being able to critically evaluate scientific results and their portrayal in the popular media is crucial, especially because there already exists a great proliferation of so-called 'neuromyths' in publications aimed at teachers (for a review, see Goswami, 2004). As discussed above, there is a growing body of pedagogical tools and literature that claims to be 'brain-based'. Teachers who are able to critically evaluate the science to which they are being exposed will not only avoid heeding advice based on inaccurate data and pseudoscience, but also will force the producers of education-related literature on the brain to provide more sophisticated and accurate information. In other words, teachers need to become 'neuroscience literate'; and, by the same token, cognitive neuroscientists need to become 'education literate' in order for strong links to be forged between fields.

Thus, in order to forge such links, traditional academic boundaries need to be crossed and mutual respect developed, perhaps building on a common and shared foundational interest in child development and learning between developmental cognitive neuroscientists and educators. This will also require Departments of Education to lower their resistance to quantitative scientific, empirical research and, at the same time, Departments of Psychology and Neuroscience to embrace the importance of applied research, which is frequently considered inferior to the pursuit of knowledge characterized by basic research.

What Does the Future Hold?

This special issue on Education and Neuroscience comes at a critical time. There has been a steadily growing interest in the potential of a connection between Cognitive Neuroscience and Education. However, this interest may be reaching its peak and may soon subside, in part because the direct application of neuroscience findings to the classroom has not been particularly fruitful. It is therefore crucial to think about the ways in which the current enthusiasm and willingness of universities and funding agencies to engage with the creation of Mind, Brain, and Education as a new field can be sustained over the long-term. We contend that this can be achieved by moving beyond thinking about the direct application of neuroscience research results to classroom practice towards thinking about the constraints that need to be set in place in order to bring educators and neuroscientists together to collaborate and inform each others' thinking and practice. It will be important to communicate the potential and promise of such indirect links to policy makers, funding agencies, and universities in order to avoid their turning away from Mind, Brain, and Education when quick fixes are not forthcoming.

This view of Mind, Brain, and Education stands in stark contrast to much of the current 'brain-based' education movement. It is of concern that much energy will need to be expended in the future to curtail the growing emergence of so-called 'brain-based' programs and publications that proliferate myths throughout the educational community. In a similar vein, school boards and districts should be careful to choose and use only programs for which there is clear, peer-reviewed, empirical support regarding efficacy. In turn, it is important that scientists do not succumb to the temptation to collaborate with industry to create intervention tools that are only loosely based on their research results and have not undergone rigorous evaluation (particularly in classroom contexts) after initial publication simply in order to avoid potential commercial losses.

Finally, we believe that the future of Mind, Brain, and Education should be characterized by much broader thinking about how Neuroscience and Education might inform each other. What new research paradigms might be developed? How might non-invasive neuroimaging methods be used to measure the relative success of educational approaches? How can synergistic collaborations create a whole that is more than the sum of the parts? Moving beyond our understanding of the neurocognitive mechanisms subserving core cognitive domains, such as reading and mathematics, Mind, Brain, and Education also encompasses consideration of issues related to the general structure of learning environments, the timing of instruction, and the roles of stress, nutrition, sleep, and social context in learning (to name a few topics). Interactions between Education and Neuroscience may also help to evaluate the relative benefits of arts and science education and thereby change the way in which we view educational priorities. Where this journey will take us may be unpredictable *a priori*, but it is relatively more certain that we will not make strides without some constraints in place and a concerted effort to map out how we are going to get there.

Acknowledgements

Bert De Smedt is a Postdoctoral Researcher of the Research Foundation Flanders–Belgium.

References

Ansari, D. & Coch, D. (2006) Bridges Over Troubled Waters: Education and cognitive neuroscience, *Trends in Cognitive Sciences*, 10:4, pp. 146–151.

Blakemore, S. J. & Frith, U. (2005) *The Learning Brain: Lessons for education* (Oxford, Blackwell).

Bruer, J. T. (1997) Education and the Brain: A bridge too far, *Educational Researcher*, 26:8, pp. 4–16.

Coch, D. & Ansari, D. (2009) Thinking About Mechanisms is Crucial to Connecting Neuroscience and Education, *Cortex*, 45, pp. 546–7.

Dehaene, S., Piazza, M., Pinel, P. & Cohen, L. (2003) Three Parietal Circuits for Number Processing, *Cognitive Neuropsychology*, 20:3–6, pp. 487–506.

Dehaene, S., Spelke, E., Pinel, P., Stanescu, R. & Tsivkin, S. (1999) Sources of Mathematical Thinking: Behavioral and brain-imaging evidence, *Science*, 284, pp. 970–974.

Gazzaniga, M. S. (2002) *Cognitive Neuroscience*, 2nd edn. (New York, W. W. Norton & Company).

Goswami, U. (2004) Neuroscience and Education, *British Journal of Educational Psychology*, 74:Pt 1, pp. 1–14.

Goswami, U. (2006) Neuroscience and Education: From research to practice? *Nature Reviews Neuroscience*, 7, pp. 406–413.

Lagemann, E. C. (2000) *An Elusive Science: The troubling history of education research* (Chicago, IL, University of Chicago Press).

Pugh, K. R., Shaywitz, B. A., Shaywitz, S. E., Constable, R. T., Skudlarski, P., Fulbright, R. K., *et al.* (1996) Cerebral Organization of Component Processes in Reading, *Brain*, 119, pp. 1221–1238.

Posner, M. I. & Rothbart, M. K. (2005) Influencing Brain Networks: Implications for education, *Trends in Cognitive Sciences*, 9:3, pp. 99–103.

Stern, E. (2005) Pedagogy Meets Neuroscience, *Science*, 310, p. 745.

Turkeltaub, P. E., Gareau, L., Flowers, D. L., Zeffiro, T. A. & Eden, G. F. (2003) Development of Neural Mechanisms for Reading, *Nature Neuroscience*, 6:7, pp. 67–73.

JOBNAME: No Job Name PAGE: 7 SESS: 9 OUTPUT: Wed Aug 4 16:44:59 2010
/v2503/blackwell/journals/epat_v43_i1-2/epat_705

Toppan Best-set Premedia Limited	
Journal Code: EPAT	Proofreader: Elsie
Article No: 705	Delivery date: 4 August 2010
Page Extent: 6	

AUTHOR QUERY FORM

Dear Author,

During the preparation of your manuscript for publication, the questions listed below have arisen. Please attend to these matters and return this form with your proof.

Many thanks for your assistance.

Query References	Query	Remark
1	AUTHOR: Please supply a brief abstract and several keywords	