AERA Brain, Neurosciences and Education SIG – Session Proposal

A Systematic Approach to Educational Neuroscience: Research within the London-based CEN

Abstract

Educational neuroscience as yet employs loosely-coordinated approaches to study how neural processes affect learning, targeting diverse content areas in uneven fashion. The London-based Centre for Educational Neuroscience (CEN) has attempted to specify a more systematic set of principles and program of activity for onward development. The purpose of this session is to articulate these principles, which rest on the notion of learners as complex systems, operating at neural, cognitive and social levels. The concomitant use of multiple methodologies to identify significant cross-level interactions is illustrated through work on the callous-unemotional subtype of conduct problems and their implications for intervention; sensitive periods in development and their curricular implications; and the use of neuroscientific studies of children with developmental dyscalculia to inform adaptive learning programs for developing number sense.

Session summary

The main objectives of this session are to: illustrate key strands of work within the London-based Centre for Educational Neuroscience (CEN); articulate general principles underlying this work; and debate the wider applicability of these. The session addresses the 2010 Annual Meeting theme by: drawing on interdisciplinary constructs and theories, complex research designs, and multiple methods of data analysis; focusing on the issue of how learning occurs within complex dynamic systems; and considering the implications for improving learning of accounts that deal with complex networks of factors.

The session comprises four papers of 15 minutes each, plus similar discussant and plenary discussion time. The paper by Tolmie outlines the main principles guiding CEN activity. These include an emphasis on learners as complex systems, operating at neural, cognitive and social levels. Full understanding of learning entails addressing this system as a whole, mapping the interactions between levels. This necessitates gathering multiple sources of evidence, searching for correspondences that indicate significant cross-level interactions. This activity must be programmatic, focused on coordinated work across a number of areas; and community-based, targeting application via the involvement of teachers and other professionals, and engaging with policy makers to ensure impact across different aspects of educational provision.

The paper by Jones and Viding illustrates key elements of this approach within work on the callous-unemotional (CU) subtype of conduct problems. This subgroup of antisocial children exhibit more severe patterns of behaviour, plus intact mentalising ability but attenuated reaction to punishment and to others' distress. Evidence from genetic, neuropsychological and neuroimaging sources suggests a high level of heritability of the CU subtype, where non-CU subtypes are more probably environmental in origin. Ongoing intervention work is focused on avoiding ineffective approaches such as punishment, and concentrates instead on strategies that are congruent with existing strengths (e.g. response to reward, which appears intact), or boosting the weak affective response system.

Thomas' paper utilises similar kinds of approach to consider a broader issue. Loss of neurons and the pruning of synaptic connections during late childhood and adolescence have the effect of reducing adaptive functional plasticity. Modelling of these effects leads in turn to the notion that there are sensitive periods in development when learning is able to proceed more rapidly. The paper considers the implications for educational curricula of this possibility – and the adjustments to educational practice that may help optimise learning once maximum plasticity has gone.

The paper by Butterworth and Laurillard focuses on intervention techniques, making use of adaptive learning technologies to instigate processes that mirror normal learning. The target of this work is children with developmental dyscalculia, a lack of number sense that affects basic abilities such as enumerating or ordering sets of objects, undermining learning of arithmetic. Pedagogies that promote the development of relationships between physical and symbolic representations of number have been developed, but have proved difficult to scale up. Technology enhanced learning presents a method of achieving this that can also be used to test key predictions from neuroscience research on the build-up of such representations.

(1) Educational Neuroscience: Some Key Working Principles

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The Centre for Educational Neuroscience (CEN) was formed in 2008, with institutional backing, by members of three co-located institutions with expertise in developmental psychology, pedagogy and learning technologies (Institute of Education London), cognitive neuroscience and educational psychology (University College London), and developmental neuroscience and computational modelling (Birkbeck College London). Although influenced by thinking elsewhere on educational neuroscience (e.g. Varma, McCandliss & Schwartz, 2008), members of CEN started with some particular conceptions of their own, which we believe have wider currency. Central amongst these are the following:

First, educational neuroscience is not reductionist in character. The developing learner constitutes a complex system, operating at neural, cognitive and social levels, with multiple interactions taking place between processes and levels, and effects running equally from social or cognitive to neural as vice versa. Theories of learning have to date been essentially fragmented in nature, focused solely on sub-elements of this system. A more complete understanding of learning is possible, but only by addressing the system as a whole, and trying to map and understand the interactions between levels in detail.

Second, this entails gathering multiple sources and types of evidence within and across studies, and in the first instance, searching for telling correspondences between these that point at significant and constraining cross-level interactions. The remaining papers in this symposium illustrate instances of work by CEN members that in one way or another adopt this approach. Particular value is attached to the use of modelling techniques, computational and statistical, as a key means of understanding how dynamic processes play out over time.

Third, this activity must be programmatic in nature, to yield a sense of the wider operating parameters of the learner system, and how processes of different types might be integrated within it. This leads us to a concern with both typical and atypical development, and with learning throughout the lifespan, as crucial aspects of triangulation. It also leads us to emphasise the importance of coordinated work across (at least) six main areas: language and literacy development (including dyslexia); number and mathematical development (including dyscalculia); cognition and learning (including conceptual development, attention and executive control, ADHD); social and emotional development; communication and interaction (including ASD); and sensory and physical development (including visuo-spatial and motor coordination).

Finally, building a new discipline of this kind must be a community activity. The complexities of the subject matter and methodologies required to investigate it make it necessary to bring together as equal partners researchers from a variety of different backgrounds. However, this community must include masters and doctoral students, to develop successive generations of fully-fledged educational neuroscientists. It must also include teachers, special educational needs coordinators, and educational psychologists, to help set the research agenda and ensure that it is targeted at application and intervention from the outset. Lastly, it must include politicians and policy makers, to ensure the new discipline has a socially-perceived reality, and is sanctioned to contribute to a reshaping of educational provision, to the benefit of learners of diverse types, backgrounds and circumstances.

(2) The Neuroscience of the Callous-Unemotional Subtype of Conduct Problems: Implications for Intervention and Education

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Early-onset antisocial behaviour (AB) carries a strong risk for persistent offending and psychiatric and physical health problems in later life (Moffitt, 2003; Odgers et al., 2007). One delineator of heterogeneity within children with early-onset AB is a callous and unemotional disposition (CU). The presence of CU designates a subgroup of antisocial children with a more severe, aggressive, and stable pattern of AB and a specific neurocognitive profile indicative of hyporeactivity to others' distress and punishment to self (Blair et al., 2006). Recent evidence, including behavioural genetic, neuropsychological and neuroimaging sources, indicates that CU is a useful method of subtyping AB (Blair et al., 2006; Jones et al, 2009; Viding et al., 2005). Research will be presented from all of these sources to demonstrate the utility of considering CU traits when working with children with AB.

Data from twin studies suggest that AB is strongly heritable in children with elevated levels of CU (AB+CU), but more likely to be due to environmental influences in children with AB, but no CU (AB-CU) (Viding, Jones, et al., 2008). Neuropsychological studies have demonstrated differences in the cognitive-affective profile associated with these two groups of children. Specifically, children with AB+CU have deficits in recognizing distress emotions (fear and sadness), and in attributing fear and guilt to themselves (Blair & Viding, 2008). Children with AB+CU also show little or no affective empathy responses to another's emotional state. Children with AB-CU show no such deficits. However, children with AB+CU have no deficits in mentalising. In other words, they are able to take another's perspective, yet their ability to show an appropriate emotional response is lacking (Jones et al., in prep). Children with AB+CU have also been shown to have differences at the level of the brain. Our group and other groups have published fMRI data demonstrating amygdala hyporeactivity in children with AB+CU compared with matched controls in response to fearful faces (Jones et al., 2009; Marsh et al., 2008). Another study from our group reported structural brain differences in children with AB+CU compared with typically developing children in brain areas that have been associated with affective empathy, self-referential thinking and moral reasoning (DeBrito et al., 2009).

After the overview of the current empirical literature, this presentation will consider the implications of these findings for education and intervention. Early indications from more traditional intervention approaches suggest that CU traits can be reduced (e.g. Hawes & Dadds, 2007). Examples will be given from an on-going school-based intervention programme for children with severe and chronic AB (CU+ and CU-). This programme represents a joint project between basic science research and Educational Psychologists and has been developed to specifically address the needs of children with AB+CU. The current neurocognitive research suggests that children with AB+CU would benefit from modified treatment approaches. Treatment should seek to avoid ineffective approaches (e.g. punishment) and either identify treatment strategies that are congruent with presenting strengths and weaknesses, (e.g. response to reward, which appears intact) or boost the weak affective response system.

(3) Sensitive Periods in Brain Development: Implications for Educational Policy

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One of the main characteristics of the human brain is its plasticity. Functional plasticity is the ability to change behaviour based on experience. When children are exposed to specially structured environments such as the instruction they experience in schools, they can learn high-level cognitive skills that are specific to their culture. Acquisition of these skills can take weeks, months, or years. The result can be a literate child, a numerate child, a multilingual child, an artistic child, a child who can reason logically, play sports, or play musical instruments.

One characteristic that the human brain shares with other species is that it exhibits marked changes with age. These include the loss of neurons and the pruning of connections. In humans, up to half of all synapses (the structures through which neurons communicate) are lost from the neocortex during late childhood and adolescence. Such structural changes are sometimes associated with a loss of functional plasticity, leading to the idea of sensitive periods in development.

In this talk, I assess the implications for educational policy of recent findings on sensitive periods in brain development. I will address three points. (1) Can the educational curriculum be optimised by teaching particular subjects at a point of maximum plasticity for the brain systems involved? (2) Do some skills need to be acquired later so that acquisition is optimised only after children reach a certain age? And (3) how should educational practice be adjusted to optimise learning for individuals who have passed the age of maximum plasticity?

(4) A New Approach to Dyscalculia Intervention Using Adaptive Learning Technologies

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Poor numeracy is a serious disability, since failure persists into adulthood. It makes children in schools deeply unhappy, is detrimental to mental and physical health, and affects education and employment prospects more than poor literacy (Bynner & Parsons, 2005).

The causes and treatments of low maths attainment have been extensively addressed in the mathematics education literature. However, little work has targeted one important cause: a congenital condition, Developmental Dyscalculia (DD) that appears to be highly heritable (Alarcon et al, 1997). DD affects the learner's ability to enumerate sets and to order sets by magnitude, which in turn make it very difficult to understand the arithmetic, and very hard to provide a meaningful structure for arithmetical facts. According to published prevalence estimates, DD can affect as many as 6.5% of learners (Papers in Berch & Mazzocco, 2008). DD is associated with functional and structural abnormalities in a small region of the parietal lobe

(Isaacs et al, 2001; Price et al, 2007), and with under-activation of the arithmetic network (Kucian et al, 2006), and is known to be specialized for enumeration (Castelli et al, 2006) .

The teaching strategies of the mainstream classroom, such as learning number bonds do not succeed for DD learners because their mental representations of numerical magnitude is so weak. However, specialized tasks, focussing on strengthening the understanding of number magnitude can succeed in the hands of specialist teachers in one-to-one settings (Butterworth & Yeo, 2004).

The presentation will report on a research project using technology enhanced learning (TEL) to improve both the scale and the effectiveness of these interventions.

The presentation will demonstrate digital interventions that use number lines and dot pattern tasks to develop number sense. The interactive and adaptive tasks are designed to emulate the effective specialist teacher, who provides learners with a great deal of practice in a supportive environment, personalized to their needs. Early results with in years 1- 4 suggest, for example, that adaptive tasks, with meaningful feedback, can help DD learners to build an understanding of simple number concepts in a more secure and sustainable way.

Other participants

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