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ASSOCIATION POUR LA RECHERCHE EN NEUROÉDUCATION / ASSOCIATION FOR RESEARCH IN NEUROEDUCATION

Revue NEUROEDUCATION Journal

September 2016 | Vol. 4 | Issue 1

5th Conference of the Association for Research in Neuroeducation

May 24-27, 2016

Université du Québec à Montréal (Canada)

SCIENTIFIC SYMPOSIUM

"Research Integrating Education and Neuroscience: Going Beyond Disciplinary Boundaries"

Abstracts in English

(Oral presentations and posters)

Published in September, 2016
Neuroeducation, 4(1), 1-6
ISSN: 1929-1833

ORAL PRESENTATIONS (MAY 26, 2016)

Opening Keynote Address

BUILDING BLOCKS OF MATHEMATICAL COMPETENCE: EVIDENCE FROM BRAIN & BEHAVIOUR

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Recent research has shown that basic number processing (such as comparing which of two numbers is larger) is related to individual differences in children's arithmetic achievement. Furthermore, children with mathematical disabilities (Developmental Dyscalculia) have been found to perform poorly on basic number processing tasks. In this talk I will review evidence for an association between basic number processing and arithmetic achievement in children with and without mathematical difficulties. I will draw on evidence from both brain and behavior and discuss the implications of this research for assessment, diagnosis and intervention.

THE ROLE OF THE LEFT INFERIOR PARIETAL LOBULE IN SECOND LANGUAGE LEARNING: A TWELVE-WEEK INTENSIVE LANGUAGE TRAINING fMRI STUDY

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Research to date suggests that second language acquisition results in functional and structural changes in the bilingual brain, however, in what way and how quickly these changes occur remains unclear. To address these questions, fourteen English-speaking monolingual adults were enrolled in a twelve-week intensive French learning immersion program in Montreal. Using functional MRI, we investigated the neural changes associated with new language acquisition. The participants were scanned before the start of the immersion program and at the end of the 12 weeks. The fMRI scan aimed to investigate the brain regions recruited in a sentence reading task both in English, their L1, and in French, their L2. The fMRI results showed brain response changes between time 1 (T1) and time 2 (T2) in several language-related areas. Of note, related to the French reading condition, there was higher activation at T2 compared to T1 in the left inferior parietal lobule (IPL) including the supramarginal gyrus. At T2 this higher activation in the IPL was correlated with French reading speed. Moreover, better improvement in French reading speed from T1 to T2 was also predicted by higher activation in the left IPL at T1. Overall, our results suggest that brain response and learning-induced plasticity related to second language learning occurs as early as 12 weeks into training. It is likely that greater brain activation in the left IPL at T2 is related to an increased semantic and phonological processing of the L2, French, as reflected behaviourally at T2 by faster reading speed.

MEASURING THE IMPACT OF DESIGN ON USERS' COGNITIVE LOAD AND PERFORMANCE IN THE LEARNING OF MATHEMATICS

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Digitalization has created new opportunities in the field of education, as more applications are developed to meet educators' and parents' needs (see Colombo et al., 2012; Falcão & Price, 2011; Rogers et al., 2002, for reviews). The objective of this paper is twofold: 1) measure the impact of design, using eyetracking measures, on users' cognitive load and performance in the learning of mathematics, and 2) present new guidelines for the creation of children's educational games on smartphones and tablets. To do so, a lab experiment was conducted using a mathematics application on a tablet. A total of 19 students between the ages of 7 and 9 were recruited over a period of five weeks. Participants were asked to answer 30 multiple-choice mathematics questions, distributed into 5 blocks. Each block featured six questions of equivalent difficulty levels and design presentation. Following the completion of each block, participants were asked to assess the nature and the intensity of their emotional and cognitive states by completing four SAM scales (Bradley & Lang, 1994). Building on Charland et al. (2015), physiological and behavioral signals, such as non-intrusive eyetracking (Tobii X-60 eyetracker, Tobii Technology AB) and facial expressions (Facereader 6 software, Noldus, Netherland), were used in order to assess visual attention and cognitive load. Research

has shown that variations in pupil size and blink rate correlate with affective and cognitive processes (Benedetto et al., 2011; Laeng et al., 2012). Preliminary results show that interface design does influence the cognitive load required from students in the learning of mathematics. Controlling for the difficulty of the multiple-choice question, learners' pupil size increased depending on the number of possible answers to be considered. The mental workload of the learner was higher when the answer was C or D, rending the question more difficult. Successful learners were also more effective at reading question statements. Overall, they spent less time interpreting the question and revisited the statement less often, before choosing the correct answer. These results should help designers in the creation of effective educational applications.

LESSONS FROM THE HISTORY OF EDUCATIONAL NEUROSCIENCE

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In this paper, we explore the motivations as well as the historical difficulties associated with four early attempts to integrate neuroscience into educational policy and practice. (1) Charles Bonnet, in his 1755 *Essay on psychology* (the first book with psychology in the title), specifically linked mind, brain and education, but without proposing any educational program. (2) William James (1899) lectured to teachers for years about the implications of his 'new psychology for how to teach young children. (3) Jean Piaget developed the ideas of Baldwin and others like Janet to make an enduring contribution to psychology and education. Throughout his career, Piaget strongly grounded his work in biology and tied it to education as phenotypic adaptation; in lesser known writings, he proposed specific curriculum to optimize learning based on his theories of learning and intelligence. (4) Finally, Lev Vygotsky together with his collaborators (especially Alexander Luria) developed a cultural–historical psychology that also aimed to integrate studies of mind, brain and education within an evolutionary and developmental framework, with a special emphasis on helping children with learning difficulties. These four early efforts at educational neuroscience will serve to illustrate how they (and by extension, contemporary efforts) are necessarily bound up with cultural understanding of how the brain works, how humanity developed, and what it means to live human life to the fullest.

"NOT ENOUGH TO KNOW, BUT ENOUGH TO CARE": EDUCATIONAL NEUROSCIENCE'S EDUCATIONAL SIGNIFICANCE PROBLEM

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The legitimacy of the neurosciences is unquestioned; their value for more traditional forms of psychological inquiry is accepted. However, whether and how neuroscience can be used to improve classroom instruction or educational systems remains speculative. Educational neuroscience has demonstrated parallel and converging lines of evidence to support long-standing findings from cognitive educational psychology. Yet these findings often fail to move the hearts and minds of educators, and there is no evidence that they can suddenly do so because of ancillary support from brain science. Similarly, although administrators seem impressed with the potential of neuroscience to inform education, coopting neuroscience as rhetorical support for imposed institutional policies seems unlikely to empower either the policies or educational neuroscience. I argue we require a teacher education strategy for advancing educational neuroscience in tandem with more research on effective instruction. Whether unduly awed, incredulous, or blasé about brain science, most educators have no grasp of the anatomical, developmental, cytological, proteomic, or genetic fundamentals of the nervous and endocrine systems, nor do they fully appreciate the methods or designs used to study them. Neuro-myth and nonsense are too often the result of sweeping descriptions intended to awe instead of inform. I propose that educational neuroscientists should recognize the accurate and ethical use of metaphor as a key to advancing entry-level understanding of neuroscience by educators and policy makers. As some educational neuroscience advocates have already asserted, a well-chosen, neurologically-grounded metaphor for classroom learning could operationalize better instructional methods that most teachers now only intuit. The overworked journalists' trope of brain-as-information processor leaves much to be desired. Analogies more amenable to nuance and resistant to reification deserve further examination (e.g., brain-as-pattern matcher, brain-as-probabilistic anticipator, brain-as-self-regulation system, learning-as-biological growth process). The historical precedent of functional psychology and cautionary evidence from the teacher education literature will be reviewed.

POSTER PRESENTATIONS (MAY 26, 2016)

BEWARE OF THE REFLECTION IN THE MIRROR, RATHER THAN UPSIDE-DOWN OR ROTATED ITEMS

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Reading is a modern cultural skill. Since writing was invented some 5,300 years ago, a relatively short lapse of time in regards of evolution, there should be no "human brain reading network". However, an area labeled as the "visual word form area" (VWFA) is specifically and systematically activated when individuals read, regardless of their languages (Cohen et al., 2000; Dehaene & Cohen, 2011; Jobard et al., 2003). The neuronal recycling (NR) hypothesis proposes an elegant solution to the paradox, arguing that we learn cultural skills through the recycling of a brain area sufficiently plastic and whose initial functions are close enough to the novel one. For instance, the VWFA is located at the junction of animals, faces and objects visual recognition areas (Dehaene, 2004). One consequence of the NR is that the visual recognition of letters and words process inherits most of the secondary visual networks' initial properties, such as gradual viewpoint invariance and mirror generalization (Axelrod & Yovel, 2012; Lachmann, 2002). Symmetry errors (e.g. confusing b and d, or n and u) in children (Asso & Wyke, 1971) can therefore be viewed as a mark of normal functional development of the VWFA through a NR process. Mirror errors (confusing b and d or p and q) are more persistent than other types of errors, but disappear all the same through learning to read and write (Nelson & Peoples, 1974). "Unlearning" mirror errors requires the inhibition of mirror generalization in children (Ahr et al., 2016) but also in adults (Borst et al., 2015). We wish to present evidence, using a negative priming paradigm, that preventing symmetry errors along a horizontal axis (b/p, d/q) or along a rotation (b/q, d/p) does not require as much inhibitory control as for symmetry errors along a vertical axis (mirror errors such as b/d, p/q).

SERIOUS GAMES FOR READING EDUCATION

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Interventions that apply knowledge from neuroscience and cognitive science to core education skills are pioneering steps in improving teaching methods (McCandliss 2003, de Graff, Bosman, Hasselman, Verhoeven 2003, Laski & Siegler 2014). Working with serious game designers, our lab is currently developing a complete tablet based reading method that applies best practices correlated with reading success, highlighted by reviews from comparative classroom studies and successful research interventions (explicit systematic graphic-phoneme instruction, blending and segmenting tasks, decodable text…) while using adaptive game software to maintain the motivational challenge in the *zone of proximal development* (Vygotsky, 1978). The method will be tested over the 2016 - 2017 school year on over 1 000 1st grade children in France; French does not have a transparent grapheme-phoneme writing structure. Participants will be separated into 3 groups: randomized within classrooms are group1, using the experimental reading game, and group2, using a previously developed number game. A third group includes children in classrooms not using tablets. Pre and post standardized tests will measure each group's reading progress. The method software will also include several options that may influence the rate of learning to read. These parameters are frequently used in basal readers, but their influence has never been tested. In fact, many of these options have been suggested as topics for further research in the National Reading Panel 2001 report. Each parameter will be tested separately from the other in 2n versions of the software, whereby n is the number of binary parameters. This project should further our understanding of what works in reading education while highlighting how software can be used to measure progress, provide adaptive remediation and motivate learning: bridging the gap between lab and classroom and putting the child at the center of his/her education.

THE EFFECT OF BILINGUALISM ON PHONOLOGICAL WORKING MEMORY IN YOUNG ADULTS: A FUNCTIONAL MAGNETIC RESONANCE IMAGING STUDY

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Previous research comparing monolingual and bilingual groups has found behavioural differences in executive function that are also reflected both functionally and structurally in the brain. To date it is not clear what impact language experience has on executive function. For example, it is not clear in what way age of second language (L2 acquisition and attained L2 proficiency impact phonological working memory. It has been shown that international adoptees, whose native language (Chinese) is discontinued very early (before age 3) and who subsequently learn French, demonstrate similar brain activation as early Chinese-French bilinguals when performing a phonological working memory (PWM) task. Specifically, brain regions implicated in cognitive control as well as typical PWM regions were active in adoptees and bilinguals, whereas, monolinguals only showed activation in typical PWM regions. This suggests that early exposure to a language can have a long-term influence on phonological processing. Some questions that remain are whether the influence of early language exposure exerts effects into adulthood, whether there are similar effects of language experience in phonological processing when the two languages of a bilingual are similar (i.e., English and French), whether PWM is similar in a native language (L1) and an L2, and whether language-experience (i.e., age of L2 acquisition, attained L2 proficiency) impacts PWM. To address these questions, 26 bilingual speakers of English and French, who varied with respect to their age of L2 acquisition and attained L2 proficiency, underwent functional magnetic resonance imaging (fMRI) while performing a phonological n-back task in their L1 and their L2. Behavioural and fMRI results were affected by language (L1 vs. L2), and language experience. These findings have implications for our understanding of how early experience may impact brain development.

PROPOSING A RESEARCH DESIGN TO INVESTIGATE THE NEURAL CORRELATES OF TWO DIFFERENT TEACHING INTERVENTIONS IN READING WORDS FOR PRESCHOOLERS

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According to neuronal recycling theory (Dehaene, 2005), learning to read requires the initial function of a specific brain region, the occipito-temporal cortex (often referred to as the “visual word-form area”, Cohen et al., 2000), to be partially transformed, allowing it to identify written words. To date, little is known about the impact of teaching on the neuronal recycling mechanisms. Research conducted with adult participants have shown that directing the attention at a grapheme-phoneme (G-P) level while learning to read words induce a stronger cerebral activity in the visual word-form area than directing the attention of participants at a whole-word (W-W) level (Xue et al., 2006; Yoncheva et al., 2010, 2015). However, no research could be found that explore the effect of reading interventions in children who have not formally started learning to read. Can different reading instructions provided to novice readers impact differently the neuronal recycling of the occipito-temporal cortex? To answer this question, 48 non-reader preschoolers were equally and randomly assigned to two experimental groups: intervention in group A directed the attention at the G-P level, while intervention in group B directed the attention at the W-W level. Both interventions focused on learning the same 25 words and were implemented for 5 weeks at a frequency of 4 sessions of 20 minutes per week. Functional magnetic resonance imaging (fMRI) was used to acquire functional images during two cognitive tasks in reading, before and after the interventions. This communication will discuss the methodological choices of the research (design of the interventions and of the two cognitive tasks, fMRI acquisition sequences and parameters, planned analysis, etc.) and its potential implications to the field of education.

WHAT CAN COGNITIVE NEUROSCIENCE TELL EDUCATION ABOUT LEARNING FROM EXTERNAL FEEDBACK? A SYSTEMATIC REVIEW OF THE LITERATURE

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Learning from errors and feedback is an important topic in the Education Sciences field as it relates as much to student achievement, teacher development, and learning in general. Its ramifications connect with reflective practice, inhibition

of spontaneous and erroneous answers, conceptual change, self-regulated learning, assessment, metacognition, etc. Research in education has studied the use of feedback from different perspectives (cognitivism, behaviorism, socioculturalism, constructivism, etc.) but has not, up to this day, considered the way the brain processes feedback to learn. Therefore, this presentation reviews the scientific literature linking neural correlates of feedback processing to general or specific learning outcomes, published from 2005 to 2015. From a total of 229 search results, 30 scientific publications were selected, according to predefined selection criteria such as pertinence for educators, presence of healthy participants only, use of experimental design, among others. Results were analyzed qualitatively by emerging themes. Reliable knowledge about feedback processing considered relevant to education is presented and discussed. Further transdisciplinary research on feedback-based learning is suggested.