THE LATIN AMERICAN SCHOOL FOR EDUCATION, COGNITIVE AND NEURAL SCIENCES

JAMES S. MCDONNELL FOUNDATION - UNIVERSIDAD DE CHILE

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Conference's abstracts

ACTION VIDEO GAMES AS AN EXEMPLARY LEARNING TOOL?

Daphne Bavelier

Although the adult brain is far from being fixed, the types of experience that promote learning and brain plasticity in adulthood are still poorly understood. Surprisingly, the very act of playing action video games appear to lead to widespread enhancements in skill performance in young adults. Action video game players have been shown to outperform their non-action-game playing peers on a variety of perceptual and attentional tasks. They search for a target in a cluttered environment more efficiently, are able to track more objects at once and process rapidly fleeting images more accurately. This performance difference has also been noted in choice reaction time tasks with video game players manifesting a large decrease in reaction time as compared to their non-action-game playing peers. A common mechanism may be at the source of this wide range of skill improvement. In particular, improvement in performance following action video game play can be captured by more efficient integration of sensory information, or in other words, a more faithful Bayesian inference step, suggesting that action gamers may have learned to learn.

WHY COGNITIVE AND NEURAL SCIENCES?

John T. Bruer

There are a number of historical, conceptual, and practical reasons that support the importance of examining the applications of the cognitive and neural sciences. There is a long history of cognitive research relevant to education, there is a close interdependence between cognitive and neural sciences as they relative to education, and they provide complementary perspectives with which to identify and address educational problems. Both the cognitive and neural sciences, and their interaction, are well represented in the interests of School faculty and students.

BRAIN-BASED MODELS OF MATH LEARNING

Stanislas Dehaene

The ability to represent numerical quantities and to combine them according to the laws of arithmetic is a fundamental competence. In *The Number Sense* (1997), I proposed that humans and many other animal species inherit from evolution a core system of approximate number that provides us with intuitions of number. My proposal is that this system, together with other representations of space and number, provides a foundation for more advanced mathematical education. Although representations of space, time and number are present in other animals, only humans learn to connect them to written or spoken symbols, thus *recycling* and expanding their initial abilities, particularly in order to perform exact arithmetical and logical tasks.

In the talk, I will review what we currently know about the coding of number at the neural level. fMRI studies in human adults indicate that mental arithmetic activates a reproducible cortical region in the depth of the intracortical sulcus. In monkeys, this region, in coordination with dorsolateral prefrontal cortex, houses neurons tuned to the approximate numerosity of sets. Neural tuning curves are Gaussian when plotted on a logarithmic scale, a compressed representation which can explain why number is represented only in an approximate manner and subject to Weber's law (imprecision increases with number size). Numerical adaptation and multivariate decoding studies in human fMRI parallel single-neuron recordings in macaque monkeys, and suggests that the human cortex may also contain numerosity-coding neurons. With Véronique Izard, we have gathered evidence that this system is present very early on in development: 3-month-old babies exhibit a fast cerebral reaction to numerical novelty, common to small and large numerosities, and which relates to a parietal negativity plausibly originating from the right intraparietal region. Only in educated humans, however, do intraparietal neuronal populations become responsive to the cultural symbols of Arabic digits.

My group studies the impact of education and culture on those numerical abilities in the Mundurucu, an Amazon people with few number words and little or no access to education. The Mundurucu have logarithmic intuitions of the number line. Similar results are seen in young children from Western societies: the mental number line starts logarithmic and becomes linear with education. With Véronique Izard and Liz Spelke, we have also begun to document core intuitions and educational change in another core domain of mathematics: Euclidean geometry. Current results from laboratories throughout the world confirm that the intuitions of space, time and number that we inherit from evolution provide a foundation for mathematical intuition, predictive of future achievements in mathematics.

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THE IMPACT OF LITERACY ON THE DEVELOPING BRAIN

Ghislaine Dehaene-Lambertz

How does literacy change the human brain? Are they gains, but also losses associated with learning to read? We measured brain activation using fMRI in 10-years-old dyslexics and normal-readers from two different socio-economic backgrounds, in 6-years-old readers and non-readers and compare their responses with those of illiterate, ex-illiterate and literate adults. In all these groups, we studied how learning to read impacts both the organization of the ventral visual system and the perception of oral speech.

In adults, literacy strongly enhances the response to written words in the visual word form area (VWFA) and reduces the responses to faces and checkers at this site. It also enhances activations outside the reading network in the right fusiform cortex to faces, in the parahippocampal cortex to houses, and in the occipital cortex responses to all visual stimuli. Even the primary visual cortex shows an increased response at the horizontal location where written words typically appear. Literacy also transforms spoken language processing. First an increase of activation is observed in the *planum temporal*e and second top-down activation of the VWFA from spoken inputs are possible (Dehaene & al, 2010).

Strong effects of literacy are also observed in children. During the first year of learning to read, 6-years-old children exhibit strong activations for words in the ventral and the dorsal pathway. As in adults, learning to read also affects the responses to other visual stimuli, in particular to faces. An increase of activation to faces is observed in the right fusiform gyrus (FFA) in 6-years readers relative to non-readers and in 9-years-old readers relative to dyslexics whereas the response to houses is unaffected. However, the response increase to all categories of visual stimuli in more primary areas, that was observed in adults was not present. This suggests that cortical specialization continues as reading fluency increases with age. As concerns speech, there was a left lateralization of the linguistic network in all populations. The first presentation of a native sentence induces an enhanced activation relative to other speech conditions, in 10-years-old normal readers, but not in younger readers nor in dyslexics, in subparts of the *planum temporale*, the left basal language area and the VWFA. This suggests an on-line access to phonological representations and a top-down activation of an additional orthographic code during spontaneous speech listening, in the most fluent children as observed in adults.

In conclusion, reading deeply affects brain organization, in visual and oral linguistic networks providing humans with enriched representations. These modifications underlie increased performances in processing speech, even in passive listening situation. The intense training induced by reading fluency also affects other visual representations, especially face perception. The development of the VWFA appears to limit the expansion of the face responses in the left hemisphere while leading to its expansion in the right fusiform gyrus. We will discuss how nature and nurture are thus competing in the children brain.

EDUCATIONAL ROLE OF EARLY NUMBER REPRESENTATIONS

Lisa Feigenson

Recent progress by cognitive psychologists, developmental psychologists, and neuroscientists has greatly advanced our understanding of the basis for numerical thinking, revealing a system of core knowledge (the Approximate Number System) that is widespread across species and development. This foundation positions us to ask whether this new understanding has consequences for the ways in which we teach and learn mathematical concepts. Here I consider three ways in which empirical work may bear on education, using number knowledge as a case study. First I discuss whether impairments to the Approximate Number System can help to explain severe difficulty with math, or dyscalculia. Second I extend this approach to the issue of individual differences in the numerical abilities of normally developing children and adults. Finally, I suggest that to even begin to understand something as complex as the acquisition of formal mathematical abilities, we must look outside of any single core system. On this view, learning (whether via formal education or via informal exploration) requires building connections between multiple core systems.

HOW DOES BRAIN RESEARCH EXPLAIN DYSLEXIA?

Albert M. Galaburda

There is substantial accumulated evidence that supports the notion that brain changes associated with developmental dyslexia date to prenatal brain development. So far, the strongest evidence for the etiopathogenesis of these brain changes implicates genetics—either through gene variants (polymorphisms) or mutations (gain of function or loss of function mutations). Following the earliest brain changes, there occurs a cascade of plasticity-related developmental changes that lead to abnormal circuits (mainly cortico-thalamic, but also cortico-cortical) that in all likelyhood comprise the main element that confers risk of dyslexia. Whether dyslexia will be ultimately diagnosed, however, depends on the degree of risk conferred by the genetic mutation or variant, the underlying wetware of the brain, the native language to be read, and the social systems that exist. Thus, one can say that developmental dyslexia encompasses the whole expanse of biology of human development and human achievement: from genes to schools. The lecture will cover many of the steps from genes to schools in a didactic fashion that will expose the student to concepts and methodologies of population genetics, cell and molecular biology, neuroanatomy and neurophysiology, and experimental psychology, including implementation in animal models. The main objective of the lecture is to acquaint the student with the richness of methodology and thinking about developmental dyslexia in particular, but also contemporary studies of developmental cognitive disorders in general.

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THE LEARNING CURVE AND THE NATURE OF LEARNING

Charles R. Gallistel

It has long been believed that learning is a process of strengthening associations through repetition. In support of this conception, many published learning curves appear to show a gradual increase in correct (or appropriate) performance as the number of trials is repeated. These curves have been shown to be an artifact of averaging across subjects (and/or items learned). In most simple paradigms used to study associative learning, the appearance of an appropriate response in an individual subject, or, in humans, to an individual item is maximally abrupt (a step). Moreover, doubling the spacing between trials halves the number of trials (repetitions) required for an appropriate response to appear. Put another way, doubling the spacing between repetitions doubles the efficacy of each repetition. A corollary is that the number of repetitions is in and of itself irrelevant to the course of learning. This finding is deeply problematic for the "strengthening" conception of learning. An alternative conception is that learning is a process of deciding between alternative models of one's experience. I discuss the possible pedagogical relevance of these findings and of the alternative conception of learning that they suggest.

PERCEPTUAL EXPERTISE

Isabel Gauthier

The study of perceptual expertise in object recognition is a relatively young field: it is concerned with the behavioral and neural changes that accompany learning domain-specific and which generalizes to new ítems of a trained category. In the last 15 years or so, my colleagues and I have used the framework of perceptual expertise to try to understand why the visual system shows so much evidence of localized specialization for different categories, such as faces, places, body parts, words and even musical notation (Bukach et al., 2008).

A central tenet of the expertise framework applied to visual processing is that the task context within which you learn objects from a given category determines their representation in the visual system and in turn constrains the manner in which these objects can be processed in the future. I will give examples of studies that provide evidence for the role of experience in shaping category-specific processing and the organization of inferotemporal areas important for object recognition (Wong et al., 2009a,b).

I will then discuss recent findings that reveal significant bottlenecks of processing at the perceptual level whereby we find interference between different domains of expertise represented in overlapping areas of the visual system (McKeeff et al, in press; McGugin et al., in press; Wong et al., in press). On the one hand, we find evidence of online competition, such that performance with one category (e.g., faces) is impaired when perceptual resources are being concurrently used for another category of expertise (e.g., cars). On the other hand, we find evidence of long term competition, whereby expertise with one category appears to co-opt neural territory for another domain, and in some cases may translate into performance costs.

The acquisition of perceptual expertise as defined here is likely a ubiquitous phenomenon. We are able to detect significant changes in the perceptual strategies applied to objects of a category and to their representation following as little as a few hours of practice. Accordingly, most of us have various degrees of perceptual expertise with a vast number of object categories and the acquisition of perceptual expertise most likely occurs daily in the classroom.

The recent focus on competition between domains of processing opens up some practical questions such as whether specific training regimen can influence whether the perceptual representations of two domains will compete? I hope we can have a discussion about how our work in the acquisition of perceptual expertise in adults may inform our understanding of the role of domain-specific perception in the classroom.

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THE GENERATIVE BASIS OF NATURAL NUMBER CONCEPTS.

Rochel Gelman

During early cognitive development children learn some concepts without formal instruction and pretty much on the fly. Yet, latter on, starting about 6 to 8 year of ages, learning requires work and formal instruction. I will use the domain of number and arithmetic to develop the distinction between Core and Non-Core domains. I will argue that the former benefit from innate skeletal domains that guide attention to relevant data. The latter are learning mechanisms that contribute to the collection of organized knowledge systems that actively search the environment for relevant inputs, ones that share the structure of the nascent knowledge domain. Non-core domains have to be acquired from scratch, which takes considerable time, dedicated effort and good instruction. This is typically the agenda for educators. I will use data about numerical concepts to illustrate the distinction, and implications.

HOW OUR HANDS HELP US LEARN?

Susan Goldin-Meadow

When people talk, they gesture. We now know that these gestures are associated with learning. They can index moments of cognitive instability and reflect thoughts not yet found in speech (Church & Goldin-Meadow, 1986; Perry et al., 1988; Alibal & Goldin-Meadow, 1993; Goldin-Meadow et al., 1993). What I hope to do in this talk is raise the possibility that gesture might do more than just reflect learning—it might be involved in the learning process itself. I consider two non-mutually exclusive possibilities. First, gesture could play a role in the learning process by displaying, for all to see, the learner's newest, and perhaps undigested, thoughts. Parents, teachers, and peers would then have the opportunity to react to those unspoken thoughts and provide the learner with the input necessary for future steps in mastering the problem (Goldin-Meadow et al., 1999; Goldin-Meadow & Singer, 2003; Singer & Goldin-Meadow, 2005). Second, gesture could play a role in the learning process more directly by providing another representational format, one that would allow the learner to explore, perhaps with less effort, ideas that may be difficult to think through in a verbal format (Goldin-Meadow et al., 2001; Cook et al., 2008; Broaders et al., 2008; Goldin-Meadow et al, 2009). Thus gesture has the potential to contribute to cognitive change directly by influencing the learner and indirectly by influencing the learning environment.

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LANGUAGE FOR READING: LESSONS FROM THE CRIB FOR THE CLASSROOM

Kathy Hirsh-Pasek.

Reading is a complex cognitive task. In less than one-second, fluid English and Spanish readers process a visually displayed word, decode what they see into language, and infuse the text with meaning. How do children learn this process? Much is known about mechanisms that foster the learning of code skills like alphabetic learning and letter-sound correspondences. These are crucial for moving children from nascent to more mature readers. However, reading is not merely about recognizing print. It is also about extracting meaning that relies on language and life experience. Surprisingly, we know considerably less about how to foster the language skills and world experience necessary for understanding texts (Neuman & Dywer, 2009; Lonigan & Shanahan, in press). As a result, educational standards and curricula often emphasize the learning of code skills over the learning of language skills in preschool and elementary classes (NELP, 2009).

Here I make a strong case for the role of language as a foundation for reading. Research suggests that language is critical for early reading and that language competencies become even more important as children go beyond learning-to-read and start reading-to-learn. Using early language development as a guide, this talk distills 6 principles that should enhance vocabulary and grammatical development from the crib to the classroom (Harris, Golinkoff & Hirsh-Pasek, in press). The 6 principles offer hypotheses about ways to enrich environments for language learning and offer new directions for research.

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THE PARADOX OF THE HUMAN DRIVE FOR CAUSAL AND EXPLANATORY UNDERSTANDING – WHY ASK WHY?

Frank C. Keil

Well before the start of formal schooling children have a deep interest in mechanisms and not merely in noticing contingencies. They ask "why" and "how" questions frequently in ways that are far more than mere bids for social attention. It seems that they might do so to build detailed concrete mental representations of the world as "clockworks" models of how the world works. Yet, when actual mechanistic understanding is probed, children seem to not have learned hardly anything. Adults are barely any better. Outside very narrow areas of expertise, the vast majority of adults also have extremely sparse mechanistic understandings of both the natural the artificial world. Even worse, they are under the sway of strong illusions of explanatory depth and illusions of explanatory insight such that they rarely realize how little they really understand at a mechanistic level. This pattern raises a puzzle. why is there such an interest in mechanism from an early age if so little of mechanistic understanding is retained? The answer may lie in a different way of thinking about what it means to develop explanatory understanding and for one to have a folk science. In fact, detailed mechanistic understandings in most areas are beyond the natural cognitive capacities of any one mind and instead humans have become highly adept at tracking causal patterns at other levels of abstraction and using those patterns to construct patterns of deference to groups of experts. More remarkably, young children show a rich array of such skills at tracking causal structures above the level of mechanism as well as using those heuristics and other strategies to learn how to navigate the division of cognitive labor that is intrinsic to all mature sciences and cultures. Their early fascination with mechanism is a way of constructing those other levels of understanding. Thinking of explanatory understanding in this way suggests quite different ways of approaching science education and science literacy.

WHAT ABOUT SCIENCE EDUCATION: THE SECOND LA SCHOOL.

David Klahr

Next year, the McDonnell Foundation and the Universidad de Chile will conduct a 2nd Latin American school similar to the current one, but with a focus on science education rather than on mathematics education. At present the planning committee has made some tentative decisions about the broad topics that will be covered, including:

1. Science learning and teaching,

2. Learning and Memory,

3. Brain plasticity and learning,

4. Computational models of learning.

In my lecture, I will focus on the first of these topics. I will raise several important issues about science education, and how to do research that may improve it. Although I will try to encompass various approaches to science education, my presentation will be limited by my own perspectives, and will not have had the benefit of an extensive planning effort, although the planning committee will have a meeting over the weekend between the two weeks of this year's school. Thus my presentation should be viewed as only partially representative of the full curriculum for the second LA school.

Because these schools are aimed at training researchers to advance the science of science education, the first question to be addressed is "What does "scientifically based education research" mean?

- Does it mean the sort of studies that cognitive and developmental psychologists do when they are interested in how students think about math or science?
- Does it mean massive national randomized field trials on the effect of class size or teacher training?
- Does it have to include the kind of emphasis on underlying mechanisms that cognitive scientists and brain scientists are so interested in discovering?
- Can it include non-experimental, qualitative, case studies and field demonstrations?
- Does it require statistical significance, or large effect sizes, or both?
- Should it include new technologies or traditional teacher-student interactions?
- What constitutes a treatment or an independent variable: the content of a lesson, the instructional approach, the qualifications of the teacher, the attributes of the students, the philosophical and educational "approach"?
- What is the appropriate grain size of the measurements and analyses: school districts, schools, classrooms, individual students, test scores, clicks on a computer screen, brain images? (Similarly for temporal resolution for measuring learning: years, months, days, minutes, or seconds?)
- What specific findings from cognitive science or cognitive neuroscience are likely to contribute to improving the practice of science education?
- Can we point to examples that warrant the label of "scientifically based education research", and can such research inform policy and practice in ways that have substantial impact?
- What happens when other stakeholders, such as practitioners, academics from other disciplines (historians, philosophers, "hard" scientists), professional groups, advocacy groups, policymakers, issue-oriented “think-tanks”, and the media begin to assess and comment on what the research enterprise is producing?

Clearly, there is enough here to fill several semesters, if not years, so my 45 minutes will have to be quite selective, and based on a few very broad statements, and a few very narrow and specific examples from my own research, on teaching elementary school children how to design simple experiments.

My goal in this presentation is to stimulate the participants in the First Atacama School to propose ways to address these questions -- as well as new questions about science education – so that we can plan a stimulating and valuable curriculum for next year.

ADVANCED TECHNOLOGIES TO SUPPORT LEARNERS AND LEARNING SCIENTISTS

Kenneth R. Koedinger

Educational technologies are being increasingly used in schools and colleges. For example, our Cognitive Tutors for middle and high school mathematics are in regular use by 500,000 students a year across the United States. Well-designed systems go beyond the support provided by teachers and textbooks to assess students as they work, adapt instruction to their individual needs, and provide stakeholders with detailed reports on students' strengths and weaknesses. Further, widely-deployed systems provide a powerful research platform for data collection and experimentation to advance theories of knowledge, learning, and instruction. In particular, methods of Cognitive Task Analysis (CTA) have been critical in developing better theories of academic knowledge acquisition and in designing improved instruction. In addition to the math Cognitive Tutors, a recent demonstration of the power of CTA-driven course design comes from a study of the Carnegie Mellon OLI on-line statistics course materials, which have been shown to contribute to better student outcomes in half of the time! One goal of our Pittsburgh Science of Learning Center is to create an e-science infrastructure that helps to automate CTA and so discover better cognitive models and fuel better instructional design. A key strategy we are pursuing is a mixed initiative human-machine discovery process whereby data visualizations enhance feature discovery by humans which in turn enhance model discovery by machines.

FROM RALPH WIGGUM TO EINSTEIN? CROSS CULTURAL BELIEFS IN TRAIT STABILITY AND IMPLICATIONS FOR EDUCATION

Kristi Lockhart

The possession of entity v. incremental beliefs about traits is related to children's expectations and motivation in educational settings. A child who believes traits are stable (an entity theorist) is more likely to give up in the face of failure than one who believes traits can be changed (an incremental theorist) (Dweck & Leggett, l988). Recent studies suggest that individual differences in beliefs about trait stability (entity v. incremental) may be overshadowed by larger developmental differences. Young children are more optimistic than older children and adults about negative traits changing towards the positive over development. Moreover, they are not simply incremental theorists, but true optimists in that they believe positive traits will be maintained (Lockhart, et al, 2002, 2008; Heyman & Gelman, 2004). This optimism for trait change in young children has also been found in Israeli children for self- traits (Disendruck, 2009) and may have an evolutionary basis. The developmental shift in older children towards an entity view of traits appears to be related to their understanding of effort's limits and matches the decrements seen in their intrinsic motivation as they progress through school (Lepper, et al, 2005; Lockhart, 2011).

Cross cultural work comparing Japan, an interdependent culture, and the US, an individualistic culture, suggests the move towards a more pronounced entity view of traits with development is not an inevitable outcome of greater cognitive sophistication and can be influenced by culture. Unlike older students and adults in the US, Japanese students of all ages believe that extreme positive changes in traits are possible throughout development and aging. Moreover, they are more likely to attribute those changes to effort (Lockhart et al, 2008).

Recent intervention studies (Blackwell, et al. 2007) reinforce the idea that beliefs about the stability of intelligence can be modified with accompanying results in educational motivation and achievement. Society's greater understanding of the role of genes in determining traits and how this shapes beliefs about trait stability is also discussed.

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DO BILINGUALS LEARN BETTER?

Jacques Mehler

I will be paying attention to issues that we as students of language acquisition in the first years of speech often neglect. Most of us presuppose that infants are born into a simple environment where only one language is spoken. This situation is becoming an exceptional.

Neonates generally have to figure out which part of the multiple stimuli they perceive provides linguistic information. If a hearing infant sees that when the parents interact with one another they move their hands or when one of them makes a gaze contact with someone else they also move the hands, then they might conclude that the hand gestures convey linguistic information. Otherwise, if the infant hears that parents generate acoustic noises coming from a moving mouth, the infant is likely to conclude that speech utterances may convey linguistic information. However, an infant can be raised with two or three languages if in the parents speak more than one language. Infants do not display confusion or delays when raised in a multilingual environment, as compared to monolinguals. Yet, a standard explanation given for the difficulties to learn new languages as an adult is that interference is the culprit. Is there no interference in the language learning infant? This is the question that I will try to analyze during my talk.

To try and provide some answers to the above issues it is necessary to revise some of the landmarks that are essential during the first months of life. I will begin with a description of the genetically encoded dispositions with which we are born. Next, I will try to argue that stimuli's distributional properties are computed to acquire the grammatical properties of the language(s). I go on to show that the construction of categories plays an important role, which is related to the "divide and group" strategy.

GRAMMAR IN THE BRAIN

Andrea Moro

Two distinct disciplines, neuropsychology and theoretical linguistics, have accumulated since the second half of the XIX century different discoveries concerning human language on different empirical grounds: typically, neuropsychology on the basis of clinical and neuroanatomical evidences, proved the selective role of the left hemisphere of the human brain in language processing; on the other hand, comparative linguistics showed that grammars cannot vary unboundedly proving that they are generated by the recursive interaction of universal principles allowing small changes.

In this talk, I try to show that these independent discoveries converge in a non-trivial way by illustrating three distinct case studies based on neuroimaging techniques (in particular, Positron Emission Tomography, i.e. PET scan and fMR). In the first preliminary experiment, by using an invented language I will provide evidence that syntax, the unique component of human languages, selectively correlates with a complex left hemisphere neural network involving both cortical and subcortical elements (essentially, a deep component of Broca's are and the nucleus caudatus); in the second experiment, I will show that manipulating artificially created non-recursive grammars does not activate the same neural network, providing evidence that the very absence of this type of grammar among the languages of the world cannot solely be regarded as a purely conventional, i.e. historical, fact but it is rather the effect of the neurofunctional architecture of the brain; as a third case study I will explore the neural correlates of negation addressing the issue concerning the relationship between language and the representation of the world: specifically, I will show that negation can partially inhibit the fronto-parietal motor planning circuits that are activated while interpreting sentences associated with simple actions.

The course, given its inherent interdisciplinary character, will not require a special training in theoretical linguistics or neurology. In fact, strictly theoretical linguistic structures as well as neuroanatomical and neurophysiological details of the experiments will not be discussed; rather, we will concentrate on the impact of theoretical syntax on the research of the biological foundations of language and the effect that these discoveries have on theoretical syntax itself within a biolinguistics perspective. Papers describing these experiments are available online; for a general introductions, one may see Moro, A. (2008) *The Boundaries of Babels. The Brain and The Enigma of Impossible Languages*, MIT Press, Cambridge, Ma.

THE TRANSITION FROM ARITHMETIC TO ALGEBRAIC REASONING.

Mitchell J. Nathan

The study of algebraic reasoning and its development is important for what it says about cognitive development, but also for its role as a "gatekeeper" for economic opportunity and later education in the natural and social sciences. Algebraic reasoning involves a multifacted set of skills and knowledge. At its core, it extends earlier matheamtical reasoning because it allows one to reason about unknown quantities, reason with an array of abstract represenations such as equations and graphs, and reason in a relational manner. Two central themes emerge in this review. One is that students' entry into algebraic reasoning is often supported through the use of pre-existing verbal reasoning abilities. I refer to this as the "verbal precedence model" of algebra development. Another is that students often exhibit reasoning about mathematical relations first as actions and operations. Only later do they exhibit reasoning about mathematical relations in terms of relations and structures. I refer to this as the "process prcedence model" of algebra development. In this talk I review findings from several areas of mathematics, including students' understanding of the equal sign, the use of variables, symbol manipulation, graphing, and story problem solving. In each of these, alone or in combination, there is strong evidence for the verbal precedence model and the process precedence model. I then show how teachers use pedagogical methods through their speech and hand gestures to help students to make links between verbal language and mathematical symbols, and between actions and mathematical structures in order to foster the development of students' algebraic reasoning. I conclude with a brief discussion of the value of doing research in classroom settings as a way to understand more fully how students transition from arithmetic to algebraic reasoning.

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PHONOLOGY AND LEARNING

Marina Nespor

This class introduces some basic properties - both universal and variable in character - of the sound patterns of human language. We will mainly concentrate on different levels of rhythmic structure. Each phonological property will be considered in light of its relevance for language acquisition, and the learning mechanisms that make it possible. Attention will be paid to the acquisition of second languages in adulthood and to the potential use of recent discoveries in language development for education. We will concentrate on the one hand, on the richness of the speech signal and the cues it offers to different grammatical properties. On the other hand, we will focus on those properties of speech that are not perceived in a foreign language, unless also present in the mother tongue.

HOW DO THE CHILDREN LEARN?

Marcela Peña

During the last decade our knowledge about the way in which the cognitive abilities of young children and infants develop and learn has significantly increased. Studies have shown that from very early in life humans have the abilities to learn from their exposure to stimuli, being influenced by neural development and their personal perspective. In fact, infants have personal perspectives to process what is particularly relevant to human development, however, neural, social, emotional and other constraints significantly modulate the advances in learning at the school. The possibility that early learning in different neural, social, emotional context influences later educational earning is a topic of intense research. I will present some recent results obtained in our laboratory concerning language and social learning in healthy infant and infants who were born extremely preterm or deaf, and discuss their possible implications for education.

BRAIN MECHANISMS IN LEARNING SCHOOL SUBJECTS

Michael I. Posner

Formal schooling is usually thought to start at 5-6 years of age, but of course learning begins much earlier. Shaping brain networks related to language, arithmetic and self regulation begins in infancy.

Experimental studies reveal how brain networks change with early experience and how these changes may influence learning during the school years. Bilingual training may have important consequences not only for language but also for attention and self regulation. Parenting quality interacts with genetic differences to influence the attention and behavior of the child. High level skills develop specialized mechanisms that may allow rapid, early access to prior leaning.

PROBABILISTIC INFERENCES IN NEURAL CIRCUITS: FROM INSECTS TO HUMANS

Alexandre Pouget

A wide range of behaviors can be formalized as instances of probabilistic inferences. This includes odor recognition in insects, navigation in rodents, motor control, decision making in primates, simple arithmetic in children and monkeys, and causal reasoning in humans, to name just a few. In all cases, the probabilistic inferences involve products of probability distributions and another type of inference known as marginalization. We will show that, given the variability reported in neural responses, products of probability distributions can be implemented through linear operations over firing rates, while marginalization over Gaussian random variables requires a particular nonlinearity known as quadratic divisive normalization. Both operations are conspicuous in many neural circuits raising the possibility that seemingly unrelated behaviors, such as causal reasoning in humans or olfactory processing in rodents, could in fact rely on very similar neural mechanisms.

SLEEP, SYNAPSES, SYNCHRONY AND CIRCUITS

Marcus Raichle

This presentation will discuss the use of imaging (both PET and fMRI) to evaluate diurnal metabolic and organizational changes in normal humans.

LEARNING CONSOLIDATION

Sidarta Ribeiro

As the pace of scientific discovery accelerates, the knowledge gap between poor and rich also tends to increase. To prevent the dire consequences of growing inequality, it is necessary to improve schooling of the poor. While there is a great open field for the investigation of how teaching techniques may enhance learning, it is also urgent to gain better understanding of the physiological determinants of learning. If we assume that laboratory findings are applicable to the school setting, lack of nutrients and sleep when the class begins probably impairs memory acquisition, while the same conditions after class may impair memory consolidation. Poor kids often come to school with insufficient nutrition. Sleep deficits are also common, due to overcrowded sleeping spaces at home. Hormonal imbalance usually follows sleep loss, leading to obesity and daytime sleepiness that generates a vicious cycle of bad health and bad learning. In Latin America, certain political groups have advocated for full-day schools that include all meals. However, it is still unclear how much of the learning impairment of the poor can be explained by inadequate physiological conditions. It is even less clear how to fix these conditions in the school environment.

Experimentation with different feeding and sleeping schedules and variables (e.g. types and amounts of nutrients, short versus long naps) is likely to elucidate how much effort must be applied at the physiological level to guarantee fertile soil for the seed planted by clever teaching techniques. I plan to discuss papers and present some preliminary data on pre-acquisition glucose administration and post-acquisition naps, obtained from students of public schools in Natal (Brazil).

LEARNING AND SYNTAX

Luigi Rizzi

This talk is divided into two part. In the first, I would like to offer a short tutorial on the basic ingredients of natural language syntax according to recent models. One salient characteristic of human language is its unbounded scope: we can constantly produce and understand linguistic expressions that we have not encountered in our previous experience. This is made possible by the combinatorial character of language: elements from certain memorized inventories (first and foremost, the lexical items) can be combined to form higher level entities, the phrases. Syntactic rules guiding this combinatory system are *recursive*, in that they can indefinitely reapply to their own output, which determines the unbounded character of the system. Recursive rules are the key elements for the characterization of discrete infinities, such as human language and the natural number system. Our species appears to be the only one capable of mastering recursive systems in certain domains, hence possess an infinite language and the capacity to perform precise calculations.

Recent syntactic models have come to the conclusion that the fundamental recursive rule is extremely elementary: Merge, simply stating that two elements can be strung together to form a third element. If Merge is extremely simple, its recursive applications can generate structural representations of great complexity, which are described in the projects known as “the cartography of syntactic structures”. Structures created by Marge can undergo further computations such as movement: certain elements can be dislocated to a positions different from the one in which they are interpreted (for instance, in a wh-question the clause-initial phrase is to be construed as a dependent of a verb which can be indefinitely far away: *Which book do you think … that we should read ___?*). Merge and Move are not elements of an arbitrary formal game, but are immediately finalized to what language is all about: the expression of meaning and its encoding in a system of sounds. Merge immediately expresses properties of argumental semantics (who does what to whom in the described event), and Move expresses scope-discourse properties: the scope of operators, such discourse-related articulations as topic-comment, focus-presupposition, and the ,like.

In the second part of the talk I would like to address issues of language acquisition. Certain kinds of movement are acquired early by the language learner, while other kinds are acquired late. I will show how linguistic theory can offer precise tools characterizing syntactic complexity along certain formal dimensions, and the resulting complexity scales are instrumental for understanding certain selective difficulties in acquisition. The illustration will be based on the intervention effects that make object relatives and (certain) object questions very hard for the learner, who can easily cope with subject relatives and questions around the age of three, but will manage to fully compute object relatives and questions, and other structures giving rise to intervention effects, only a few years later.

MEANING ACROSS MODALITIES: SIGN VS. SPOKEN LANGUAGES

Philippe Schlenker

We will suggest that new insights into meaning can be gained from the study of sign languages. Our main focus will be on indirect discourse, i.e. the grammatical constructions by which we convey another person's thoughts. A traditional theory holds that, short of *quoting* another individual's words, we can never convey in indirect discourse the details of her first person perspective (note for instance that 'Mary thinks that I am an idiot' certainly could not attribute to Mary a first-person thought about herself - the thought has, alas, to be about me, the speaker). Recent research on spoken language has cast doubt on this claim: there are languages (e.g. Amharic, Zazaki) in which a sentence such as 'John says that I am hero' does attribute to

John a belief about himself. Contemporary theories have introduced abstract operations of 'context shift' to account for these surprising facts. Data from sign language (in particular ASL) bring new light to this debate because such operations are visibly realized: in such cases, the signer literally shifts her body to adopt another person's perspective ('role shift'). This makes it possible to ask detailed questions about the grammatical mechanisms by which changes of perspective are realized in grammar.

READINESS

Mariano Sigman

I will discuss different approaches bridging experimental psychology and education, with particular emphasis in applications to Latin American and third world schools. First I will present an early intervention aimed to foster cognitive development in schools of Buenos Aires on a population of children with Unsatisfied Basic Needs (poverty criteria based on National Standards). The intervention combines training in memory, attentional and executive function networks. Results although very preliminary - show a very rapid and dramatic effect in the development of control networks. This effect has little specificity to the characteristics of the training programs. Next I will discuss a contemporary recreation of the dialog between Socrates and Meno´s slave. Some two hundred four hundred years ago, Socrates gave a remarkable lesson of geometry, perhaps the first detailed record of a pedagogical method in vivo in history. Socrates asked Meno's slave fifty questions requiring simple additions or multiplications. At the end of the "lesson", after simply responding to the questions by yes or no, the student discovered by himself how to duplicate a square using the diagonal of the given one as the side of the new square. We investigated the reproducibility of this dialog in educated adults and adolescents of the XXIst century. Results show a very close agreement most remarkably in questions in which Meno's slave makes a mistake. Within an unbounded number of possible erred responses, the vast majority of empiric responses coincide with the error of the dialog demonstrating the universality of mathematical intuitions. I will build on this example to discuss emerging possibilities of education for third world countries in the digital era. Specifically I will discuss the OLPC (One Laptop Per Child) project which currently assigns a computer to virtually every single child in Uruguay to discuss novel perspectives for education and for the understanding of cognitive development at a country-wide scale.

SLEEP, MEMORY, AND DREAM: THEIR ROLES IN LEARNING AND MEMORY

Robert Stickgold

In the first century AD, the Roman rhetorician Quintilian, commenting on the benefits of sleep, noted that, "what could not be repeated at first is readily put together on the following day; and the very time which is generally thought to cause forgetfulness is found to strengthen the memory". Two thousand years later, we finally have good scientific evidence to back up his claim.

The benefits that sleep confers on memory are surprisingly widespread. For simple procedural skills – how to ride a bicycle or distinguish different coins in one's pocket – a night of sleep, or an afternoon nap, leads to an absolute improvement in performance. Thus, on a procedural finger tapping task, in which subjects learn to type a sequence such as "4-1-3-2-4" as quickly and accurately as possible, a night of sleep results in a 20% increase in speed along with a 30-50% reduction in errors.[1] Similarly, sleep can stabilize verbal memory, dramatically reducing its susceptibility to interference and decay, processes that otherwise tend to lead to the loss of the learned material. For example, when subjects were trained on a list of word pairs and tested 12 hours later with or without additional training on a second list, subjects trained in the morning and tested that evening (with no intervening sleep) forgot 50% of the initially learned pairs after interference training, while subjects trained in the evening and tested the next morning after a night of sleep only forgot 18% following interference training.[2]

But the action of sleep can be more sophisticated than simply strengthening and stabilizing memories. It can lead to the selective retention of emotional memory, or even of emotional components of a scene, while allowing other memories and scene components to be forgotten.[3] It can extract the gist from a list of words,[4] or the rules governing a complex probabilistic game.[5] It can lead to insights ranging from finding the single word that logically connects three otherwise unrelated words[6] to discovering an unexpected rule allowing the more efficient solving of mathematical problems.[7] It can facilitate the integration of new information into existing neural networks of related information[8] and help infants learn artificial grammars. Taken as a whole, these findings suggest that a major function of sleep, and dreaming, is to create meaning.

Perhaps the most complex accomplishment of the human brain is the construction of meaning – a process that requires the analysis of large bodies of data and the identification of associations, relationships, regularities, and rules in the world around us. Each and every one of us does this constantly, from the moment that we are born to the instant of our death, creating our own private meaning of the world.

While almost all of the time consciously spent in pursuit of this meaning occurs during waking, it is unclear how much of the total time spent in this search occurs in this state. The states of sleep and dreaming may well contribute more to this discovery and creation of meaning than does the waking state.

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LEARNING STRATEGIES IN BILINGUALS

Janet Werker

Infants are born with a set of abilities that set the stage for language acquisition. All human languages share universal properties, yet they also vary in the sound systems, syntax, and of course words that will be used. Considerable research has revealed how infants become tuned to the perceptual properties of the native language during the first year of life, and how these changing sensitivities prepare the child for acquisition of their native language. Many babies grow up learning two languages from the first days of life. These children will establish two phonologies (the sounds of the language), two grammars (the word order of the language), and two lexicons (the words of the language). In this lecture I will describe the challenge faced by bilingual learning infants, and will then review research describing how the bilingual infant begins to establish two such systems – starting from language separation shown by the first moments of life through the beginnings of establishment of a lexicon. Work from my lab, as well as from several other laboratories around the world will be presented. A detailed presentation of some of the procedures and tasks used for determining what infants know will be included in the presentation. Through elucidation of how bilingual infants begin to separate their two languages, acquire the properties of each, and begin to establish a lexicon, students will learn not only about bilingual acquisition, but will also be positioned to reflect more deeply on the universal process of language acquisition. The implications of this research for educational expectations for bilingual children will be discussed.

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