THE PONTIFICAL ACADEMY OF SCIENCES

Working Group on

# Human Neuroplasticity and Education

Casina Pio IV • 27-28 October 2010




VATICAN CITY 2010

Thus, Augustine's entire intellectual and spiritual development is also a valid model today in the relationship between faith and reason, a subject not only for believers but for every person who seeks the truth, a central theme for the balance and destiny of every human being. These two dimensions, faith and reason, should not be separated or placed in opposition; rather, they must always go hand in hand. As Augustine himself wrote after his conversion, faith and reason are "the two forces that lead us to knowledge" (*Contra Academicos,* III, 20, 43). In this regard, through the two rightly famous Augustinian formulas (cf. *Sermones,* 43, 9) that express this coherent synthesis of faith and reason: *crede ut intelligas* ("I believe in order to understand") – believing paves the way to crossing the threshold of the truth – but also, and inseparably, *intellige ut credas* ("I understand, the better to believe"*),* the believer scrutinizes the truth to be able to find God and to believe.

Benedict XVI, *General Audience*, Paul VI Audience Hall, 30 January 2008

# INTRODUCTION

Antonio M. Battro, Stanislas Dehaene and Wolf J. Singer
*Pontifical Academicians*

This meeting can be considered as the continuation of the workshop on "Mind, Brain and Education" held at the Pontifical Academy of Sciences in November 2003 (Battro, A.M., Fischer, K.W & Léna, P. Editors. *The educated brain*: *Essays in neuroeducation.* Cambridge University Press & Pontifical Academy of Sciences, 2008). Since then the theory and practice of neuroeducation have shown a significant progress. Several advanced research institutions in America, Asia and Europe are now involved in the transdisciplinary study of the neurocognitive foundations of learning and teaching, and the topic of neuroplasticity appears as the perfect link to address some fundamental questions coming from different fields.

The human species has developed an educational system to create and transmit knowledge and values from one generation to the next. With the help of education humans have expanded their cognitive potential by many orders of magnitude, well beyond the limits imposed by biological evolution. In particular the human cerebral cortex has revealed impressive capabilities to change its functionality and even its architecture during the process of education. Several mechanisms of neuroplasticity have been detected in the laboratory, the clinic and the school, that could sustain different learning styles.

Our workshop will discuss several topics at the cutting edge of the mind, brain and education sciences. For example the theory of a neuronal recycling process provides a new framework to understand, and to improve, the way young children learn to read and calculate. A wealth of experimental results illustrates the different neurocognitive pathways in the acquisition of first and second languages and the unfolding of basic arithmetical and geometric operations. Also the development of the social aspects of cognition, essential to educational practice, is now studied with new and powerful technologies and new theoretical models. The gap between genomics and education has shown in recent years a significant reduction. Neurocognitive models of developmental dyslexia and genotype- phenotype research studies in mental retardation and learning disabilities may show that heredity is not destiny. Some unexpected outcomes for treatment of those mental handicaps will be addressed.

Perhaps one of the most relevant tendencies in the mind, brain and education sciences of today is the expansion of the neurocognitive studies beyond the laboratory into the school and the community. The possibility to monitor online many aspects of the learning and teaching activities using the powerful tools provided by digital networks and wi-fi technology opens a new horizon of research and practice. In particular we experience the formidable impact of computer and communication devices in the new ways children learn, and even teach, in a digital environment. Brain activities can be recorded nowadays in many ways in natural conditions with portable and wearable equipments. But the great novelty is the change of scale in education that the new digital technology triggers. Millions of children around the world can now be educated in a global cognitive environment.

## Wednesday, 27 October 2010

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|---|---|
| 9:00 | *Introduction and Welcome* (Antonio M. Battro) |
| | Session I • Chair: Antonio M. Battro |
| | **LANGUAGE AND LITERACY** |
| 9:30 | *The Massive Impact of Literacy on the Human Brain*<br>**Stanislas Dehaene** |
| 10:15 | *The Extent and Limit of Speech and Language: Reorganization After Brain Injury in Childhood*<br>**Faraneh Varga-Khadem** |
| 11:00 | Coffee break |
| | **LEARNING AND TEACHING** |
| 12:00 | *Plasticity in Learning Pathways: Assessments That Capture and Facilitate Learning*<br>**Kurt W. Fischer** |
| 12:45 | Lunch at the Casina Pio IV |
| 14:30 | *Natural Geometry*<br>**Elizabeth Spelke** |
| 15:15 | Discussion |
| | Session II • Chair: Wolf J. Singer |
| | **THE INFANT BRAIN** |
| 16:00 | *The Architecture of the Baby Brain*<br>**Ghislaine Dehaene-Lambert** |
| 16:45 | Coffee break |
| 17:30 | *How Infants Crack the Speech Code: Exploring the Infant Mind Using the Tools of Modern Neuroscience*<br>**Patricia K. Kuhl** |
| | **GENETICS AND LEARNING** |
| 18:15 | *Experiential Genetic and Epigenetic Effects on Human Neurocognitive Development*<br>**Helen J. Neville** |
| 19:00 | General Discussion (duration 45 min.) |
| 20:00 | Dinner at the Casina Pio IV |

## Thursday, 28 October 2010

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|---|---|
| 9:00 | *Fulfilling the Promise of Molecular Medicine in Developmental Brain Disorders*<br>**Mark F. Bear** |
| 9:45 | *If Learning Disabilities Have a Genetic Origin What Should Educators Know?*<br>**Albert M. Galaburda** |
| 10:30 | Coffee break |
| 11:30 | **Papal Audience** |
| 13:30 | Lunch at the Casina Pio IV |
| Session III • Chair: Stanislas Dehaene | |
| **BRAIN DEVELOPMENT AND SOCIETY** | |
| 15:00 | *Synaptic and Clock Genes in Autism Spectrum Disorders*<br>**Thomas Bourgeron** |
| 15:45 | *The Development of Social Cognition: Early Learning, Neuroplasticity and Education*<br>**Andrew N. Meltzoff** |
| 16:30 | Coffee break |
| 17:00 | *The Second Chance*<br>**Wolf J. Singer** |
| 17:45 | Conclusions |
| 18:00 | Departure from the Casina Pio IV by bus to attend the concert at Palazzo Boncompagni Ludovisi |
| 18:30 | Concert followed by dinner |
| 21:30 | Bus leaves Palazzo Boncompagni Ludovisi to take participants back to the Domus Sanctae Marthae |

### Fulfilling the Promise of Molecular Medicine in Developmental Brain Disorders

Mark F. Bear

Proper brain function requires the sculpting of connections between neurons during early postnatal life. Synapses are formed and strengthened, weakened and lost, under the influence of sensory experience. Over four decades of research on visual cortex have culminated in a deep understanding of the mechanisms responsible for whittling away inappropriate synaptic connections. Insights derived from this line of research have recently suggested the remarkable possibility of new treatments – and possibly a cure – for fragile X syndrome, the most common inherited form of human mental retardation and autism.

### Synaptic and Clock Genes in Autism Spectrum Disorders

Thomas Bourgeron

Autism spectrum disorders (ASD) affect at least 1/200 individuals and are characterized by impairments in communication skills and social interaction, as well as restricted, repetitive and stereotyped patterns of behavior. Our previous studies pointed at one synaptic pathway, including synaptic cell adhesion molecules (neuroligins and neurexins) and scaffolding proteins (SHANK3) associated with the disorder. These proteins are crucial for synapse formation/maintenance as well as correct balance between GABA and glutamate synaptic currents. Following these results, we recently performed a high-throughput genotyping of 400 patients with ASD and could confirm the involvement of the NRXN-NLGN-SHANK pathway in the susceptibility to ASD and detect new synaptic genes associated with ASD. In parallel, we could show that mutations within the *ASMT* gene, encoding the last enzyme of melatonin synthesis, lead to melatonin deficiency in a subset of patients with ASD. Melatonin is known to play a key role in the regulation of circadian rhythms such as sleep-wake cycles and was shown to modulate GABAergic currents, as well as neurite and memory formation in different animal models such as fish, birds, and mammals. Based on these results, we propose that ASD could be the consequence of an alteration in the homeostasis of the synaptic currents in specific regions of the brain. In some cases, imbalance of excitatory/inhibitory currents could be revealed or amplified by an alteration of the melatonin pathway and/or abnormal sleep homeostasis. Consistent with this hypothesis, a better characterization of the interplay between synaptic and clock genes may shed light on new pathways associated with ASD and hopefully new therapeutic strategies.

### The Massive Impact of Literacy on the Human Brain

Stanislas Dehaene

Reading is a wonderful invention that allows us to access the language system through visual symbols and "listen to the dead with our eyes" (Francisco de Quevedo). The neuronal recycling view of reading acquisition suggests that we acquire reading through the pre-emption and minimal reconfiguration of evolutionarily older neuronal circuits for this novel cultural use. In this manner, education to literacy enhances the human brain beyond its initial inherited abilities. In a recent neuroimaging study of the illiterate brain, performed in collaboration with Lucia Braga, Paulo Ventura, Régine Kolinsky, Jose Morais and others, we found the impact of alphabetic literacy to be even more pervasive that we initially expected. Compared to illiterates, literates have specialized a visual area of the brain, the visual word form area (VWFA), that becomes highly responsive to the shapes of letters and their combinations. This brain area originally evolved for object recognition and its properties are only partially suited to the reading task. Thus, in this region, learning to read involves adaptation as well as partial un-learning of previous competences (loss of mirror symmetry invariance, reduced responsivity to faces). However, literacy also enhances visual responses much earlier in the visual system, thus providing us with a refined resolution that can be helpful beyond reading tasks. Literacy also changes the brain's response to spoken language. The *planum temporale* becomes much more responsive to speech, perhaps reflecting enhanced phonological coding. Furthermore, in literate subjects only, orthographic representations in the VWFA can be activated in a top-down manner from spoken inputs if the task requires it, thus adding a new level of representation that presumably enhances memory for spoken language. Altogether, the competence of the literate brain is augmented at both visual and auditory levels. Beyond the specific example of literacy, I argue that the role of education is to identify evolutionarily ancient brain systems that can be recycled, capitalizing on the exuberant synaptic plasticity present in young children. Through education, brain development is partially reoriented, thus expanding the competences of our species. Mathematical, musical or moral education might be reanalyzed along similar lines.

### The Architecture of the Baby Brain

Ghislaine Dehaene-Lambertz

The first months of life are the "terra incognita" of our knowledge on child development. Although research in psychology showed that the child is the prime actor of his learning from the first days of life on, we have difficult access to what the child of this age thinks, feels, and learns because he still does not possess any code of communication. Yet in order to understand how the complex human cognitive functions, language, mathematic, music, etc … have emerged in humans, we need to understand their beginnings in human infants. Understanding early cerebral development is one of the most promising and stimulating challenge of the last years thanks to the development of non invasive brain imaging techniques. These new tools allow a better exploration of infant early capacities and of their cerebral bases and shed new light on the continuity between the infant and the adult brain. In our work, we have combined structural and functional studies to study what the features of the human infant brain, that drive language learning, are. In adults, speech processing relies on precise and specialized networks, located primarily in the left hemisphere. Contrary to the classical hypothesis of an initial equipotential brain, we observe strong asymmetries in the infant brain both at a structural level and at a functional level, equivalent to what is described in adults. Furthermore, from the first weeks of life on, brain activity is not limited to sensory regions but involves high-level associative areas, such as the frontal areas, suggesting that infants are more actors than passive receptors in learning. More specifically concerning language learning, the results obtained with functional magnetic resonance imaging (fMRI) and event-related potentials (ERPs) show that the neuronal networks engaged when infants listen to speech are close to those described in adults and comprise multiple brain areas that are involved in phonological representations, lexical storing, attention, short-term and long-term memory in adults. These similarities between preverbal infants and adults expert in their native language, suggest a continuity in functional and anatomical structures that underlie language processing. Language development appears thus to be based on a progressive differentiation of pre-constrained networks that are shaped by the native language. The new insights provided by cerebral imaging should change our experimental approaches of learning and development in humans by focusing on the description of the infant cerebral resources (i.e. the computational properties made available by the activated networks) to process the external world and constraint hypotheses about learning algorithms. This will provide a strong basis for the study of early developmental disorders affecting language and communication in humans.

### Plasticity in Learning Pathways: Assessments That Capture and Facilitate Learning

Kurt W. Fischer

The primary goal of the emerging field of Mind, Brain, and Education is to join biology, cognitive science, development, and education in order to create a sound grounding of education in research. Although most industries use research to ground their practical decisions, education mostly lacks an infrastructure for connecting research with practice and policy. Fortunately the knowledge base for educational practice is deep because of many advances in analysis of learning and plasticity in cognitive and neuroscience. We use this base to build tests that are both standardized and formative, grounded in research about learning, and richly educative. The tests start with a universal scale for learning, based in evidence from cognitive development, brain development, and learning – which greatly increases the power of assessments. Around this scale we have built a toolkit for modeling and assessing the diverse learning sequences and developmental pathways through which real people individuals in real-world contexts learn and develop. A key part of the toolkit is Dawson's Lectical™ Assessment System, a psychometrically validated domain-general developmental assessment system. We use these tools to design a new kind of testing infrastructure, known as the DiscoTest™ Initiative. Our goal is to change the practice of testing, moving beyond using tests as sorting mechanisms and toward using them as powerful aids to education.

### If Learning Disabilities Have a Genetic Origin, What Should Educators Know?

Albert M. Galaburda

Literacy is a recent human acquisition, and it is tightly bound to culture. Throughout human history we have had cultures without literacy, but there are no examples of literacy without culture. Since literacy is recent among human societies, we cannot expect to have special genes for reading. However, an interesting theory (see presentation by S. Dehaene) proposes that ancient systems for visual form processing have been recycled to handle the challenge of decoding print. But, reading presents different challenges to individuals depending on the language being read. A corollary of this is that in the case of developmental disorders of reading, it makes a difference whether the print is for an orthographically transparent language, like Italian, or one more opaque, like English; dyslexia has different manifestations in either type of language. Dyslexia has been linked to candidate risk genes discovered by genome wide association and other genetic approaches in several human populations. Some of these candidate genes have been confirmed in more than one distinct population. In some cases, a gene variant that is associated with dyslexia in one population is not associated with dyslexia in a different population. So, it behooves us to know what these genes do, in order to understand why such variability may occur (other than the variability in the language mentioned above), and even in an attempt to get at the question of subtypes of dyslexia. So far our laboratory has studied three candidate dyslexia genes and all interfere with normal neuronal migration during development, leading to abnormal circuits in the brain. The developmental biology is intricate and much more needs to be learned. Separate cellular and molecular pathways are affected by each candidate gene, and there may be interactions among them that still need to be sorted out. One useful outcome of this research for the field of education could be enhancing our ability to identify children at risk early in order to initiate appropriate pedagogical treatments before complications arise. Another benefit would be to discover ways by which medications could be used to positively affect early brain plasticity toward more efficient circuits and improved learning.

### How Infants Crack the Speech Code: Exploring the Infant Mind Using the Tools of Modern Neuroscience

Patricia K. Kuhl

Some of the most revolutionary ideas in brain science are coming from cribs and nurseries. In this talk I will focus on the new discoveries about early learning and the neural coding of information with special attention to language. Infants are born 'citizens of the world' and can acquire any language easily. But by the end of the first year of life, infants exposed to one language have developed a specialty in that language, and their ability to discern phonetic differences from other languages declines. Research on infants is showing that infants use computation to 'crack the speech code,' but that social interaction plays a critical role in learning. "Motherese," the exaggerated, high-pitched speech we use to speak to infants and children, is used in virtually every language studied, and infants' interest in it contributes to their ability to learn. These precursors to language in typically developing infants are leading to the identification of children at risk for developmental disabilities involving language, such as children with autism. Over the next decade, the techniques of modern neuroscience will play an ever-increasing role in our understanding of the interaction between biology and culture in human learning.

### The Development of Social Cognition: Early Learning, Neuroplasticity, and Education

Andrew N. Meltzoff

Some of the most important advances in understanding human nature have come from the study of young children, even preverbal babies. Scientific discoveries from developmental psychology have changed theories of how the mind grows, and the role that emotions, curiosity, self-concepts, and self-motivation play in human development. The emerging field of "social cognition" – our understanding of other people – has been especially revolutionary. Science has discovered that human beings are born with the ability to connect to other people socially: We have an innate capacity to learn from imitating social others. Young children are also capable of engaging in joint attention – following the gaze of adults as they highlight important objects and events surrounding them. In early childhood, young children begin to be influenced by cultural stereotypes. I will discuss new research about how stereotypes in the culture about race and gender become internalized and influence the formation of children's self-concepts, which in turn affects future learning. At a more overarching level, I will suggest a theory about childrens' growing understanding of self and other, which I call the "Like Me" framework. The framework proposes a developmental progression: from acting "like the social other" at the level of motor behavior (action *imitation*), to feeling like the other at the level of emotion (*empathy*), to sharing identity with the other by adopting an attribute associated with a group (*self-concept*). This 'Like Me' developmental trajectory has neuroscience roots and educational implications, especially in the preschool education but with ramifications for life-long learning.

### Experiencial, Genetic and Epigenetic Effects on Human Neurocognitive Development

Helen J. Neville

For several years we have employed psychophysics, electrophysiological (ERP) and magnetic resonance imaging (MRI) techniques to study the development and plasticity of the human brain. We have studied deaf and blind individuals, people who learned their first or second spoken or signed language at different ages, and children of different ages and of different cognitive capabilities. Over the course of this research we have observed that different brain systems and related functions display markedly different degrees or 'profiles' of neuroplasticity. Some systems appear quite strongly determined and are not altered even when experience has been very different. Other systems are highly modifiable by experience and are dependent on experience but only during particular time periods ("sensitive periods"). There are several different sensitive periods, even within a domain of processing. A third 'plasticity profile' is demonstrated by those neural systems that remain capable of change by experience throughout life. We have also observed the two sides of plasticity in several domains of processing: i.e. systems that are most modifiable (i.e. display more neuroplasticity) display both more enhancements in the deaf and blind and greater vulnerability in those with or at risk for developmental disorders. Guided by these findings, we are conducting a program of research on the effects of different types of training on brain development and cognition in typically developing children of different ages. In one series of studies we are targeting the most changeable and vulnerable systems in 3-5 year old preschoolers (at-risk for school failure for reasons of poverty) whom we study before and after 8 weeks during which the children receive daily attention training and their parents receive training in parenting skills once a week. Standardized measures of cognition and ERP measures of attention and language document large and significant effects of these different types of inputs on neurocognitive finction. Genetic and Gene X Environment (training) interactions are also evident in these data. These studies will contribute to a basic understanding of the nature and mechanisms of human brain plasticity. In addition, they can contribute information of practical significance in the design and implementation of educational programs.

### The Second Chance

Wolf J. Singer

Developmental studies in animals and human subjects have provided ample evidence for the existence of critical periods in early post-natal development during which connections in the cerebral cortex are highly susceptible to experience dependent modifications. This activity dependent shaping of cortical circuits is a necessary prerequisite for the development of normal sensory functions. The majority of these studies have concentrated on the visual system and the consequences of sensory deprivation. Much less direct evidence is available from other sensory systems but it is generally held that they develop according to the same rules, their maturation depending also on an interplay between genetic and epigenetic factors. Indirect evidence from studies about the acquisition of certain skills (language competence, mastering musical instruments, riding bicycles etc.) suggests the existence of critical periods also for other developmental processes whereby the temporal windows are more protracted than for the maturation of basic sensory processes. In humans, brain development extends way beyond puberty and comes to an end only at around age 20. However, much less work has been devoted to the investigation of these later developmental stages. There is good evidence from anatomical studies and non-invasive morphometry that these later developmental processes are associated with substantial, region specific changes in the ratio between gray and white matter. Recent investigations of electrophysiological variables such as oscillatory activity in different frequency bands and the long distance synchronisation of these oscillations indicate further, that late adolescence is characterized by a massive rearrangement of functional networks. This transitional phase is associated with a transient disorganization of already established proto-networks. Thus, there appears to be a late critical period of brain development that precedes the final maturation of cortical architectures. Behaviorally, this phase coincides with the acquisition of elaborate social skills. Freud, without having any neurobiological evidence, had recognized this late labile phase and addressed it as the second chance. He proposed that errors that have incurred during early development could be corrected during this late phase. To the best of my knowledge, this late developmental stage is not in the focus of education policies. In view of the growing neurobiological evidence on the protracted maturation of human brains, it might be worthwhile to examine more thoroughly the putative opportunities of this second chance.

## Natural Geometry

Elizabeth Spelke

How do human beings – finite devices that connect to the world through sensors and effectors – conceive of lines that are infinitely long and imperceptibly thin? Converging studies of human infants, non-human animals, and human children and adults varying in culture and education suggest that abstract geometrical concepts build on cognitive systems with many of the properties of perceptual systems. These "core systems" are limited in their application and their resolution, but each captures some geometrical information. By combining the information from these systems, children may construct their first abstract concepts of Euclidean geometry.

## The Extent and Limits of Speech and Language Reorganization After Brain Injury in Childhood

Faraneh Varga-Khadem

It has long been recognized that because of its abundant plasticity and reorganizational capacity, the immature human brain can rescue critical cognitive functions, notably speech and language. Although the degree of sparing of function is related to hemispheric side of damage and age at injury, other factors also contribute to the course and extent of plasticity and recovery of function after lesions of the speech and language network. This presentation will focus on the extent and limits of reorganization of speech and language in the presence of unilateral versus bilateral pathology.

**Mark F. Bear** is an Investigator of the Howard Hughes Medical Institute, and Picower Professor of Neuroscience in The Picower Institute for Learning and Memory and the Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology. Dr. Bear served as Director of The Picower Institute from 2007 to 2009. Prior to moving to MIT in 2003, Dr. Bear was on the faculty of Brown University School of Medicine for 17 years. After receiving his B.S. degree from Duke University, he earned his Ph.D. degree in neurobiology at Brown. He took postdoctoral training from Wolf Singer at the Max Planck Institute for Brain Research in Frankfurt, Germany, and from Leon Cooper at Brown. His honors include Young Investigator Awards from The Office of Naval Research (1988) and Society for Neuroscience (1993), and the Brown University Class of 2000 Barrett Hazeltine Citation for Teaching Excellence. He was elected as a Fellow of The Neurosciences Institute and Dana Alliance for Brain Initiatives in 1999, the American Association for the Advancement of Science in 2003, the American Academy of Arts and Sciences in 2004, and the American College of Neuropsychopharmacology in 2005. In 2006, Dr. Bear was the recipient of the William & Enid Rosen Research Award for outstanding contributions to our understanding of Fragile X by The National Fragile X Foundation.

**Thomas Bourgeron**. After a Master in the field of plant biology, I did my Ph.D in human genetics to study mitochondrial diseases. I studied the deletions of mtDNA and identified the first mutations of the Krebs cycle (*FH*) and of the nuclear genes of the respiratory chain (*SDHA*) in humans. I obtained a permanent position as Assistant Professor at University Denis Diderot Paris 7 and joined the Institut Pasteur to study the role of the Y chromosome in male infertility. In 2003, I established a laboratory to study the genetics of autism spectrum disorders (ASD) in the Department of Neuroscience. Our most recent results include the identification of one synaptic pathway associated with ASD. The causative genes code for cell adhesion molecules (*NLGN3*, *NLGN4, NRXN1*) or scaffolding protein (*SHANK2* and *SHANK3*), which are crucial factors for appropriate synaptic function. In parallel, we recently identified genetic mutations disrupting melatonin synthesis in individuals with ASD. On the bases of these results, our present projects aim to understand the role of the synaptic and circadian-clock genes in the development of language and social communication in humans.

**Ghislaine Dehaene-Lambertz** Originally qualified as a paediatrician, Ghislaine Dehaene-Lambertz is a full-time associate researcher at Institut national de la santé et de la recherche médicale ( INSERM) U562, Paris, France, where she investigates the development of cognitive functions with brain imaging techniques. She published pioneering work using high-density event-related potentials (Nature 1994), functional resonance magnetic imaging (Science 2002) or optical topography (PNAS 2003) to study language acquisition. The goal of her research is to study the brain functional organization at the beginning of life in order to understand how complex cognitive functions, such as language, music, mathematics, etc… emerge in the human brain. Her approach is to examine the primitive functions that are accessible to the human brain to process the external word at the beginning of life, then to study how initial biases in brain organization could be shaped by the human environment to give rise to the mature state.

**Kurt W. Fischer** leads an international movement to connect biology and cognitive science to education, and is founding editor of the journal *Mind, Brain, and Education* (Blackwell), which received the award for Best New Journal by the Association of American Publishers. As Director of the Mind, Brain, and Education Program and Charles Bigelow Professor at the Harvard Graduate School of Education, he does research on cognition, emotion, and learning and their relation to biological development and educational assessment. He has discovered a general scale that makes it possible to create standard assessments of learning and development in any domain. His most recent books include *The Educated Brain* and *Mind, Brain, and Education in Reading Disorders* (Cambridge University Press, 2008 and 2007, respectively).

**Albert M. Galaburda** is currently the Emily Fisher-Landau Professor of Neurology and Neuroscience at Harvard Medical School, and Director of the Division of Cognitive Neurology at Boston's Beth Israel Deaconess Medical Center. His career has spanned research on the biological basis of cerebral dominance and language-based learning disabilities. He currently has an NIH grant to study the effects of candidate dyslexia susceptibility genes on brain development, and he is closely involved in teaching college students about mind and the brain within the initiative set up at Harvard University by the name of *Mind, Brain, and Behavior*. His hope is to see some of the advances in the brain and cognitive sciences be implemented in improved educational systems for both typically developing children and children with learning disabilities.

**Patricia K. Kuhl**, Ph.D. holds the Bezos Family Foundation Endowed Chair in Early Childhood Learning and is Co-Director of the UW Institute for Learning and Brain Sciences, Director of the University of Washington's NSF Science of Learning Center, and Professor of Speech and Hearing Sciences at the University of Washington in Seattle. She is internationally recognized for her research on early language and bilingual brain development, and studies that show how young children learn. She presented her work at two White House conferences (Clinton White House in 1997 and Bush White House in 2001). Dr. Kuhl is a member of the National Academy of Sciences, the American Academy of Arts and Sciences, the Rodin Academy, and the Norwegian Academy of Science and Letters, and is a Fellow of the American Association for the Advancement of Science, the Acoustical Society of America, and the American Psychological Society. Dr. Kuhl was awarded the Silver Medal of the Acoustical Society of America in 1997. In 2005, she was awarded the Kenneth Craik Research Award from Cambridge University. She received the University of Washington's Faculty Lectureship Award in 1998. In 2007, Dr. Kuhl was awarded the University of Minnesota's Outstanding Achievement Award. In Paris in 2008, Dr. Kuhl was awarded the Gold Medal of the Acoustical Society of America for her work on early learning and brain development.

**Andrew N. Meltzoff**, Ph.D., is a developmental psychologist at the University of Washington and is an internationally renowned leader in child development research and cognitive science. His interests include imitative learning, the development of self-other understanding, the development of human empathy, and how cultural stereotypes affect children. Dr. Meltzoff received a B.A. from Harvard University and Ph.D. from Oxford University. At the University of Washington, Dr. Meltzoff holds the Job and Gertrud Tamaki Endowed Chair and is the Co-director of the Institute for Learning and Brain Sciences. He has co-authored three books about learning and the brain: *The Scientist in the Crib: What Early Learning Tells Us about the Mind* (translated into 20 languages)*, Words Thoughts and Theories*, and *The Imitative Mind: Development, Evolution and Brain Bases*. Dr. Meltzoff received an award from the Society for Developmental & Behavioral Pediatrics for outstanding research (2005), the Kenneth Craik Award in Psychology from Cambridge University in England (2005), and a MERIT research award from the U.S.A National Institute of Health. He has been selected as a Fellow in many professional societies including: American Academy of Arts & Sciences, American Psychological Association, Association for Psychological Science, American Association for the Advancement of Science, and the Norwegian Academy of Science and Letters. Dr. Meltzoff has advised governors, science museums, and media leaders about the discoveries in early learning and the implications for educational theory and practice.

**Helen J. Neville** was awarded the Ph.D. from Cornell University. Dr. Neville is currently The Robert and Beverly Lewis Endowed Chair and Professor of Psychology and Neuroscience, Director of the Brain Development Lab, and Director of the Center for Cognitive Neuroscience at the University of Oregon in Eugene. Her work experience includes Director of the Laboratory for Neuropsychology at the Salk Institute. She has published in many journals including *Nature, Nature Neuroscience, Journal of Neuroscience, Journal of Cognitive Neuroscience, Cerebral Cortex* and *Brain Research and has made a DVD about the brain for non-scientists*. She has received many honors including being elected to the American Academy of Arts and Sciences, the Board of Governors of the Cognitive Neuroscience Society, the Academic Panel of Birth to Three and is active in many educational outreach programs.

**Elizabeth Spelke** teaches at Harvard University, where she is the Marshall L. Berkman Professor of Psychology. She previously taught at MIT, Cornell University, and the University of Pennsylvania after studying at Harvard, Yale and Cornell Universities. Spelke studies the origins and nature of knowledge of objects, actions, number, geometry, and social relationships through studies of human infants, children, human adults and non-human animals. A member of the National Academy of Sciences and the American Academy of Arts and Sciences, her honors include the Distinguished Scientific Contribution Award of the American Psychological Association, the William James Award of the American Psychological Society, the IPSEN prize in neuronal plasticity, and the Jean Nicod Prize.

**Faraneh Vargha-Khadem** completed her doctoral and post doctoral studies at the University of Massachusetts in the US, and at McGill University in Montreal, Canada. She took up a lectureship in 1983 at the Institute of Child Health and Great Ormond Street Hospital for Children where she helped create the first academic department of Developmental Cognitive Neuroscience in the UK, and its clinical counterpart, the Department of Clinical Neuropsychology. Professor Vargha-Khadem conducts research on the effects of brain injury on cognition and behaviour in children. Her work is focused on developmental amnesia, brain and speech abnormalities resulting from the mutation of the FOXP2 gene, and reorganization of brain function in children who have undergone neurosurgery for epilepsy. She holds the chair of Developmental Cognitive Neuroscience, and the headship of that department at University College London Institute of Child Health, and is the Director of the UCL Centre for Developmental Cognitive Neuroscience. She was elected Fellow of the Academy of Medical Sciences in 2000, and has received a number of awards including the 2006 Jean Louis Signoret Prize for her contributions to genetics of behaviour.

**For the biographies of the other Academicians of the PAS, cf. Pontificia Academia Scientiarvm, *Yearbook* (Vatican City 2008), p. 15 ff. and http://www.vatican.va/roman_curia/pontifical_academies/acdscien/own/documents/pasacademicians.html**

**Prof. Antonio M. Battro**
Chief Education Officer, One Laptop Per Child
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**Prof. Thomas Bourgeron, Ph.D.**
Geneticist and Director of the Human Genetics and Cognitive Functions Unit, Department of Neuroscience at the Institute Pasteur, Paris (France)

**Prof. Stanislas Dehaene**
Collège de France;
Head of the INSERM-CEA Cognitive Neuroimaging Unit, NeuroSpin, Saclay
(France)

**Dr. Ghislaine Dehaene-Lambertz**
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**Prof. Helen J. Neville**
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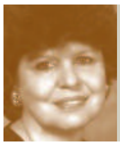
**H.E. Msgr. Prof. Marcelo Sánchez Sorondo**
Chancellor
The Pontifical Academy of Sciences
(Vatican City)

**Prof. Dr. Wolf J. Singer**
Max-Planck-Institute for Brain Research, Frankfurt am Main
(Federal Republic of Germany)

**Prof. Elizabeth S. Spelke**
Cognitive Psychology, Department of Psychology, Harvard University; Director of the Laboratory for Developmental Studies
(USA)



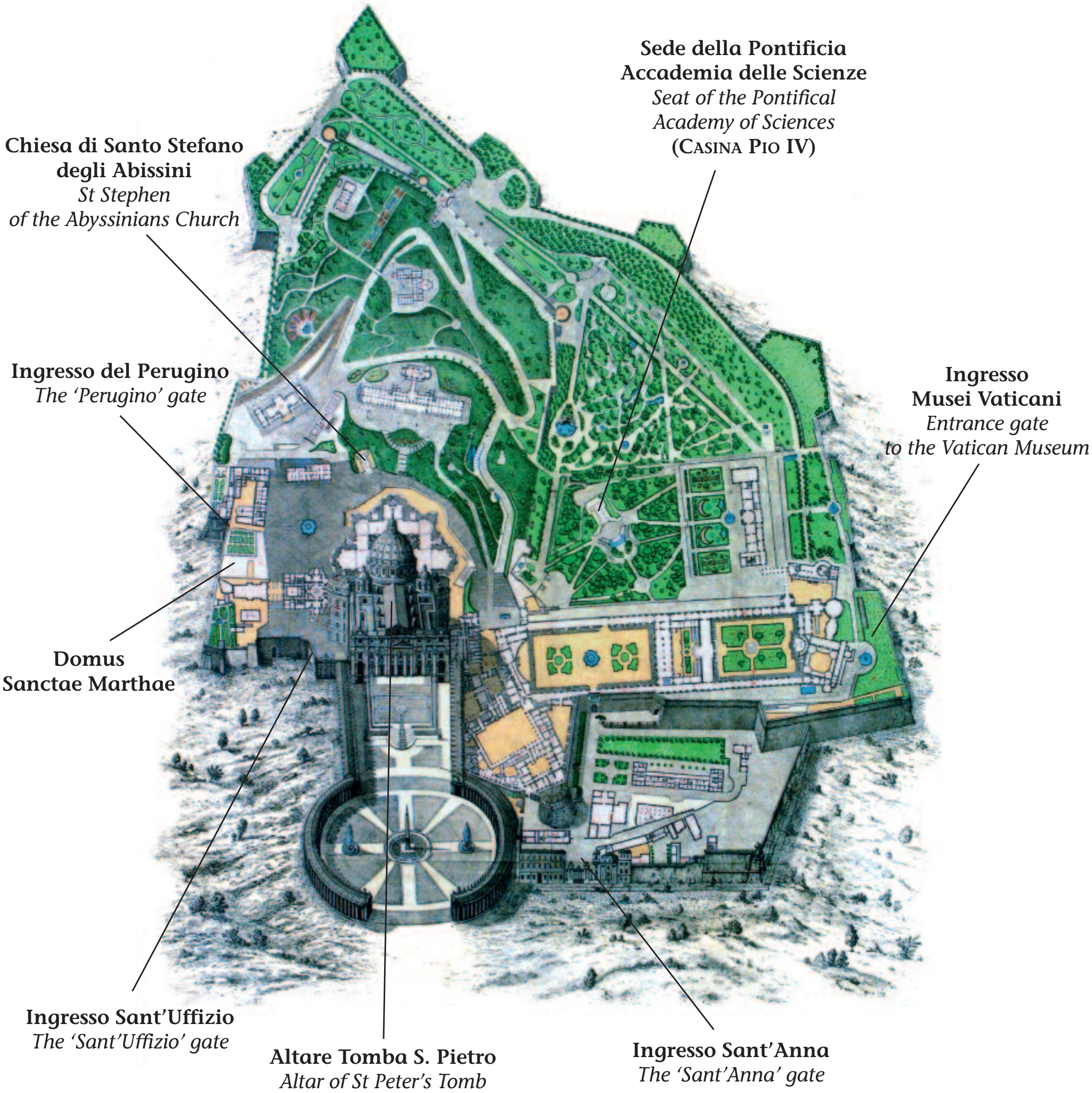
**Prof. Faraneh Varga-Khadem**
Head of the Developmental Cognitive Neuroscience Unit and Institute of Child Health, University College London
(UK)

## Memorandum

– On 27 and 28 October 2010 a bus will leave the Domus Sanctae Marthae for the Academy, fifteen minutes before the beginning of the session. A bus will depart from the Academy after dinner at the end of the afternoon session to take participants back to the Domus Sanctae Marthae. Lunch and dinner for the participants will be served at the Academy except dinner on Thursday 28 October.

– On Thursday 28 October a bus will take the participants from the Casina Pio IV at the end of the session (h. 18:00) to the concert and dinner at the residence of Prince Boncompagni Ludovisi and back.

*Note*
Please give your **form for the refunding of expenses** to the secretariat at least one day before your departure so that you can be refunded immediately.

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*For further information please visit*:
http://www.vatican.va/roman_curia/pontifical_academies/acdscien/index.htm

FRONT COVER:
Pablo Picasso,
*Portrait of Ambroise Vollard*, 1910
The Pushkin State Museum of Fine Arts, Moscow