

**“Ciencias del aprendizaje e investigación sobre el cerebro:  
2ºencuentro de las redes de expertos en lecto-escritura y cálculo”**

**“Learning Sciences and Brain Research:  
2<sup>nd</sup> Literacy & Numeracy Networks Meeting”**

**EL ESCORIAL - MADRID, ESPAÑA/SPAIN, 1-2-3.03.04**

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*Note: The following paper synthesises three days of presentations at El Escorial, Spain, from March 1 to 3, 2004 (see Appendix A). It should be noted that this meeting predated by just one week the terrorist atrocity in Madrid on March 11, 2004. Each of the organisers and participants wishes to offer and extend condolences to those victims who suffered and to their families.*

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## PREFATORY REMARKS

Please note that this report draws on presentations by the various authors. In some cases, we have used verbatim passages; in other cases their presentations have been paraphrased. In the current report, a small number of PowerPoint slides from some of the presentations are reproduced. The copyright on these images remains with the original owners.

The reader of this report might find it helpful to refer to the other reports on the OECD Brain Research website, in particular the OECD report on the Literacy and Numeracy Network Deliberations, January 2003, Brockton, USA. Not only does that report provide the most direct foundation for the current report, but the advisory from that report, noting that the reader should be familiar with other reports/publications, remains pertinent:

1. The first publication is by Dehaene S. (1997) "The number sense," Oxford, UK: Oxford University Press.
2. The second publication is "Understanding the Brain: Towards a New Learning Science" by the OECD (2002), which summarised the findings from the first three workshops conducted in phase one of this project. Of particular interest in this report is the section entitled, "Learning seen from a neuroscientific approach," which deals with research tools and methodologies of brain imaging, and which also reviews pertinent literature on the relationship between the brain and mathematics learning and the brain and literacy. This OECD report reiterates Hideaki Koizumi's contention that progress in cognitive neuroscience and education will necessitate the creation of a transdisciplinary effort.
3. The third report is a review of educational research in mathematics learning from grades K – 8 by the National Research Council (2001), "Adding It Up: Helping Children Learn Mathematics", Washington, DC: National Academy Press. The fourth report describes the deliberations of the US National Reading Panel (2000).

### **Disclaimer:**

It should be noted that the implications drawn from the research presented in this report, for educators, is early supposition, and serves at the current time to guide research, but not yet policy.

## INTRODUCTION

Tom Schuller of OECD/CERI set forth the following objectives for the EI Escorial meeting:

- Review network progress to date.
- Critique the proposed lifelong learning framework.
- Strengthen the link between the two networks, and to educational policy/practice.
- Review the planned project outputs:
  - Publications; tools; website; agenda-setting.

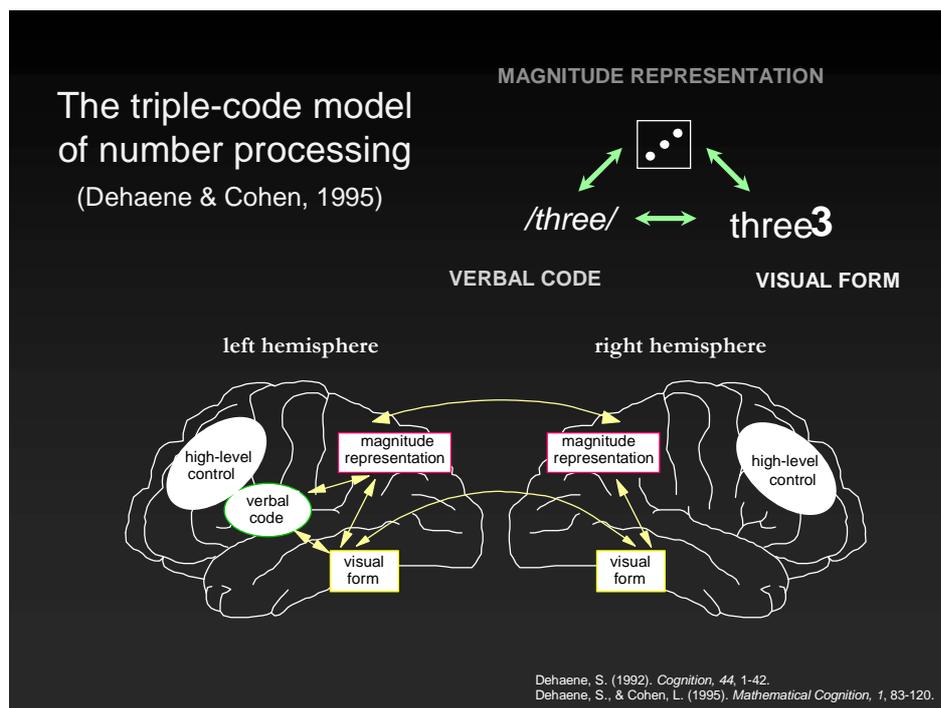
He reminded the participants of the overall mission of the OECD brain project (which includes the Life-Long Learning network) and outlined the management structure of the Phase 2 project by presenting a provisional 4-part matrix (see below), which has been designed in order to help structure the dissemination of findings into an educational framework, and to link these results to other OECD work (such as PISA; the International Adult Literacy Survey (IALS); Programme for International Assessment of Adult Competences (PIAAC)) and to Gardner's seven forms of intelligence:

- *Periodicity*: marking discrete biological, socio-cultural, and chronological periods in the lifespan of a human being, with regards to learning.
- *Skills and competences*: identifying the basic functional elements that need to be acquired, such as literacy and numeracy.
- *Conditioning factors*: such as nutrition, sleep, and environment, which have a significant impact on learning.
- *Neuronal plasticity*: the extent to which developmental changes can take place at different points, and the degree to which they are (ir)reversible.

The purpose of this second annual meeting of the two networks was for the scientists to give an update of their research work in literacy and numeracy; to develop activities linking intervention training techniques to specific cognitive and brain imaging research; and to offer positive suggestions about how to make this knowledge accessible to a global audience of educators. The meeting marked a milestone, as it cemented the collaboration between the two networks, and proved that they could work together in a transdisciplinary fashion with the educationalists present at the meeting. The two networks present at the meeting demonstrated a strong belief in the value of the OECD-CERI project and their willingness to make a concrete contribution will undoubtedly have a direct impact on education. There was a growing agreement about how to make this knowledge accessible to educators and policymakers.

These two networks (unlike the Lifelong Learning network), are focusing more on the brains of children with a range of basic literacy and numeracy skills, from preschool (where they are still developing these skills) to the end of primary school (where they have usually mastered them). For content, the Network is guided by Stan Dehaene's framework in which clear linkages between mathematics and language are apparent (i.e., his Triple Code model, see fig. 1).

**Figure 1. The Triple-Code Model of Number Processing**



At the El Escorial meeting, participants also discussed the ultimate aims of the website – to disseminate areas of scientific consensus and to render the Brain project's findings accessible to educators and policymakers – and finally agreed, on the whole, about the best way it could be designed to achieve these objectives.

It was decided that, on a scientific level, both the Literacy and Numeracy networks have progressed sufficiently for Phase 2 to be able to continue to work via the listserv. Their next joint meeting will take place in mid-2005 in conjunction with the Lifelong Learning network to disseminate and exchange findings. However, several symposia on literacy and numeracy focus topics are possible for the remaining mandate of Phase 2.

## PRELUDE – PRELIMINARY OBSERVATIONS

### A Brief History of Literacy and Numeracy

A brief history of literacy and numeracy was plotted by Jarl Bengtsson. From a historical perspective the fields of literacy and numeracy were very much two separate worlds, apart from mathematics and geometry, which, in ancient times, fell under philosophy.

**Historically speaking we can say that reading for all, is a relatively recent development compared to mathematics.**

With the birth of universities, two distinct, noble disciplines, theology and philosophy, emerged and held on strongly into the 19<sup>th</sup> Century. It was the Humboldt University that elevated science and mathematics to the status of prestigious disciplines.

Reading was formerly considered a luxury, as opposed to counting, which was a skill necessary for survival in the early modern world. Reading entered the public arena with the protestant movement and the French Revolution. So historically speaking we can say that reading for all is a relatively recent development compared to mathematics for all.

Bengtsson highlighted the emergence of the knowledge economy, which is a feature of developed countries, for example OECD countries. However, one sixth of the world's population remain illiterate. One out of four adults in the IALS survey is unable to function in the knowledge economy. Bengtsson stated that in today's society, with increased competition in production and in dissemination of knowledge, there are two challenges that lie ahead for those dealing with numeracy and literacy: 1) to work towards a lifelong learning approach, as the problems in these disciplines are also present in adults and 2) to develop a new synthesis of basic and broader skills for survival in the knowledge economy.

### Mathematics and Reading Focus

The second phase of the Learning Sciences and Brain research project's management is to focus on limited content knowledge, that is, mathematics and reading. Further, it has become clear over the past several years that the complexity of the brain is perhaps best understood when it is dysfunctional. The brain has many complex parts interacting in complex ways. Moreover, educational and instructional interventions are also complex. Cultural and language contexts add yet another layer of complexity to both preceding layers.

**It has become clear over the past number of years, that the complexity of the brain is perhaps best understood when it is dysfunctional.**

By studying the brain in dysfunction<sup>1</sup> or in its very rudimentary expressions among primates and human infants, we are able to some extent to control this complexity and to gain an important window into how the brain is structured, how it functions and how structure and functions are related to improving learning. Carmen Lopez Escribano said “If we know which part of the process is failing and why, we can concentrate our efforts on remedying the specific problem and we can also prevent reading difficulties by early detection.” Usha Goswami stressed the importance of a good cognitive framework in order to explore the neural underpinnings of language or numeracy acquisition, stating that: “it is important to know what the precursor skills are that will enable a child to become literate or numerate, and to explore if these precursors are universal across languages and cultures. Only then can we see what the impact will be of schooling on these cognitive and neural variables and the impact of different kinds of educational practice.”

It should be noted, of course, that there have been decades of research into how children learn mathematics and how children learn to read. This, of course, includes existing educational, as well as scientific, research. However, in the current phase of the Learning Sciences and Brain Research project we will only be able to focus on hard-core scientific research and implications (comparisons between these could be considered only for a third phase of the project). The scientific research in these areas has been conducted primarily at the behavioural level of the classroom, or in some cases at the level of the cognitive processes underlying such learning. What we have found in the OECD brain research project is that the addition of the cognitive neuroscience layer allows us to refine the work that's being done at the behavioural and cognitive levels. We have learned how to take complex instruction in reading, for example, and reduce it to a number of rather simple tasks that can be used in cognitive neuroscience research, particularly with fMRI technology.

### **Cultural Factors Including Language Orthographies**

In successful reading, the brain must first make a correct connection between the sound of a word and its orthographic character (i.e. visual appearance). For example, the words cow and bough rhyme in English, as do true and through, though you would not expect it from appearances. Moreover, the “ough” is sounded differently in bough; through; though and enough.

**Reported rates of dyslexia are higher in countries with more complex orthographies.**

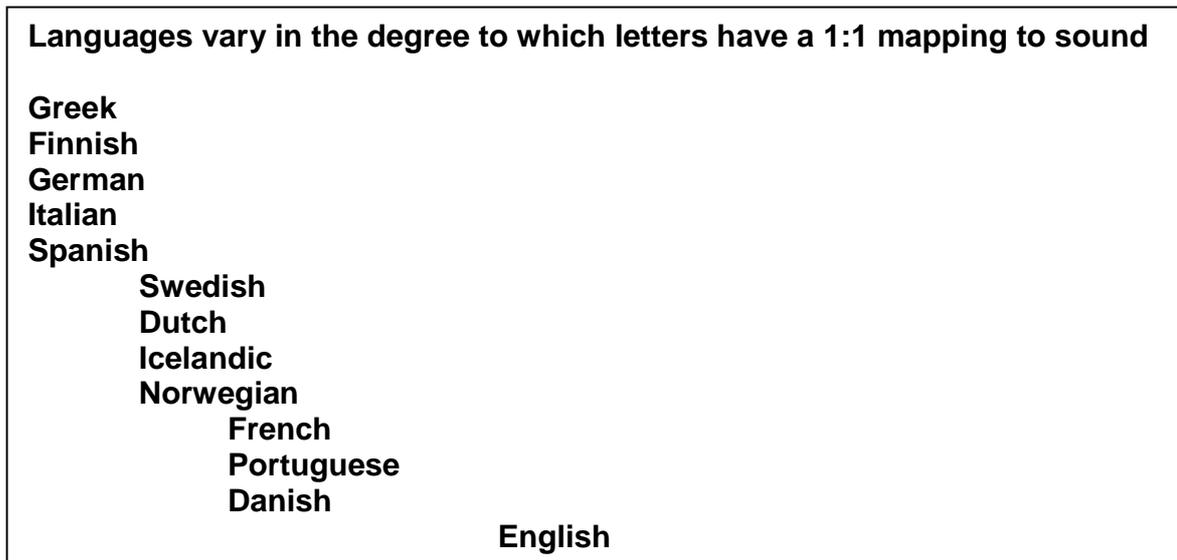
We shall see later in the report that languages vary in their orthographies: some languages, like Finnish, have very simple and transparent orthographies; other languages, such as English, have deep and confusing orthographies. Usha Goswami presented an EU gradient transparency of different European

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<sup>1</sup> In this meeting we also heard of a study of hyperlexia, a dysfunction related to precocious reading ability, see below.

languages (see fig. 2) that shows English, having the deepest orthography, at the far end of the scale.

**Figure 2: Orthographic Transparency**



Goswami showed how the level of orthography also seems to correlate with PISA data, but this has yet to be confirmed by the OECD. While in many cases dyslexia derives from neurological problems, the manifestation of dyslexia varies with orthographic transparency (even though reported rates of dyslexia are approximately the same across orthographies). This gives rise to the hypothesis that there is possibly a relationship between the ratio of the severity of dyslexia, this being lower for shallow orthographies.

Historically, language orthographies have changed and evolved. In some cases they have been deliberately simplified. Much about them is merely convention. Interestingly, difficult orthographies, such as that of English, can lead to reading difficulties and instructional complexities in teaching reading, both for phonemic awareness and spelling. The hypothesis that was presented in El Escorial by several scientists (Goswami, Heikki Lyytinen, Frederick Morrison, Linnea Ehri, Bruce McCandliss, Eraldo Paulesu and Uta Frith) is that the difference in orthographic transparency might affect the emergence of the skill of phonemic awareness, which we know is important for literacy. The presentation by Paulesu noted:

Italian, English or German, for instance, show different levels of regularity in the way letters correspond to speech sounds. Italian uses a highly consistent mapping between a small set of speech sounds and a small set of letters or letter combinations (graphemes). English has a highly irregular representation with more than 1000 possible letter combinations

to represent the 40 sounds of the language. This makes a difference to the ease of acquisition of reading. It also makes a difference to dyslexic readers who are much better placed when learning to read in a consistent language, such as Italian. Furthermore, it makes a difference even to highly skilled readers of university level. A comparative study of the brain activation patterns of such students has revealed the existence of a multi-component reading system in the brain. This system is very similar in different languages, but different preferences are given to different components, and the preference depends on the consistency of the writing system.

Paulesu noted that the orthographic problems are compounded by dialects, accents, local variations, the addition of foreign or newly created words, and changes in pronunciation over time. The burden of these phonemic complexities must be borne by a limited set of alphabetic symbols. Historically, some language orthographies (e.g., Serbo-Croatian) have purposefully been simplified. Yet, while orthographies may contribute to reading difficulties, making changes in them would require immense political capital.

### **Diagnosis of Dyslexia**

A number of speakers made the point that a diagnosis of dyslexia is neither simple nor straightforward. Regarding the definition of dyslexia, Elise Temple stated:

**[For dyslexia,] there is no consistent diagnosis or agreed upon diagnostic criteria or gold standard of diagnosis or even consistency across different cultures or school districts.**

There is no consistent diagnosis or agreed upon diagnostic criteria or gold standard of diagnosis or even consistency across different cultures or school districts. Developmental dyslexia is simply defined as a reading difficulty despite education, intelligence or motivation necessary for successful reading.

Temple noted that developmental dyslexia, an unexpected difficulty in reading, affects between 5-17% of the population. Depending on the estimate, that accounts for 2-10 million children in the US alone. While, dyslexic children (and adults) have been shown to have a disrupted neural response to phonological and rapid auditory processing, the fundamental cause (or causes) remains unknown, and an active area of research on many fronts.

Paulesu points out that a diagnosis of dyslexia involves behavioural and psychological, as well as biological indicators. At the biological level, a further distinction should be made between “system level descriptions (i.e. those based on the study of large populations of neurons) [and] cellular level descriptions (i.e. those based on anatomical observations).”

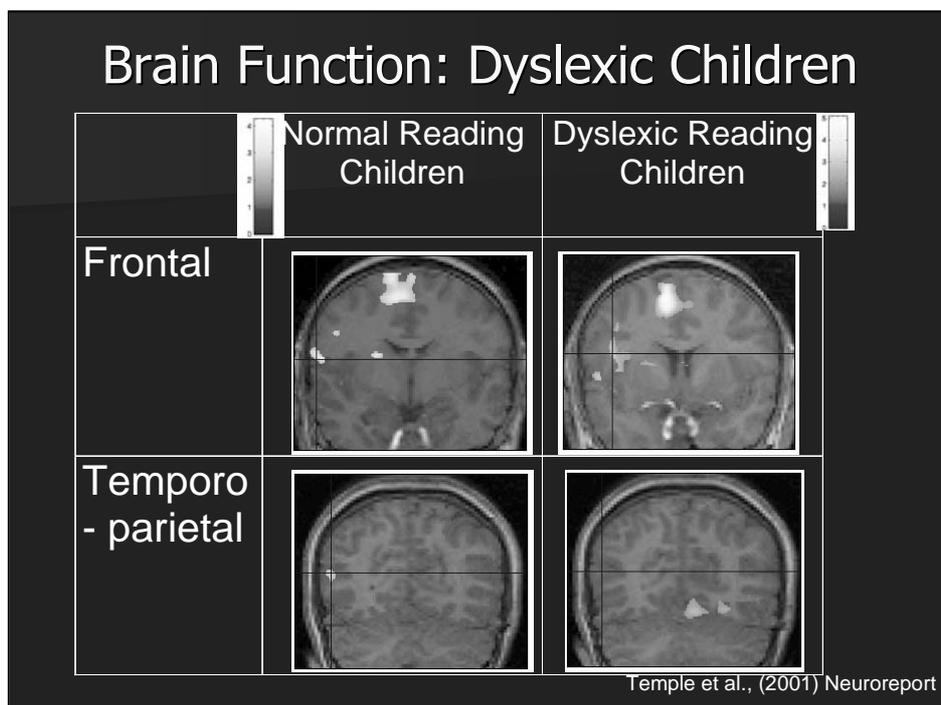
Lyytinen’s studies show that children born to families who have members or close relatives with dyslexia are at a highly elevated risk for reading problems. This is one indication showing that there is evidence that there is a strong genetic component to this brain disorder.

As noted in the introduction to the report, Ehri indicated that it is often difficult to determine whether or not a diagnosis of poor reading involves phonology, particularly when factors such as normal maturation patterns, complex instructional models, and insensitive assessment instruments may cloud a diagnosis. Even so, there is a growing consensus about the neural bases for reading.

Leo Blomert noted that the first<sup>2</sup> essential step in reading development is acquiring grapheme-phoneme correspondences. He showed that grapheme processing is associated with the left inferior occipital-temporal cortex, whereas phoneme processing is associated with the left posterior superior temporal cortex.

Temple showed a slide that tied brain activity to reading for normal and dyslexic children (fig. 3).

**Figure 3. Brain Function in Normal and Dyslexic Children**



<sup>2</sup> Note that this is the first, but not the only, essential step; see Eraldu Paulesu’s word of caution on p.11: “Reading is not just ‘single words’, and when interpreting the data on dyslexics it is often on single word reading.”

Similar to what studies of dyslexic adults reveal, dyslexic children show left frontal but no significant temporo-parietal activity.

### **Different learning methods and strategies for mathematical learning**

fMRI studies on learning arithmetic in Austria on healthy young subjects (see Margarete Delazer, p. 23) compared two different strategies: training by strategies and training by drill, and the effects on retrieval. Strategies refer to step-by-step algorithms and drilling means rote learning without meaning. Results suggest that training leads to a modification of activation patterns and that different training methods lead to different activation patterns in retrieval. As reflected by differences in behavioural measures, as well as in brain activation patterns, the mastery of new facts relies on different cognitive processes, depending on the training method. Importantly learning by drill was more error prone than learning by strategies. Thus, learning by drill should be preceded by strategic learning. This finding holds an important message for educators as it has implications for many other subjects that are traditionally taught using rote methods.

### **Methodological Issues and drawbacks of scientific studies**

Complexities still face us as we try to integrate educational research and practice with emerging findings from cognitive neuroscience. A number of these were outlined by Ehri in her presentation on reading instruction. Similar arguments apply to mathematics instruction, especially at the higher grades where language (and reading) play an increasingly important part (see fig. 1. Dehaene's Triple Code Model for mathematics learning).

**Neuroscientific studies are very much exclusive to the macro-architecture of the brain.**

### Problems with study data and remedial programmes

José Manuel Igoa González stated that there are three essential problems for educators looking at neuroscientific study findings: firstly, they are difficult to establish unequivocally; secondly they do not always carry straightforward educational implications; and thirdly, they are very much exclusive to the macro-architecture of the brain. González stressed that neuroscientific evidence needs to be interpreted more in functional terms.

Paulesu issued a word of caution on interpreting the data from dyslexic studies:

Reading is not just “single words”, and when interpreting the data on dyslexics it is often on single word reading.

With regard to training programmes, they often have many components, and

the goals of people making remediation programmes is basically to throw in everything they can think of that might make a difference. Temple stated<sup>3</sup>:

Children participating in remediation programmes want every possible thing that might help their reading to be included in a remediation programme, but it makes it difficult for the people trying to understand the neural basis or even any basis for the improvement that you see, because we don't know which aspects of the training programme might have driven which aspects of the changes in brain function.

One of the criticisms Sharon Griffin encounters is that teachers are afraid that remedial game programmes are too innovative. Children become too intrigued by the architecture and this loses the instructional purpose. However, Lyytinen states that with his "Literate" game – developed for at-risk, dyslexic pre-readers – this is, on the contrary, the whole point: the children need to find the game addictive enough to continue playing it long enough for the benefits to sink in. However, he agrees that the instructionally valid core content should be carefully implemented to any games meant for training, and only skilful empirical validation research can confirm that the benefit "edutainment" may provide has really been achieved.

#### Lack of Standardisation in Instructional Practices

While variety in instructional practices is generally to be welcomed, from a research perspective instructional practices are not easy to define and vary considerably in practice, even when similar labels are used. For example, in her presentation, Ehri noted the following about the instructional process commonly known as "phonics instruction":

It is important to note that phonics programmes may differ in many ways. For example, they can differ in how many letter-sound relations are taught, how they are sequenced, whether phonemic awareness is taught, the pace of instruction, whether programmes include oral drill-and-practice or reciting phonics rules or filling out worksheets, whether children read a decodable text, whether phonics instruction is segregated from the literacy curriculum, whether the teaching approach involves direct instruction or a "constructivist" problem-solving approach.

#### Difficulty in Controlling Maturation and Classroom Influences on Learning

Ehri, citing the work of Scarborough (2001), noted that skilled reading combines both language and word recognition skills. Fluent language use implies important variables, such as prior and background knowledge, vocabulary, language structure including syntax and semantics, and verbal reasoning, including the use of inference and metaphor. Word recognition implies

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<sup>3</sup> This is important from an epistemological point of view.

phonological awareness, decoding, and sight recognition of familiar words, which then interact with the language and variables in complex ways. Skilled reading (and by extension skilled mathematics, with its own, additional complexities) involves the fluent execution and coordination of both the language level and word level processes. Teasing these apart, especially as the learner grows and is exposed to more instruction, is a difficult issue for researchers. Not only must measures be sensitive to separating each of these strands, but some data reviewed by Ehri suggest that effective strategies earlier in learning to read may be less effective later on when the student has mastered yet other strategies.

### Insensitive Assessment Instruments

Research at the intersection of cognitive neuroscience and education is hampered by measurement instruments that are not very sensitive. Ehri noted that many tests lacked strong predictive power, and identify false positives and false negatives. For example, Ehri cited a longitudinal study of kindergarteners by Vellutino which showed that readers who made the least gains during tutoring did not look any different cognitively than students making the most gains based on their pre-test scores. Ehri writes, “they also show that the use of at risk criteria to identify potential disabled readers snares many false positives who reach normal reading level with good instruction.” In general, she noted that comprehension tests sample from content across many grade levels and are therefore insensitive to small differences, even when making treatment versus control group comparisons. Overall progress in cognitive neuroscience is hampered by coarse measures at the cognitive and behavioural levels.

Even so, the earliest successes and advances at the intersection of cognitive neuroscience and education have occurred at the level of assessment design. This advancement has come about because many of the researchers who are working at the intersection of cognition, education, and neuroscience have a deep understanding of the subject matter (i.e. mathematics and reading). This deep understanding allows them to design tasks that are at the same time true to the cognitive behavioural understanding we have of both reading and mathematics and that can also operate within the limitations on the current technologies for studying the brain.

### A Mixed Picture, Instructionally

Unfortunately, there are also data presented both here and at the first Literacy and Numeracy Network meeting to show that some neurological deficits in learning appear not to respond to instructional interventions. These difficult cases may be traced to brain injury or genetic factors. It will be part of the important work of this network and future generations of researchers to identify learning problems that are chronic and debilitating for neurological reasons and determine if it is possible to remediate these problems using a combination of therapeutic interventions and innovative approaches to instruction. In some

cases, this network and its successors may be able to identify the various prosthetic devices and technologies in calculation, reading, and communication that can augment the benefits of standard and improved models of instruction.

### **Affective and Emotional Factors**

Far more attention needs to be paid to the emotional impact of poor achievement in mathematics and reading from whatever source. For example, the parents of those students who are merely following a delayed, but normal, progress in reading may be encouraged to know that part of the difficulty is the need to master an arbitrarily difficult orthography (or, in the case of Chinese, an arbitrary morphology also – see the Brockton report). If parents, teachers or the child misinterpret this delay as a neurological problem, then debilitating self-fulfilling prophecies may emerge.

**Far more attention needs to be paid to the emotional impact of poor achievement in mathematics and reading from whatever source.**

Moving forward, a fundamental challenge for cognitive neuroscience research in education is to help us determine the various factors that account for difficulties in learning to read and learning to perform mathematics, and to separate difficulties due to conventional cultural choices, and ineffective instructional practices, from those that actually can be traced to defective or delayed neural factors.

The theme of emotional learning has surfaced only partially in these Network meetings (particularly in Anna Bevan's presentations on dyscalculia at the first Literacy and Numeracy Network Meeting), and it was raised with regard to mathematics anxiety (in El Escorial by Mark Ashcraft), emotional stress experienced by dyscalculics (by Brian Butterworth) and also with regard to reading (by Lyytinen). Perhaps the deliberations on the emotional brain from Ulm and Copenhagen (see the OECD website) may be better integrated into the future deliberations of this Network.

## THE LITERACY SESSIONS

### Cognition and Instruction in Early Literacy Development

Educators face two major challenges related to reading difficulties, namely assessment and instruction. For a long time, poor reading was associated with weak visual perception problems, but there is no evidence to suggest that visual therapy benefits reading ability.<sup>4</sup> The same is true for rhythm or spatio-temporal orientation instruction, which is often chosen in schools to remediate reading problems. **Carmen Escribano** believes neurological findings are beneficial for educators in helping to improve assessment and instruction by centring approaches and efforts in the right way. She gave specific examples of how findings from neurology have brought about improvements in assessment and instruction.

It has become evident that reading difficulties can be overcome by means of reading intervention targeting phonological processing and decoding skills.

The first of these was that phonological processing is causally related to reading difficulties (notably in studies on dyslexics) and awareness of this has seen the wide introduction of instructional programmes that focus mainly on the development of phonemic awareness, and which show significant gains in reading skills for all children tested with dyslexia, including dramatic changes in their visual brain activation patterns. These results have important implications for education, in that it has become evident that reading difficulties can be overcome by means of reading intervention targeting phonological processing and decoding skills. It also shows that neural systems are more plastic than previously believed: if the intervention targets the appropriate skills and is sufficiently intense to have an impact on the brain, reading difficulties can be reversed.

The second research finding that Escribano presented is that dyslexics process many kinds of information much more slowly than non-dyslexic children of equivalent age and ability. In studies it has been discovered that dyslexic brains have aberrant development of the magnocellular system (i.e. cells responsible for fast and transient processing). One interesting intervention programme to improve the speed processing deficit is RAVE-O, which stands for Retrieval, Automaticity, Vocabulary Elaboration and Orthography (this programme is still in the experimental phase). This programme emphasises the importance of practice, and wide and repeated reading for the achievement of fluency.

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<sup>4</sup> There is a current “double-deficit” hypothesis on the causes of dyslexia, derived from cross-linguistic research, which contends that it is not solely a phonological core deficit, but that there is a second cause which is due to a visual deficit.

**Richard Bartholomew** presented the results of England's National Literacy strategy, which was begun in 1998 and which focused on the 5 to 11-year-old age group. This programme was initiated after it was discovered that a very significant number of young people were not developing adequate literacy and numeracy skills. The initial gains made by the programme have levelled out to about 73% in 2000. However, Bartholomew said they were finding it increasingly difficult to attain the objective of 80% and he suggested that this is where brain science could help, by showing how they can achieve above the existing level, i.e. how to reach that much harder-to-reach group of 20% of children who have more complex problems. What is necessary is not just an understanding of the underlying principles but how they may be applied and developed; the issue being more about ownership, motivation and belief in this system.

**Linnea Ehri** described the National Reading Panel in the USA's meta-analyses, conducted to evaluate the impact of phonemic awareness instruction and systematic phonic instruction on the acquisition of word reading, spelling, and reading comprehension abilities in children, from kindergarten through to sixth grade. The work in this programme was carried out with groups of at-risk readers who had been predicted to become disabled readers. Unfamiliar words may be read by decoding, that is converting letters into sounds and blending them to form recognisable words. Reading words by analogy involves using parts of familiar words to read unfamiliar words. Prediction involves using partial letters plus contexts to guess familiar words. However, guessing words is less reliable than processing letters to fully identify words. Systematic phonics programmes teach students to read words by attending to all the letters, as they represent the word's pronunciation. To become skilled at learning sight words, Ehri says that readers need to know phonemic segmentation, grapheme-phoneme correspondences and spelling patterns. Poor readers lack decoding skills and words are not distinctly represented in their memories. Words remain weakly connected because poor readers habitually guess words from partial letters and context and do not process all the graphemes and phonemes in the words. Therefore, instruction that remediates these processes in poor readers is thought to hold the most promise of insuring that they learn to read. Findings showed phonemic awareness instruction improved reading for at risk as well as older disabled readers, but the effects were larger with at risk readers. Training also transferred to spelling but only in the at risk readers, not the older disabled readers. Ehri suggests that explicit spelling instruction is required to produce improvement in older disabled readers, or it could be that spelling is especially resistant to remediation. Another interesting question was whether phonics instruction (systematic instruction where all the grapheme-phoneme correspondences are taught and covered in a clearly defined sequence) is effective regardless of whether it begins early or later, after students have acquired some reading ability. Findings revealed that early intervention was more effective than late intervention. Of interest was whether phonics instruction helps to prevent reading failure in at-risk beginning readers and remediate reading difficulties in older poor readers. Phonics, like phonemic awareness instruction,

failed to improve the spelling of disabled readers, which supports the idea that spelling is especially difficult to remediate in poor readers.

**Fred Morrison's** presentation focused on his research on literacy in the schooling process and especially the factors that are influential prior to walking in the school door. Morrison points to a large number of studies over the last 10-15 years which show that children's language and literacy makes a big difference to school performance, but that this is also influenced by proximal factors such as parenting, preschooling, child care influences, etc., which are in turn influenced by distal socio-cultural factors like parent education or income-to-needs. To the pertinent question "how do schools deal with the variability of different children?" he says that it has become evident that schools treat that variability by introducing even more variability in teaching. He presented the results of a series of studies examining the effect of language arts instruction on growth in children's early reading skills and the degree to which the impact of instruction depends on the language and reading skills children bring to the classroom. To summarise the results, essentially children with low decoding skills require more teacher-managed explicit instruction, whereas children with higher skills benefit from child-managed implicit instruction. These results therefore suggest that we need to rethink the idea of what high quality instruction is, and be more specific about the notion of balanced instruction.

### **Basic Processes of Literacy: Insights from fMRI about Developments and Disorders**

**Leo Blomert's** research team in the Netherlands are looking at activation patterns by using functional magnetic resonance imaging (fMRI)

**Most people can easily master the written language even though our brains are not evolutionarily prepared for such a task.**

between the different areas in the brain while these areas are processing associations between letters and sounds. His results are compared with results from lip-reading studies, which is an older, more evolutionary state of language where there is always the automatic association of the movement of the mouth with the hearing of the voice. The hypothesis is, therefore, that most people can easily master the written language, even though our brains are not evolutionarily prepared for such a task. Blomert's data indicate that it is possible that we are using an older evolutionary system to make these letters and speech sound connections in the brain, based on a naturally evolved neural mechanism for integrating audiovisual speech. This was supported in the presentations that followed, those by both Guinevere Eden and Elise Temple. Their studies show similar results to Blomert's in terms of areas of activation, and relate to what Ehri said about our early oral language environment being very important to reading acquisition.

**Guinevere Eden** presented data on a single case study of a boy with hyperlexia (in this case an autistic child with very precocious reading ability),

which shows hyperactivity in the left hemisphere of the brain and in those areas that we know play an important role in terms of mapping graphemes onto phonemes. Moreover, we also know that these areas, as well as some of the right visual areas, are involved in manipulating the oral sound structure of language. Hyperlexic reading is therefore associated with hyper-activation of the left superior temporal cortex, much in the same way as developmental dyslexia is associated with hypo-activation of this area. She ties these results in with what is known about developmental dyslexia, suggesting an important role for this region in reading acquisition, although the behavioural manifestations of dyslexia vary somewhat.

**Elise Temple's** talk homed in on the brain's response to auditory-focused remediation to dyslexia. She explored the neural effects of behavioural training with dyslexic children through fMRI brain imaging before and after a behavioural training programme that improved their reading ability. Results suggested that developmental dyslexics have disrupted brain function in both rapid auditory and phonological processing, and that disrupted brain function can be at least partially ameliorated through behavioural training.

### **Development of Brain Mechanisms for Word Recognition – Electrophysiology and Computational Modelling**

**Daniel Brandeis's** research team conducted a two-year longitudinal study on non-reading kindergarten children in Switzerland where there is no literacy training at all in kindergarten. Children who learn to read can already correctly speak and understand language, so essentially the seeing part must somehow get connected to the language part. Fluent adult readers, on the other hand, are able to activate fast, specialised visual processes within less than 200ms. Their brains (occipito-temporal region) exhibit automatic sensitivity to print (word-like strings vs. symbol strings). What is purported to have happened in the adult brain is essentially some specialisation of this visual area with new connections forming and mapping in the brain – a major example of plasticity. The study examined whether this fast visual specialisation emerges with learning to read, and what was discovered is that it is found already in 2<sup>nd</sup> graders, and emerges with less than 2 years of reading training following kindergarten. This suggests that visual plasticity and perceptual expertise play a major role in literacy acquisition.

**Visual plasticity and perceptual expertise play a major role in literacy acquisition**

**Heikki Lyytinen** presented his longitudinal study, which he began 10 years ago, by selecting a group of pre-natal infants who had a familial risk (i.e. dyslexia in first- and second-degree relatives) for following their development from the first days of life. The main goals of the study have been to detect if there are distinct precursors and predictors of dyslexia. The study is testing the dominant theory that dyslexic children have a phonological core difficulty for processing speech and the hypothesis that the impairment of speech perception observable soon

after birth is a precursor of dyslexia among familially affected individuals which face reading problems at school age. Intensive developmental assessments have examined early signs of difficulties with reading acquisition by evaluating language in relation to cognitive development, monitoring motor development and skills, and taking into account environmental factors such as parent-child interaction, etc. Early speech processing assessments have been carried out using very sophisticated brain measuring ERP recordings (brain event-related potentials: by monitoring the brain responses to various speech stimuli in babies of six months of age by observing their head-turn responses, and by imitation experiments). Children were assessed 1-4 times each year of life until the end of the 3<sup>rd</sup> grade (9 years in 2003). The results of the study show clearly that at-risk group children have atypicalities in their speech processing observable from birth, poorer skills in the identification of phonological segments (syllables & phonemes) and in phonological synthesis, and that their early letter knowledge and emerging phonological awareness both predict not only later orthographical and vocabulary skills, but also speech acquisition. The literary home environment also has a significant additional contribution. Importantly, Lyytinen's study shows that early language indices are successful in predicting early reading capabilities and reading problems via different routes. This is how the child achieves letter knowledge between ages 4 and 7 years before school instruction (starting at 7 years of age in Finland). Every child who tended to have problems had lower than expected development in this specific domain.

The study also highlights interesting gender differences at an early age: boys have lower scores in comprehension of instructions, remembering names, and reading at the beginning of reading acquisition, but boys have higher scores for number concept and arithmetic skills.

Lyytinen also presented an intervention tool based on his research findings to work on the core phonological difficulties associated with dyslexia. The remediation is in the form of a computer based "edutainment" programme, which practices the retrieval of grapheme-phoneme associations. Pilot results show that this game is also effective in providing preventive training for pre-readers at risk of developing dyslexia in Finnish. As Finnish has a very regular orthography, Lyytinen is currently exploring how this programme might be adapted to other, less regular orthographies.

The work of **Bruce McCandliss** was presented by **Jason Zevin** at El Escorial. Firstly, he explained that the core impairment of developmental dyslexia is phonology and that this leads to poor representations between spelling and sound. He showed how computational models can be implemented as computer programmes and can provide many insights into the nature of the representations and processes of skills reading. The model presented was a simulated reading intervention that uses "lessons" based on the Beck word-building scheme. This method emphasises the componential structure of words and their relation to components of sound. Training by this method addresses

proximal causes of reading difficulties, stressing the importance of spelling-to-sound relationships in teaching and reading. The success of such approaches suggests that increased collaboration between computational modellers and educators can foster both theoretical and practical advances. With this approach there is hope that the modelling work can begin to deal directly with the complexities facing real educators, by providing a testing ground for remediation strategies, and in designing curriculum materials to promote literacy.

### **José Manuel Igoa González reviews the Literacy Sessions**

As a psycho linguist working with healthy adults on language processing in comprehension and production, José Igoa was very neutral to the group present, and offered his views and conclusions as an outsider looking in. Igoa defines learning as a dynamic process that is focussed on changes over time. So if we want to make use of neuroscientific evidence, we should place it in the context of underlying processes which should be defined in functional terms. Cognitive models could help to clarify the nature of learning and learning tasks, which are sometimes defined in very fuzzy terms, and this means providing systematic and detailed descriptions of the learning processes that educators are not always in the position to provide. Igoa lays out a strategy for looking at two types of cognitive models: one is cognitive models that arise in the context of basic process research, and these models tend to focus on general, perhaps universal, processing mechanisms that underlie cognitive tasks; the second is cognitive models that are proposed from the psychological literature which focuses on specific problems that pose relevant questions about these underlying mechanisms. From there a set of goals can be defined from the standpoint of the learning or teaching theoreticians, teaching practitioners, or teaching disciplines that should be in direct correspondence with theoretical problems, as they are understood in basic research disciplines. None of the talks in El Escorial were explicitly sympathetic to this approach, but most of them were implicitly. Igoa said that the literacy network should work on basic processes by going beyond the level of word recognition or lexical recognition to include morphological processing, investigating syntactic processing or parsing, etc. The challenge ahead is to convince policy-makers that this line of research is worth pursuing. He left off with a rhetorical question for the networks to ponder: to what extent do we need neuroscientific evidence beyond what experimental or what behavioural evidence has already provided us in different fields of research?

**Cognitive models could help to clarify the nature of learning and learning tasks, which are sometimes defined in very fuzzy terms.**

## THE NUMERACY SESSIONS

### Dyscalculia and Arithmetic Difficulties

**Vicente Bermejo Fernandez** introduced the concept of mathematical learning from a micro-genetic point of view. Micro-genetic refers to the evolutionary internal

There is a new notion of an emotionally related disorder with regards to numeracy which he refers to as “math anxiety”.

mechanisms in the brain needed to perceive numbers, whereas macro-genetic is more to do with the whole process of improving maths in the classroom (teachers, students, maths content, classroom dynamics etc.). The micro-genetic method tries to accelerate the process of natural change, through raising the density of the exercise above the normal standard. The advantages of micro-genetic learning are that change can be observed directly and in more detail, and you can study different features of change. It is also flexible in that it can be used to analyse different concepts. Bermejo presented his PEI Model – Evolving Instruction Programme – which underlines four fundamental parameters for intervention to increase the student success rate in mathematics: teachers, students, programme content, and classroom dynamics. The bases of this model are constructivist and they imply the idea that a strong relationship between development and instruction is necessary to favour teaching and learning. Nowadays the micro-genetic method is applied widely in different sectors. Bermejo showed, for example, how micro-genetic models can be used for the acquisition of numeric cardinals.

**Anthony Kelly** noted in his presentation that mathematics education research has occurred primarily at the behavioural level. He stated that a recent National Research Council report (NRC 2001) does not mention cognitive neuroscience and touches only briefly on cognitive science.<sup>5</sup>

**Mark Ashcraft** presented the notion of an emotionally related disorder with regards to numeracy that he refers to as “math anxiety”. He states that this is genuinely detrimental to maths learning and achievement, despite the difficulties that experimentally-orientated researchers have in appreciating this fact. Although we do not know as yet what factors lead to the development of math anxiety, longitudinal research is necessary to help decide among several plausible hypotheses. Some of the direct consequences that children with math anxiety suffer from are that they take fewer maths courses, have consistently lower grades, have a poor attitude, and report negative cognitions.

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<sup>5</sup> It is noteworthy that there is no mention of publications available around the time of the NRC report [e.g., Dehaene (1997) Number Sense; Carey, S. (1998). Knowledge of number: Its evolution and ontogenesis. *Science*, 242, 641-642. ; Dehaene, S., Spelke, E., Pinel, P., Stanescu, R., & Tsivkin, S. (1999). Sources of mathematical thinking: Behavioral and brain-imaging evidence. *Science*, 284, 970-974; What Counts: How Every Brain Is Hardwired for Math Brian Butterworth, Free Press, New York, 1999.]

Strong associations like operands (6+7) and the answer (13) pose a problem simultaneously, as you must store three numbers at a time. The relationship between counting skills and subsequent retrieval is not as straightforward as one might assume, and of course this task grows with larger figures. There are also interfering facts that prevent retrieval. The human brain is not good at doing sequential operations. **Michel Fayol** presented two studies designed to investigate the procedures used to solve addition, subtraction and multiplication problems, the hypothesis being that presenting the operand sign first would shorten the solution time with additions (+) and subtractions (-), but not with multiplication (x). The results confirmed a significant gain for addition and subtraction, but not for multiplication. The second study was to see what becomes of the memory traces during the solving of simple operations. The results show that direct retrieval can fail due to insufficient practice of facts or interference of facts preventing retrieval. The associations between operands and results are not encoded due to blurred memory traces showing that algorithmic (subtraction and addition) solutions involve both time duration and attention shifting that lead to damage to memory traces and to weakening of the strength of associations. Fayol also pointed out that cultural differences exist with addition; for example there is a big difference in the storing of facts between Chinese and American children, but this difference is not seen in adults.

**Ruth Shalev** presented a chart showing the prevalence of dyscalculia in school-age children:

**Figure 5: Prevalence of dyscalculia**

■ <b>England (Lewis et al, 1994)</b>	■ <b>3.6%</b>
■ <b>USA (Badian, 1982)</b>	■ <b>6.4%</b>
■ <b>Germany (Hein et al, 2000)</b>	■ <b>6.6%</b>
■ <b>India (Ramaa &amp; Gowramma, 2002)</b>	■ <b>5.5%</b>
■ <b>Israel (Gross-Tsur et al, 1996)</b>	■ <b>6.5%</b>

The natural history of developmental dyscalculia is similar to that of other learning disabilities, but unlike other neurocognitive disorders, such as dyslexia and ADHD, it is found to be as common in girls as in boys. Although dyscalculia can manifest itself as an isolated learning disability, comorbidity with ADHD and dyslexia is common, occurring in 15-25% of affected children. The risk factors

often become evident through IQ tests and poor attention. It should be noted that dyscalculia is a problem that persists.

**Nancy Jordan** stated that “numbers inspire fear as well as fascination”. There have not been as many studies in numeracy as in reading, and Jordan stressed that it is first important to understand the difficulties in order to provide the most effective intervention. The growth rate is fundamental to understanding learning and learning difficulties and young children show uneven patterns in competencies in mathematics. Jordan differentiates between a) children with specific deficits related to mastery of arithmetic facts and calculation fluency, but who are good readers, and b) children with both maths difficulties and reading difficulties who are characterised by weaknesses in solving word problems as well as arithmetic fact mastery. Her experience with children with maths difficulties warns against finger counting<sup>6</sup>, as she says it distracts mental calculation and that children rely on it too much. She suggested that it could be used initially and then children should, rather, learn to build on mental calculation. She has also observed that girls seem to use their fingers for calculations more than boys. Another observation that Jordan has made is that parents seem more comfortable providing help with literature and that as far as maths is concerned it is up to the schools to teach their children.

**Marie-Pascale Noël** had some take-home messages for policy makers derived from her studies in Belgium: although maths disability is diagnosed after at least one year of schooling, maths development starts well before the formal teaching of maths. Children at risk of maths disability can be detected in kindergarten and preventive education programmes should be introduced for those children.

**Margarete Delazer**'s research work at the University of Innsbruck in Austria, where studies are performed on patients affected by dyscalculia (Behavioural measures) and on healthy young subjects (Brain imaging). These studies suggest that rehabilitation has good results when targeted intervention is provided. Furthermore, they show that learning changes cerebral activation patterns and that different learning strategies lead to different brain activation. Her studies show a good success rate when targeted intervention is provided. Using behavioural measures and fMRI, Delazer has sought to provide an answer to a question discussed repeatedly in arithmetic education: whether learning by strategies is more effective than learning by repetition. Strategies in this context mean step-by-step algorithms and drilling means rote learning without meaning. What her studies found is that although reaction times were equally fast with both methods, error rates were higher for drill. As regards transfer, a partial transfer was noted for strategies so that subjects could also answer new problems with the same algorithms. In contrast to this, there was no transfer effect with drill operation. The long term effects were that strategies there were always better

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<sup>6</sup> However, as there is no scientific evidence, the Learning Sciences and Brain Research project has not validated this claim.

with accuracy. Results suggest that training leads to a modification of activation patterns and that different training methods lead to different activation patterns in retrieval. As reflected by differences in behavioural measures, as well as in brain activation patterns, the mastery of new facts relies on different cognitive processes, depending on the training method. These conclusions have direct implications for healthy school subjects: the behavioural effects suggest that, when you have the same number of repetitions and the same time spent on learning, strategies lead to better accuracy than drill learning.

**Sharon Griffin** remarked that “we try to stick disequilibrium under the carpet, whereas Asian cultures highlight their mistakes in order to learn from them.” Environmental conditions are crucial, as well as the quality of instruction, motivation of the learner and the context of the intervention. Griffin presented her pragmatic approach to teaching children number sense, which is consistent with Piaget’s theory of intellectual development (e.g. Central Conceptual Structure theory), and which has been formulated into twelve instructional principles to make up the Number World’s programme. These can be summed up as follows: providing rich activities for making connections; exploring and discussing concepts and ensuring; providing carefully guided sequences of activities and an appropriate sequence of concepts. The Number Worlds programme enables children to actively explore maths concepts, such as position on a number line, in a game context, and their participation is kept at a controlled pace that they can keep up with.

## Advances in Mathematical Education and Rehabilitation

**Jan de Lange** highlighted the paradoxical situation where pre-school kids are obviously anxious to learn, are very good problem-solvers, are creative and constructive in a

After two years at school, math competencies have been “destroyed” or at least “neglected”.

wide variety of aspects that are in fact part of maths as a scientific discipline, but where, after two years at school, these competencies have been “destroyed” or at least “neglected”. He states that curricula are often taken for granted and validity is seldom in question. De Lange says that there are fundamental questions that need to be addressed with regards to mathematics such as:

- How does children’s reasoning in mathematics (& science) develop across the years?
- What are pre-school children’s capabilities in mathematics?
- In what ways does mathematical (and scientific) development in early childhood represent a distinct set of processes?
- How do these relate to the development of language skills?

De Lange’s prescription is to form closer cooperation between discipline-specific educationalist researchers, cognitive psychologists and neuroscientists so that a variety of different methodologies might be morphed into a coherent research design. He stresses also the rethinking of the roles and influences of parents, i.e.

the balance between in-school and out-of-school learning to encourage kids to develop their talents in a more natural and effective way and by so doing ultimately contribute towards a better functioning society.

## THE JOINT LITERACY/NUMERACY SESSIONS

### Unique Challenges for Literacy Acquisition Across Languages

**Juan Antonio Madruga**

propounded ideas of thinking to promote reading comprehension and mathematical reasoning. He stated that the final goal of education in

The difference in orthographic transparency might affect the emergence of the skill of phonemic awareness which we know is important for literacy.

literacy and numeracy is to promote thinking, reading comprehension and reasoning in mathematics problem solving. He presented two new studies to measure working memory capacity for reasoning, where individuals have to recall as a result of inference. He defined text comprehension as a construction of a mental situational model in which text information and the reader's prior knowledge is integrated, and this is carried out in the working memory. Reasoning depends on envisaging the possibilities compatible with the premises. In the working memory, mental models are constructed, held and manipulated within it (the working memory). For comprehension in mathematical reasoning, it is necessary to construct a problem representation of space, and to find the solution you have to explore the problem space by selecting strategies and applying them. Madruga therefore stresses that the comprehension phase is vital in mathematical problem solving. Comprehension in reading and mathematics is a complex cognitive process that demands people to activate working memory resources. His studies show that the central executive of working memory is crucial for the maintenance and manipulation of information in thinking. The use of working memory measures can evidently help to clarify the diverse processes through which "reasoners" reach a conclusion.

Awareness of syllables and onset rhymes precedes learning a particular spelling system, however awareness of phonemes is developing as reading is taught. **Usha Goswami** described developmental studies showing that syllabic representation is basic to many languages. By looking at cross-cultural orthographic transparency it provides a good window because languages vary a great deal in the degree to which letters have a one-to-one correspondence with sound. The hypothesis is that the difference in orthographic transparency might affect the emergence of the skill of phonemic awareness, which we know is important for literacy. Goswami presented an EU gradient transparency of different European languages (see fig. 2). The studies showed that at eight years of age German children are far ahead of English children in terms of their phoneme awareness. Even German dyslexic children were shown to have better phoneme awareness at the same point in their schooling, compared to an English dyslexic child. It would therefore appear that transparent orthographies which have the advantage of one-to-one mapping between letters and phonemes facilitate rapid phonemic awareness, so this suggests that it might affect early

reading behaviour. Goswami offered a second hypothesis, suggesting that some of the neural processes underpinning language acquisition, particularly auditory processes, are disrupted in developmental dyslexia. Looking at syllables and the onset and rhyme, development is similar across languages. However, at the phoneme level, development differs a lot depending on the language a child is learning to read. This could mean that there is some kind of auditory deficit in the perceptual experience of rhythmic timing that might be the cause of the phonological deficit and which might apply across languages.

**Eraldo Paulesu** presented the impact of the structure of orthography seen when studying Italian adults compared with adults from other cultures. He spoke about the “reading instinct” as being divided between our readiness, on the one hand, to become proficient readers, and the “social control instinct”, on the other hand, that human beings have shown historically (and consistently) for developing strategies to produce enduring messages to be transferred to one another across time. Paulesu focused on one important factor that affects dyslexia, and that is the environment, i.e. the socio-economic status, the value attributed to literacy, the pressure to become a proficient reader, teaching methods, etc., which all have an impact on the proficiency that is attained in reading, especially when beginning to read. Of these environmental factors, he stresses that orthography has the most impact on the severity of the symptoms, even though the cognitive deficit perhaps remains substantially the same. His research shows that the regularity of a given alphabetic orthography appears to have an effect on reading strategy and efficiency, and that the normal brain is sensitive to subtle cultural differences in orthographies. The issue of different orthographies also appears to have an impact on dyslexia, and differences in reading performance among dyslexics from different countries are due to different orthographies.

### **Challenges for Numbers Acquisition: Two Hypotheses**

**Brian Butterworth** quotes the qualitative criteria preferred by the DfES to define dyscalculia:

**Humans are born with a capacity for representing numerosities.**

A condition that affects the ability to acquire arithmetical skills. Dyscalculic learners may have difficulty understanding simple number concepts, lack an intuitive grasp of numbers, and have problems learning number facts and procedures. Even if they produce a correct answer or use a correct method, they may do so mechanically and without confidence.

Dyscalculia is a selective deficit, it is congenital, and it may be linked to a specific brain abnormality, which could be due to a genetic abnormality in some or all cases. It is found to be persistent in most cases. Butterworth states that there is converging evidence from various sources on the idea that humans are born with a capacity for representing numerosities, which he refers to as the

“number module”. This capacity is a specialised neural system for recognising and representing numerosities. There is evidence that infants are sensitive to numerosities, and that some non-human species in the wild are sensitive to numerosity (including evidence that some non-human species can be trained on numerosity tasks).

Butterworth described a new diagnostic test for dyscalculia by the DfES in the UK – the Dyscalculia screener. The Dyscalculia Screener is an assessment and research tool for screening individual pupils aged 6 to 14 for dyscalculic tendencies and mathematical difficulties. (See: <http://www.schoolzone.co.uk/pip/evaluations/evaluation.asp?p=GRAN-7446104>).

Butterworth quotes from case studies on what it feels like to be a dyscalculic providing evidence of the emotional trauma the condition can provoke:

*Moderator: How does it make people feel in a maths lesson when they lose track?*  
*Child 1: Horrible.*  
*Moderator: Horrible? Why's that?*  
*Child 1: I don't know.*  
*Child 3 (whispers): He does know.*  
*Moderator: Just a guess.*  
*Child 1: You feel stupid.*  
\*\*\*\*  
*Child 5: It makes me feel left out, sometimes.*  
*Child 2: Yeah.*  
*Child 5: When I like - when I don't know something, I wish that I was like a clever person and I blame it on myself –*  
*Child 4: I would cry and I wish I was at home with my mum and it would be - I won't have to do any maths –*

**Annette Karmiloff-Smith's** research explores how genetic disorders may hold the promise of being windows into the development of cognitive domains, number sense being considered as one of these domains. Her message to educators is that development is crucial, as studying the adult phenotype may be very different from the developmental trajectory that led to it. What she has found is that very low-level impairments outside the number domain can make an impact over developmental time on number development and cause numerical impairments. So what appears to be a domain-specific impairment in an older child or adult may have been caused by a more general deficit in the infant, this is because one domain, such as number sense, happens to be more vulnerable to that impairment compared to others. Karmiloff-Smith therefore stresses the importance of studying number-relevant behaviours in infants.

## Commonalities of Cognitive Education Research in Literacy and Numeracy

### Stan Dehaene

A central question that is present in the two networks is: How is it possible that we can learn to read and calculate with our brains, if “our brains” have not evolved for the purposes of reading or calculating? Do we have to create a completely new brain circuit for a new activity?

**Numerosity in the brain is present in very young infants as well as in animals.**

Stan Dehaene's presentation had some very direct take-home messages for educators. Firstly, he warned against the preconceived notions that educators, along with the general public, have; for example, when pictures of the brain are shown to educators, they will tend to interpret them as static pictures showing a rigid deficit in the brain anatomy, which is present from birth and therefore nothing can be done about it. The truth is that it is not yet known to what extent such problems can be changed and rehabilitated. Another incorrect belief stemming from the cultural relativism movement is that the brain is an extremely plastic organ, and that therefore brain biology is almost irrelevant because it places no constraints on cultural acquisitions, which are in fact remarkably diverse, and that cultural inventions therefore have a highly variable cerebral basis. Dehaene's presentation set out to negate these beliefs in order to educate educators on the fact that education is not about completely changing brain circuits, but about influencing or “recycling” existing brain circuits. He explained his theory of “neuronal recycling”, which stresses that the architecture of our brains is in fact tightly limited by strong biological and genetically driven architecture.

Even though there is plasticity, this is limited by genes, the rules for plasticity being set by the genes and evolved for a specific purpose. This means that educational and cultural acquisitions are possible only in as much as they fit within this architecture that has been laid down. Dehaene's research makes it evident that we recycle our pre-existing cerebral organisation in support of another function – we are not able to actually reshuffle the entire organisation. Instead we can change it, and capitalise on existing representations to connect them in different ways. In his research studies looking at brain activation during arithmetic, the striking finding is that identical brain networked regions are fired, and that is reproducible from culture to culture. Even simple tasks, such as detecting digits in a stream of shapes, will give rise to activation in the same brain region. The sense of numerosity in the brain is present in very young infants as well as in animals, and it is this system that we capitalise on to be able to give meaning to the number symbols we have created and to connect them to the pre-existing quantity of representation in our brains. Dehaene referred to studies of pathologies of the brain number systems, such as dyslexia and Turner's syndrome (which is a genetic disease). These all show a disorganisation

of the cortical grey matter in the area of number processing, which very much coordinates with where activation occurs in normal subjects, and which can lead to lifelong difficulties in arithmetic in both cases. What remains unclear is how much such problems can be shifted by intervention. Dehaene's team is currently in the process of trying to develop an intervention study, based on his theories, to target the number sense by progressively training the connection between symbols and quantities in order to rehabilitate the precisions and connections of the quantity system in the brain, and to see if this might have an impact on difficulties that some children experience. This intervention game will be made freely available on the OECD project website in March 2005.

Dehaene expanded his theory to reading, where he has found that even if you take subjects from different cultures, reading different languages, you will still find very similar brain activations. The system has become finely attuned to adaptation to a particular language, because even when words are presented in lower or upper case, the pattern of brain activation shows that the same area has recognised the same word even though the case and shape of the stimuli changed completely. This raises an interesting question: why is there brain area localisation which is evidently so reproducible across individuals? And how can the brain adapt so well to the problem of reading? Dehaene believes that we tap into the occipital temporal pathways involved in visual object recognition and recycle this area for reading.

Dehaene's message for education is that it is not about completely changing new brain circuits, but about minimally changing existing ones. The localisation in the brain does not mean that there is a single module for reading, but that there is a bias in the system which can be turned into something very useful in our culture by making this area sensitive to visual words. Education cannot be a complete reshuffle of the brain, brain science can help to enlighten awareness of the existing representations and how to capitalise these. Not everything is learnable, education science should capitalise on the strength of infant and child cognition and discoveries in this field on child competences. This is particularly true in the numeracy domain, where there is a preconceived belief that a child comes to school without any knowledge of arithmetic whatsoever. This is completely untrue; teachers should be aware that there is an inherent system of quantity knowledge which is "fuzzy", and they should learn how to capitalise on this when teaching children how to acquire the numerical symbols. Cognitive neuroscience can also play a vital role in helping to predict the domains where children are likely to experience difficulties. In the domain of reading there is a similar phenomenon that is possibly related to the depth in the structure of the visual system, so therefore brain science can shed light on the advantages and the inconveniences of the "pre-representations" that we have prior to acquiring reading or maths formally.

Dehaene's controversial challenge is to find out if there is a way to prove that in our brains there is a competition for cortical space when acquiring knowledge

or skills, i.e. a loss or partial loss of some other functions that were the function of the cortical territory in question prior to the acquisition. Could this mean that when we learn a new language or new skill, in competing for cortical territory there is temporary or permanent forfeiture of another?

## **Bruce McCandliss**

Bruce McCandliss summed up the ultimate goals of the second phase of the Literacy Network as being to try to make some sort of link between the neurobiological bases of literacy, the changes that occur,

**Billions of dollars are spent by countries on the process of creating literacy in their cultures and yet so far these attempts make no connection whatsoever to basic science.**

the individual differences in these brain structures, and their functional organisation that may have a profound impact on the cognitive processes of focusing on text, and reorganising phonological representations. He said that the scientists in this network are working at different levels of complexity to report to each other, to see if there is an explanatory framework for understanding human literacy development and individual differences within human literacy development. McCandliss made the point that billions of dollars are spent by countries on the process of creating literacy in their cultures and yet so far these attempts make no connection whatsoever to basic science. From what has emerged thus far in the Literacy Network there is evidence that the brain has specialised mechanisms for visual recognition, and it also has specialised mechanisms for understanding auditory input and mapping it to language. These are, however, not necessarily directly connected to any evolutionary process. The brain is faced with the problem of having to build an interface between these two very different brain mechanisms. Usha Goswami made the statement "Reading changes the brain" in her presentation. Learning to read appears to drive reorganisation within these language areas, and perhaps these visual areas. Part of the fundamental reorganisation process is phonology. Looking at kids who were struggling and failing at reading, it appears that these kids have trouble reorganising the phonology via the process of learning to read. There appears to be a strong convergence across multiple laboratories using different techniques to suggest that one of the big differences between dyslexics and non-dyslexics is that the regions of the brain that might be associated with phonology or processing sound or language are very different in their activity. This might provide us with the insight to come up with some basic principles that can be used to understand the development of literacy.

Based on the results of Heikki Lyytinen's longitudinal study, which show that the response to speech at 6 months of age is significantly related to reading success, McCandliss said that is vital to get scientists to commit to looking at the longitudinal development of kids from pre-readers to readers.

The process of the brain changing from the pre-literacy brain to the reorganised literate brain, does not work the same for everybody. We need to understand the individual differences. McCandliss points to multiple studies that show that the choice of a school system has a profound impact for an at-risk child; the big difference between these school choices is the degree to which they focus their attention on training letter-sound relationships. He highlighted Fred Morrison's presentation, which showed that the number of minutes that teachers spend on systematically focussing children's attention on letter-sound relations has a systematic impact on improving reading skills for at-risk children. Finally McCandliss pointed out the fact that seven year old children – who are at the critical age at which literacy is profoundly reorganising their language circuitry – can now be put inside brain scanners to see what is going on their brains. fMRI is not sensitive to the changes that occur in children over the course of two or three months of intensive instruction in one form or another. This opens up a possibility now where we can systematically examine differences that might matter in schools in terms of curriculum choices, at the level of the impact of reorganisation of these brain regions which we think are critical to the process of developing in literacy.

## CONCLUSIONS FOR RESEARCH DIRECTION AND POSSIBLE POLICY IMPLICATIONS

Reading and arithmetic are very recent cultural inventions, so that the architecture of our brains has not had enough time to adapt to their specific constraints. The brain also has limitations due to the fact that it is laid down by genetic control. However, due to the plasticity of the brain, and as cultural inventions have a highly variable basis, we can work on those. Understanding how the brain works in literature comprehension and when undertaking numeracy computations can show how the architecture is constructed and point to how to capitalise on this. It is difficult to take models as theoretical tools (very abstract and theory driven) and incorporate them into the classroom, but we can look at how they can be adapted and used in practical fields. The key is that we need to find the underlying processes as in cognitive models and learn from those, and by clarifying the nature of learning we can begin to describe the learning processes. However, it should be borne in mind that the brain is not an organ that is dissociated from the body and it is also necessary to study the physiological effects/factors of learning and performance as a whole.

### Take home messages from the final panel presenters

**Diane Coben** cleverly summarised the El Escorial meeting by taking the “bridge” concept<sup>7</sup> between neuroscience and education and breaking it down into grapheme representations (playing on the literacy training dyslexic modules presented):

*B is for BRAIN*

*R is for RESEARCH*

*I is for ILLNESS; INCAPACITY; IMPAIRMENT and also IMPROVEMENT*

*D is for DISCOURSE and DISCUSSION*

*G is for GROWTH (in the developmental sense)*

*E is for EDUCATION (last and not least!)\**

**Finbarr Sloane** preferred to base his wisdom on the Piaget model, offering advice to the networks and the project to continue to strive for exploration, social interaction, maturation and equilibrium. He described the work as a journey towards the development of a broad based science of learning, and while these components can interact sensibly with each other, it is not about changing curriculums per se.

**Carmen Escibano** stated that the meeting allowed for an exploration that has emphasised the brain, cognition and behaviour. Although it has begun to

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<sup>7</sup> The idea of a bridge has been present in the project from the outset (partly in response to John Bruer’s “Education and the brain: a bridge too far”, *Educational Researcher*, 26:8, November 1997) as a major goal of the project to form a bridge between the neuroscientific and education community.

address other issues, she suggested that cognitive models should be explored to link neurology with cognitive studies. She left educators with two main messages, the first is that if we know brain mechanisms involved in reading and the cognitive processes associated with them, we will be able to decide better approaches to assessment and instruction; and the second is that it is vital to update our teachers and language therapists with more specific and practical knowledge on reading difficulties based on the latest neurological findings and studies.

**Peter Hannon** asked the pertinent question: How does research change education? He said that this can make an impact firstly by informing and stimulating educators. He stressed that educational priorities have not yet been sufficiently addressed. A critical well-informed teaching force is vital and problems should be highlighted for the public, not concealed. Research can confirm current practice, but it can also challenge it and when it is really good, it can even show that A is doing better than B. However, this might not always be achievable. Optimism and ambition need to be kept constant. Hannon reflected that two or three topics of research should be identified and highlighted by the OECD. We should reflect on how research changes education and what happens next.

The OECD project's ultimate aim for Phase 2 is not necessarily to formulate rigid recommendations for policymakers' use. The plan is to move away from this usual procedure and instead present policymakers with a set of educationally-relevant information and findings containing the key points they may want to consider before they decide on several aspects of policy and practice. At the El Escorial meeting it was decided that, to begin with, both the Literacy and Numeracy networks would compile a nine/ten point entry list of key points to know with regards to literacy and numeracy in light of recent brain research findings.

### **Possible policy implications**

- ***For the Environment***

The environment is an important factor and literacy and numeracy must be studied not just at the number and word level – all levels should be targeted. It is necessary to look across cultures and at social education systems at large. Emotional factors<sup>8</sup>, such as mathematics anxiety and emotional disturbances experienced by children and adults with reading and/or mathematics difficulties, should be highlighted and studied in more detail.

- ***For Literacy***

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<sup>8</sup> This includes the motivation of the learner, instilled by teachers and reinforced by quality instruction and engaging methods.

As English (and some other languages, such as French) lacks the transparency of other languages, children have greater difficulty figuring out the system. This makes English alphabets even more important to teach.

Phonics instruction (systematic instruction where all the grapheme-phoneme correspondences are taught and covered in a clearly defined sequence) is effective regardless of whether it begins early or later, after students have acquired some reading ability. However, findings have revealed that early interventions are more effective than late interventions.

It is not yet apparent if there is a “critical period” per se for learning to read.

A study was presented on kids who miss the cut-off date for going to kindergarten. The results show that where reading skills are concerned, these children seem to catch up just as easily as those who have a head start.<sup>9</sup>

- ***For Mathematics***

Although maths disability is diagnosed after at least one year of schooling, maths development starts well before the formal teaching of maths. Children at risk of maths disability can be detected in kindergarten and preventive education programmes should be introduced for those children.

A very important finding is that studies in mathematics learning have shown that learning by strategy leads to more stable results than learning by drill, and that different strategies lead to different brain activations.

Finger counting is good for beginners but scientists warn that children should be weaned off it so that they don't become too reliant upon it.<sup>10</sup>

- ***For Parents***

Parental involvement appears to have tremendous impact on literacy skills and reading ability. A rethinking of the roles and influences of parents is deemed necessary, i.e. a rethinking of the balance between in-school and out-of-school learning to encourage kids to develop their talents in a more natural and effective way and, by so doing, ultimately contribute towards a better functioning society.

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<sup>9</sup> On the other hand, studies such as the OECD PISA Study [[www.pisa.oecd.org/](http://www.pisa.oecd.org/)] have shown a marked difference in other aspects of schooling for children who have attended kindergarten. Kindergarten, traditionally a sort of “pre-school”, is above all a socialising setting, where among other things, the roles and the “language” of school are (at least partially) acquired. This can make a huge difference afterwards, including aiding learning to read.

<sup>10</sup> See footnote 5.

- ***For Teachers***

What is high quality for one child may actually be low quality for another, and we also need to be more specific about the notion of balanced instruction. We need to ask questions about the amount of instruction, the type of instruction and how changes occur over the school year, in order to predict what the effect of any kind of instruction or intervention is going to be. For teachers to be effective, they need to know at a more specific level than they do currently what children's actual skill levels are, so that assessment is really important.

National strategies cannot work effectively if you have a teaching body of stressed teachers implementing them.

- ***For Researchers***

A note to researchers is that in order to have an impact on education policy, they need to look beyond their own immediate scientific interests when engaging in studies. As studies are costly, the benefits and outcomes need to be considered before engaging in work. All the scientists agreed that it would be especially valuable to conduct more longitudinal studies, as the growth rate is seen as fundamental to understanding learning and learning difficulties.

APPENDIX A

**“Ciencias del aprendizaje e investigación sobre el cerebro:  
2º encuentro de las redes de expertos en lecto-escritura y cálculo”**

**“Learning Sciences and Brain Research:  
2<sup>nd</sup> Literacy & Numeracy Networks Meeting”**

**EL ESCORIAL - MADRID, ESPAÑA/SPAIN, 1-2-3.03.04**  
**Agenda**

**Agenda of Presentations**

**1 de Marzo – Lecto-escritura/ March 1 - Literacy**

**Sesión 1/ Session 1, 08:00-10:45**

Cognición e instrucción en el desarrollo temprano de la lecto-escritura  
Cognition and Instruction in Early Literacy Development

Moderadores/ Chairs: A. Kelly & F. López Ruperez

- 08:00-08:10 Bruno della Chiesa  
Presentación y objetivos del seminario/ *Introduction & Goal Setting*
- 08:10-08:30 Carmen López Escribano  
Contribuciones de la biología a la enseñanza y evaluación de las dificultades lectoras/ *Biology Contributions to Assessment and Instruction of Reading Difficulties*
- 08:30-08:50 Richard Bartholomew  
Estrategia nacional sobre la lecto-escritura: Inglaterra/ *National Literacy Strategy: England*

08:50-09:05

Discusión/ *Discussion*

09:05-09:30

Linnea Ehri

Conciencia e instrucción de la fonética en el tratamiento de las dificultades lectoras: hallazgos y problemas/ *Phonemic Awareness and Phonics Instruction to Treat Reading Disabilities: Findings & Signes*

09:30-09:55

Discusión/ *Discussion*

09:55-10:20

Fred Morrison

Más allá de las guerras entorno a la lectura: Interacciones niño-instrucción en la adquisición temprana de la lectura/ *Beyond the Reading Wars: Child-Instruction Interactions in Early Reading Acquisition*

10:20-10:45

Discusión/ *Discussion*

10:45-11:00

Café/ *Coffee break*

## **Sesión 2/ Session 2, 11:00-13:30**

Procesos básicos de la lecto-escritura: Aportaciones de la Imagen por Resonancia Magnética funcional sobre su desarrollo y sus problemas

*Basic Processes of Literacy: Insights from fMRI about Development & Disorders*

Moderadores/ *Chairs: T. Carr & E. Sebastián Gascón*

11:00-11:25

Leo Blomert

Un modelo cerebral para la integración de los grafemas y fonemas/ *A Brain Model for the Integration of Graphemes and Phonemes*

11:25-11:50

Discusión/ *Discussion*

11:50-12:15

Guinevere Eden

Estudios gráficos del cerebro en actividades de lectura típica y atípica/ *Brain Imaging Studies of Typical and Atypical Reading*

12:15-12:40

Discusión/ *Discussion*

12:40-13:05 Elise Temple  
Procesamiento auditivo y dislexia: Respuesta cerebral a las terapias contra la dislexia basadas en la audición/ *Auditory Processing and Dyslexia: Brain Response to Auditory-Focused Remediation to Dyslexia*

13:05-13:30  
Discusión/ *Discussion*

13:30-15:00  
Almuerzo/ *Lunch*

### **Sesión 3/ Session 3, 15:00-17:45**

#### Desarrollo de mecanismos cerebrales en el reconocimiento de palabras – Modelos Electrofisiológicos e Informáticos

#### *Development of Brain Mechanisms for Word Recognition – Electrophysiology and Computational Modelling*

Moderadores/ *Chairs: P. Hannon & N. Sebastián Galles*

15:00-15:25 Daniel Brandeis  
Aplicación neurofisiológica de la impresión visual instantánea especializada en el desarrollo de la lecto-escritura temprana/ *Neurophysiological Mapping of Fast Visual Print Specialization onto Early Literacy Development*

15:25-15:50  
Discusión/ *Discussion*

15:50-16:15 Heikki Lyytinen  
Niños con riesgo de dislexia familiar: Efectos conductistas y electrofisiológicos desde la infancia durante de los primeros años como lectores/ *Children at Familial Risk of Dyslexia: Behavioral and Electrophysiological Effects from Infancy through Early Reading Years*

16:15-16:40  
Discusión/ *Discussion*

16:40-17:05 Jason Zevin  
Modelos informáticos y el desarrollo de la destreza de lectura/ *Computational Modelling and the Development of Reading Skill*

17:05-17:30  
Discusión/ *Discussion*

17:30-17:45 José Manuel Igoa González  
Observaciones finales (primer día)/ *Concluding Remarks (first day)*

18 :00 ...

Actividad cultural y cena institucional/ *Cultural Activity and Institutional Dinner*

## **2 de marzo- Jornada conjunta lecto-escritura y cálculo**

### **March 2 – Joint Literacy & Numeracy Day**

#### **Sesión 4/ Session 4 - 08:00-10:45**

Retos comunes y específicos en la adquisición de la lecto-escritura en distintas lenguas  
*Common and Unique Challenges for Literacy Acquisition Across Languages*

Moderadores/*Chairs: T. Ortiz Alonso & B. Sloane*

08:00-08:10 Tom Schuller

Presentación de las sesiones conjuntas/ *Introduction to the Joint Sessions*

08:10-08:30 Juan Antonio García Madruga

Pensamiento y habilidades de lectoescritura y matemáticas: comprensión, razonamiento y memoria operativa/ *Thought and Ability in Reading and Mathematics: Comprehension, Reasoning, and Working Memory*

08:30-08:50 Jarl Bengtsson

Destrezas de lectura y cálculo en una economía del conocimiento/ *Literacy and Numeracy Skills in a Knowledge Economy*

08:50-09:05

Discusión/ *Discussion*

09:05-09:30 Usha Goswami

Lectura y dislexia a través de distintas lenguas: análisis evolutivo/ *Reading and Dyslexia Across Languages: A Developmental Analysis*

09:30-09:55

Discusión/ *Discussion*

09:55-10:20 Eraldo Paulesu

Efectos culturales en lectura normal y disléxica/ *Cultural Effects in Normal and Dyslexic Reading*

10:20-10:45

Discusión/ *Discussion*

10:45-11:00

Café/ *Coffee break*

11:00-11:45 **Acto Oficial/ *Official Opening***

- Bruno della Chiesa (CERI-OCDE/*CERI-OECD*): Presentación/ *Introduction*
- Francisco García (CNICE <sup>11</sup>)  
Presentación de la página Web en español/ *Presentation of the Spanish website*
- Tom Schuller, Director del CERI-OCDE/ *Head of CERI-OECD*  
El “Proyecto Cerebro” en el marco de los trabajos del CERI y la OCDE en materia de educación/ *The “Brain Project” in the Context of CERI and OECD Education Work*
- José Luis Cádiz Deleito, Subsecretario del Ministerio de Educación, Cultura y Deporte, España/ *Undersecretary – Ministry of Education, Culture and Sport, Spain*
- La visión de España respecto al “Proyecto Cerebro”/ *Spain’s Vision of the “Brain Project”*

### **Sesión 5/ *Session 5, 11:50-13:30***

Retos entorno a la adquisición de los conceptos numéricos: Dos hipótesis  
*Challenges for Numbers Acquisition: Two Hypotheses*

Moderadores/ *Chairs: R. Bartholomew & A. Puente Ferreras*

11:50-12:15

Brian Butterworth

¿Se puede atribuir la discalculia a un “Módulo numérico defectuoso”?/ *Is Dyscalculia Due to a “Defective Number Module”?*

12:15-12:40

Discusión/ *Discussion.*

12:40-13:05

Annette Karmiloff-Smith

¿Pueden constituir los trastornos genéticos una ventana hacia la cognición numérica?/ *Are Genetic Disorders a Window on Numerical Cognition?*

13:05-13:30

Discusión/ *Discussion*

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<sup>11</sup> Centro Nacional de Información y Comunicación Educativa/ *National Center for Educational Information and Communication.*

13:30-15:00

Almuerzo/ *Lunch*

**Sesión 6/ Session 6, 15:00-16:55**

Aspectos comunes de la investigación sobre los aspectos cognitivos de la educación en materia de lecto-escritura y cálculo

*Commonalities of Cognitive Education Research in Literacy and Numeracy*

Moderadores/ *Chairs: T. Schuller & L. López García.*

15:00-15:25

Stan Dehaene

¿Cómo puede el cerebro de un primate aprender a leer y calcular? – La hipótesis del reciclaje neuronal/ *How Can a Primate Brain Learn to Read and to Calculate? - The Neuronal Recycling Hypothesis*

15:25-15:50

Bruce McCandliss

Las capacidades de lecto-escritura y de cálculo como sistemas de plasticidad cerebral: conexión entre la investigación sobre la actividad cerebral y la actividad educativa/ *Literacy and Numeracy as Systems Level Brain Plasticity: Linking Research on Brain Activity and Educational Activity*

15:50-16:40

Discusión/ *Discussion*

16:40-16:55

Tom Schuller

Observaciones finales (segundo día)/ *Concluding Remarks (second day)*

**Sesión/ Session W\*, 17:00-17:45**

Estrategia de difusión y el sitio Web/ *Dissemination Strategy & Website*

Moderadores/ *Chairs: C. Davis & E. Servan-Schreiber*

17:00-17:20

Cassandra Davis & Emile Servan-Schreiber

Comunicación en la red a través de listas de servidores, características de sitio Web, interactividad y contribuciones de los socios permanentes de las redes/ *Listserve Network Communication, Website Features, Interactivity and Core Member Contributions*

17:20-17:45

Discusión/ *Discussion*

20:30 ...

Cena/ *Dinner*

\* Solo para socios de las redes/ *For networks core members only*

### **3 de Marzo – Cálculo/ March 3 - Numeracy**

#### **Sesión 7/ Session 7, 08:00-10:45**

Discalculia y dificultades aritméticas (Parte 1)

*Dyscalculia and Arithmetic Difficulties (Part 1)*

Moderadores/ Chairs: Ch. Brookes & J. R. Fernandez del Castillo Díez

- 08:00-08:20 Vicente Bermejo Fernández  
Microgénesis y aprendizaje de las matemáticas/ *Microgenesis and Mathematics Learning*
- 08:20-08:40 Anthony E. Kelly  
Tendencias actuales en el aprendizaje de las matemáticas en los EEUU:  
¿dónde está el cerebro ?/ *Current Trends in Mathematics Learning in the USA:  
Where is the Brain?*
- 08:40-09:05  
Discusión/ *Discussion*
- 09:05-09:30 Mark Ashcraft  
Factores emocionales y cognitivos en las dificultades aritméticas/ *Emotional  
and Cognitive Factors in Arithmetic Difficulties*
- 09:30-09:55  
Discusión/ *Discussion*
- 09:55-10:20 Michel Fayol  
Problemas en el aprendizaje de la suma, resta y multiplicación/ *On Learning to  
Solve Addition, Subtraction and Multiplication Problems*
- 10:20-10:45  
Discusión/ *Discussion*
- 10:45-11:00  
Café/ *Coffee break*

#### **Sesión 8/ Session 8, 11:00-13:30**

Discalculia y dificultades aritméticas (Parte 2)

*Dyscalculia and Arithmetic Difficulties (Part 2)*

Moderadores/ Chairs : D. Coben & P. Martín Plasencia

- 11:00-11:25 Ruth Shalev  
Discalculia evolutiva: frecuencia e historia natural/ *Developmental Dyscalculia: Prevalence and Natural History*
- 11:25-11:50  
Discusión/ *Discussion*
- 11:50-12:15 Nancy Jordan  
¿Por qué los niños tienen dificultades en el dominio de conceptos numéricos básicos? – Una investigación longitudinal/ *Why do Children have Difficulties Mastering Basic Number Facts? - A Longitudinal Investigation*
- 12:15-12:40  
Discusión/ *Discussion*
- 12:40-13:05 Marie-Pascale Noël  
Las capacidades de la memoria operativa en el aprendizaje de las matemáticas/ *Working Memory Capacities in Learning Mathematics*
- 13:05-13:30  
Discusión/ *Discussion*
- 13:30-15:00  
*Almuerzo/ Lunch*

**Sesión 9/ Session 9, 15:00-17:30**

Avances en la educación y rehabilitación matemáticas  
*Advances in Mathematical Education and Rehabilitation*

Moderadores/ *Chairs: J. Bengtsson & R. Mur Montero*

- 15:00-15:25 Jan de Lange  
Factores clave en la educación matemática de los niños/ *Key Factors in Children's Mathematical Education*
- 15:25-15:50  
Discusión/ *Discussion*
- 15:50-16:15 Margarete Delazer  
Efectos de los distintos modelos de enseñanza de la aritmética/ *Effects of Different Training Methods in Arithmetic*
- 16:15-16:40  
Discusión/ *Discussion*

16:40-17:05 Sharon Griffin  
Factores clave en el desarrollo y rehabilitación tempranas en aritmética/ *Key Factors in Early Arithmetic Development and Rehabilitation*

17:05-17:30  
Discusión/ *Discussion*

Panel de conclusions

Concluding Panel, 17:30-18:00

Moderadores/ *Chairs* : B. della Chiesa & F. López Ruperez

Conclusiones finales/ *Concluding remarks by* : Diana Coben, Peter Hannon, Tomás Ortiz  
Alonso, Barry Sloane

20:30 ...  
*Cena/ Dinner*

## APPENDIX B

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