Abstracts

Second Literacy and Numeracy Network Meeting

EMOTIONAL AND COGNITIVE FACTORS IN ARITHMETIC DIFFICULTIES

Mark H. Ashcraft
Cleveland State University

Math anxiety is a genuine detriment to math learning and achievement, despite the difficulties that experimentally-oriented researchers have in appreciating this fact. In this talk, I will discuss the personal, educational, and cognitive consequences of math anxiety, focusing especially on performance-related deficits in tasks that depend on working memory. We do not know what factors lead to the development of math anxiety, although longitudinal tests should help decide among several plausible hypotheses. Planned work on the neurological patterns of activity associated with math anxiety may reveal the degree to which it combines emotional and cognitive components, and possibly shed light on the difficult relationship between math anxiety and math achievement.

A BRAIN MODEL FOR THE INTEGRATION OF GRAPHEMES AND PHONEMES

Leo Blomert
(Nienke van Atteveldt, Elia Formisano, Rainer Goebel)
Dept. of Cognitive Neuroscience
Faculty of Psychology
Universiteit Maastricht
The Netherlands

Most people are surprisingly well capable of using literacy skills even though the human brain is not evolutionary adapted to this relatively new cultural phenomenon. Associations between letters and speech sounds form the basis of reading in alphabetic scripts. We investigated the functional neuroanatomy of associations between letters and speech sounds using functional magnetic resonance imaging (fMRI). The most interesting finding is a modulation of the response to speech sounds in early auditory cortex by visual letters. Based on the analyses of single-subject data and group data aligned on the basis of individual cortical anatomy, we will present a model for the integration of graphemes and phonemes. Our data indicate that the efficient processing of culturally defined associations between letters and speech sounds may be based on a naturally evolved neural mechanism for integrating audiovisual speech.

NEUROPHYSIOLOGICAL MAPPING OF FAST VISUAL PRINT SPECIALIZATION ONTO EARLY LITERACY DEVELOPMENT

Daniel Brandeis
(Silvia Brem[1], Kerstin Bucher[2], Felicitas Kranz[1], Rosemarie Benz[1], H.Ch Steinhausen[1], Urs Maurer[1])
Department of Child and Adolescent Psychiatry
University of Zurich

Learning to read must involve a plastic reorganisation of the visual system, with regions specializing for print processing and connecting with phonological and semantic systems. Fluent adult readers activate such fast, specialized visual processes within less than 200ms. Their occipito-temporal N1 microstate exhibits coarse, automatic orthographic sensitivity (word-like strings vs. symbol strings) in neurophysiological studies, suggesting that the adult N1 indexes print categorization and perceptual expertise. We recently demonstrated that this N1 print sensitivity is absent in children who can not read words and have low letter knowledge (Maurer et al submitted). This 2-year longitudinal follow up examined whether this fast visual specialization emerges with learning to read.

Children (N=20) were initially tested in an implicit reading task as Kindergartners who could not yet read words (age 6.5), and subsequently after learning to read in 2^{nd} grade (age 8.3). Behavioral and electrophysiological (43 channel ERP) measures were recorded while children detected immediate repetitions of words, pseudowords, symbol-strings made from geometric forms, and pictures. The ERP data was segmented into microstates. Map strength (Global field power; GFP) and centroid topographies of the N1 segments are reported here (age x wordlike MANOVA).

Children developed a performance advantage for detecting words and pseudowords over symbol strings with learning to read. Large differences between the visual N1 ERP maps to words and symbols (age x wordlike) also emerged with learning to read, for both map strength and topography ($p<.001$, $p<.05$ respectively). The N1 maps increased dramatically in strength for words-like stimuli only. The topography of the word N1 negativity was mid occipito-parietal in Kindergarten and became more adultlike, i.e. bilateral inferior occipitotemporal in 2^{nd} grade. Only minor topographic changes were observed for symbol strings. None of these specializations for words over symbol strings was significant in Kindergarten.

Our findings demonstrate that fast, coarse, adult-like visual specialization of the N1 for print is found already in 2^{nd} graders, and emerges with less than 2 years of reading training from virtually null in non reading Kindergartners. This increase is specific to words, excluding general maturational factors. Fast visual specialization for print thus develops during an early stage of reading acquisition, suggesting that visual plasticity and perceptual expertise play a major role in literacy acquisition.

References

Maurer et al, submitted

Supported by grants SNSF 32-59276, Stiftung "wissenschaftliche Forschung", Universität Zürich, and by the NCCR on Neural Plasticity and Repair.

[1]Department of Child and Adolescent Psychiatry, University of Zurich
[2]Neuroradiology & Magnetic Resonance, Dept. Diagnostic Imaging, University Children's Hospital, Zurich, Switzerland

IS DYSCALCULIA DUE TO A "DEFECTIVE NUMBER MODULE"?

Brian Butterworth
University College London

Dyscalculia is typically characterised as a (severe) difficulty in learning about numbers and arithmetic ("dyscalculia). Although there is significant co-morbidity with other conditions affecting learning, such as dyslexia, selective difficulties seem to predominate. But why should children have difficulty learning arithmetic? Dyscalculic children also difficulty with basic number tasks involving recognising and comparing numerosities. Evidence from various sources converge on the idea that humans are born with a capacity representing numerosities (a "number module"), if so, then one possibility is this capacity is defective in dyscalculics.

EFFECTS OF DIFFERENT TRAINING METHODS IN ARITHMETIC

Margarete Delazer
University Innsbruck

In arithmetic education it has been repeatedly discussed whether learning by strategies or learning by repetition leads to a better mastery of novel arithmetic facts. Though educational studies and few rehabilitation studies addressed this issue, no brain imaging studies so far investigated the effect of different learning methods on brain activation in arithmetic fact retrieval. We investigated the effect of extensive training (one week, 90 blocks of training) on behavioural measures (reaction times, accuracy) and on brain activation patterns in healthy young adults (Delazer et al., in prep.). Two different learning methods, either by repetition or by strategy, were applied. Subjects showed higher accuracy with strategic training as compared to pure repetition, while reaction times were comparable after both methods of training. The difference in accuracy rate was stable over a six-weeks delay. In the fMR session significant differences were found between the different learning methods, as well as between trained and untrained problems. The most significant differences were found bilaterally in parietal regions, as well as in both frontal lobes. Results suggest a) that training leads to a modification of activation patterns and b) 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, mastery of new facts relies on different cognitive processes depending on the training method.

BRAIN IMAGING STUDIES OF TYPICAL AND ATYPICAL READING

Guinevere Eden
Georgetown University

A better understanding of the functional anatomy of typical reading acquisition is essential in the efforts to develop successful reading instructions and remediating reading disabilities. Functional MRI (fMRI) provides a means to non-invasively assess the neural signature of reading in children and adolescents and visualize the trajectory of reading acquisition. Using an implicit reading task that isolates reading-related brain activity free of performance confounds (Price et al., 1996), we found that, between the ages of 6 and 22 years, learning to read was associated both with increased activity in left hemisphere middle temporal and inferior frontal gyri, and with decreased activity in right infero-temporal cortex. The left posterior superior temporal sulcus was engaged in the youngest readers in relation to the maturation of their phonological processing abilities (Turkeltaub et al., 2003).

PHONEMIC AWARENESS AND PHONICS INSTRUCTION TO TREAT READING DISABILITIES: FINDINGS AND ISSUES

Linnea C. Ehri
GC – CUNY

The National Reading Panel conducted two meta-analyses to evaluate the impact of phonemic awareness instruction and systematic phonics instruction on the acquisition of word reading, spelling, and reading comprehension abilities in students from kindergarten through sixth grade. Only controlled experiments were included. Effects were considered separately for typically developing readers, at risk readers, and readers with a reading disability. Findings revealed that early intervention was more effective than later intervention. In this presentation, I will focus on studies involving students with a reading disability and will consider findings and issues that involve effects of instruction.

EARLY PREDICTORS OF NUMERICAL FLUENCY

Michel Fayol
LAPSCO/CNRS

In two series of studies, we (Roussel, Thévenot, Fayol) investigate the procedures used to solve addition, substraction and multiplication problems. The distinction made by Anderson between procedural and declarative resolution makes it possible to suppose that in production tasks (e.g., 7 + 5 = ?), additive (or subtractive) procedures could be primed by the simple presentation of the sign, whereas declarative knowledge (multiplications) can only be primed by its constitutive components (i.e. the numbers themselves). This hypothesis leads to predict that priming by the sign (i.e., the sign + or x is presented before the figures using a variable SOA) would indicate the use of an algorithmic operation solving procedure.

We report testing sign-based priming in production tasks. We study the performances of children (at age 10-11) and adults when asked to solve additions, multiplications and subtractions in tasks involving a variable SOA (- 150 ms; 0; + 150 ms). We test the hypothesis of an Operation x SOA interaction: systematic priming by the sign (SOA - 150 ms) should appear only in the case of operations which are solved by means of an algorithm (subtraction, and additions) but not in the case of memorized operations (multiplication). If this research yields positive results, we intend to develop software which will allow us both to test the solving of the operations in question and to train children in their resolution. This software could be tested among children with arithmetic learning difficulties.

We also study what becomes of the memory traces during the solving of simple operations. An algorithmic solution requires the manipulation and transformation of the representations of each of the operands. Consequently, the memory traces of these operands should be degraded following the calculation. In contrast, a comparison operation (27 > 32?) makes it necessary to conserve these representations. Consequently, the time required to retrieve the operands from memory after the calculation should be greater for additions than for comparisons. We plan to extend this paradigm to the solving of subtractions (for which the degradation of the memory trace should be even greater) and multiplications (in which case it should be reduced). Here, too, we are considering developing assessment and training software.

References

Barrouillet, P. & Fayol, M. (1997). Selecting between competitors in multiplication tasks : An explanation of the errors produced by adolescents with learning difficulties. International Journal of Behavioral Development, 21, 253-275.

Barrouillet, P. & Fayol, M. (1998). From algorithmic computing to direct retrieval. Evidence from number- and alphabetic-arithmetic in children and adults. Memory & Cognition., 26, 355-368.

Fayol, M. (2002). Langage et développement apprentissage de l'arithmétique cognitive. In J. Bideaud et H. Lehalle (Eds.), Le développement des activités numériques. Paris: Hermès

Fayol, M, Barrouillet, P. & Marinthe, C. (1998). Predicting arithmetic achievement from neuropsychological performance: A longitudinal study. Cognition, 68, 63-70.

Fayol, M. et Seron, X. (in press). On numerical representations. Insights from experimental, neuropsychological, and developmental research. In Campbell (Ed.), Handbook of numerical cognition.

Roussel, J.L., Fayol, M. et Barrouillet, P. (2002). Procedural vs. direct retrieval strategies in arithmetic : A comparison between additive and multiplicative problem solving. European Journal of Cognitive Psychology, 14, 61-104.

Thévenot, C., Barrouillet, P. & Fayol, M. (2001). Algorithmic solution of arithmetic problems and operands-answer associations in long term memory. The Quarterly Journal of Experimental Psychology, 54A, 599-611.

READING AND DYSLEXIA ACROSS LANGUAGES: A DEVELOPMENTAL ANALYSIS

Usha Goswami
University of Cambridge

In this paper, I will provide a brief theoretical overview at the cognitive level of reading acquisition and developmental dyslexia across languages. I will describe developmental studies showing that syllabic representation is basic to many languages, and that children's ability to recognise syllables and rhymes precedes learning a particular spelling system. I will argue that this developmental analysis can readily explain cross-language differences in reading acquisition, phoneme awareness and in the manifestation of developmental dyslexia. I will then suggest that some of the neural processes underpinning language acquisition are disrupted in developmental dyslexia, particularly basic auditory processes. This leads to deficits in the development of phonological representation before literacy is acquired, and these deficits will manifest differently in different languages.

KEY FACTORS IN EARLY ARITHMETIC DEVELOPMENT AND REHABILITATION

Sharon Griffin
Clark University

Consistent with Piaget's theory, most if not all modern theories of intellectual development (e.g. Central Conceptual Structure theory) postulate 4 major factors to explain conceptual change: exploration, social interaction, maturation, and equilibration. Although much has changed in the modern theories (e.g. the specific definition of each factor), much remains the same. Based on current theory and research, especially research with disadvantaged children with atypical life experiences, Piaget's four factors have been reformulated as follows:

Instead of general exploration, opportunities to solve problems in specific content domains (e.g. numeracy, science, literacy) and to encounter central concepts in these domains is now seen to be crucial to development.

Instead of general social interaction, the availability of mentors and guides who can provide opportunities for the child to acquire the language and the cultural tools (e.g. reading, writing, counting, oral discourse) of various content disciplines is now seen to be crucial.

Instead of general maturation, the growth of working memory capacity and the way this itself is influenced by the child's previous learning (e.g. chunking of information on the basis of practice) is now seen to provide a powerful explanation for conceptual change.

Instead of equilibration that occurs naturally in life as the child encounters novel situations, opportunities to actively confront misconceptions, in a social context, and to test hypotheses empirically, is now seen to be crucial. Allowing the child the luxury of experiencing the stress of cognitive dissonance—and the resulting motivation to overcome it—is also increasingly seen to be important.

On the basis of these four developmental principles, several key factors in the rehabilitation of dyscalculia can be generated. Subsumed under the heading, Instructional Principles, these factors have provided the backbone for successful intervention programs (e.g. Number Worlds) and they are described more fully in the paper I will present.

Finally, the success of any intervention program depends not only on the quality of the instruction that is provided but also on the quantity and the quantity is heavily influenced by environmental conditions (e.g. the motivation of the learner and the context in which the intervention occurs). Data to illuminate this point will also be presented.

WHY DO CHILDREN HAVE DIFFICULTIES MASTERING BASIC NUMBER FACTS? A LONGITUDINAL INVESTIGATION

Nancy C. Jordan
University of Delaware

Young children show uneven patterns of competencies in mathematics. In particular, some children cannot master basic arithmetic facts despite relatively strong problem-solving skills. Specific deficits related to mastery of arithmetic facts and calculation fluency is a defining characteristic of children with math disabilities (MD) who are good readers. Children with both MD and reading difficulties (RD), on the other hand, are characterized by weaknesses in solving word problems as well as in arithmetic fact mastery. In the present study, we focused specifically on children who have difficulties mastering addition and subtraction facts. We examined two groups of children: children with poor fact mastery (PFM) and children with good fact mastery (GFM). Children with PFM at the end of third grade were compared to grade-level peers with GFM in competencies related to reading and math. Children were assessed longitudinally across second and third grades with 4 time points. When predictor variables, such as IQ, were held constant, the PFM and GFM groups performed at about the same level and progressed at a comparable rate on math story problems and on broad reading achievement. The groups also progressed at a comparable rate on broad math achievement, although children with PFM performed at a significantly lower level. Children with PFM showed remarkably little growth in rapid fact retrieval during the study period, despite normal growth in other areas of math. Deficits in fact mastery are highly persistent and appear to be independent of reading and language abilities. Children with PFM performed as well as children with GFM difficulties in language but not in nonverbal reasoning. Our findings indicate that weaknesses in accessing and manipulating nonverbal number representations underlie rapid processing of addition and subtraction number facts rather than difficulties associated with language and memory. Implications for diagnosis and intervention will be discussed.

ARE GENETIC DISORDERS A WINDOW ON NUMERICAL COGNITION?

Annette Karmiloff-Smith
University College London

Genetic disorders hold the promise of being windows on the development of cognitive domains such as number. However, a number of caveats force us to treat this promise with some caution. First, the adult phenotype may turn out to be very different from the developmental trajectory that led to it. Hence the importance of studying number-relevant behaviours in infants. Second, very low-level impairments outside the domain of number may impact on the development of number over developmental time and give rise to emergent numerical impairments. In other words, what looks like a domain-specific impairment in the older child or adult may arise from a more domain-general deficit in the infant, simply because one domain, such as number, is more vulnerable to that impairment compared to others.

BIOLOGY CONTRIBUTIONS TO ASSESSMENT AND INSTRUCTION OF READING DIFFICULTIES

Carmen López Escribano
Universidad Complutense de Madrid

Educators face two major challenges related to reading difficulties: assessment and instruction. Very often our teachers and language therapist misinterpret relationships and causes of reading problems, in this way, their approaches are not as effective as they could be.

Neurology science and their findings can help us educator to improve assessment and instruction with more specific and effective approaches.

There are two interesting lines of neurological research on reading: “Phonological Processing” and “Visual and Auditory Processing”, two examples of these research lines, that consider neurology and education are: Simos et al. (Phonological Processing), and Wolf et al. (Visual and Auditory Processing)

In Spain we need to prepare and actualize our teachers and language therapist with more specific and practice knowledge on reading difficulties based in the last neurological findings.

CHILDREN AT FAMILIAL RISK OF DYSLEXIA: BEHAVIORAL AND ELECTROPHYSIOLOGICAL EFFECTS FROM INFANCY THROUGH EARLY READING YEARS

Heikki Lyytinen
University of Jyväskylä

Highlights of the results of the differential developmental paths of children born with or without familial risk for dyslexia are reviewed. Statistically significant differences comprise electrophysiological and behavioral responses to speech sound in infancy, a spectrum of language-related skills and predictive correlates of early reading acquisition. Early reading skill/difficulties can be predicted relatively accurately and better in the at risk group. Thus early identification dyslexia is possible and leads to questions concerning preventive interventions. A promising approach available to children reading in a regular orthography will be suggested.

LITERACY AND NUMERACY AS SYSTEMS LEVEL BRAIN PLASTICITY: LINKING RESEARCH ON BRAIN ACTIVITY AND EDUCATIONAL ACTIVITY

Bruce McCandliss
Sackler Institute for Developmental Psychobiology

This talk will serve to synthesize many of the themes and findings presented throughout the course of the literacy network meeting to help direct discussion toward issues of how contemporary scientific investigations into the development of reading skills might hold implications for education. First, working at the systems neuroscience level, I present a framework in which cultural demands for reading development can be seen as posing a specific biological challenge to children, requiring the development of an efficient integration of two *pre-established* functional pathways in the cortex: ventral-temporal object recognition pathways and left lateralized pathways for converting auditory information into linguistic categories of words, syllables and phonemes. Next, I review findings that demonstrate how the typical developmental course of learning to read drives changes both in occipito-temporal regions associated with coding visual word forms as well as in left-perisylvian regions associated with phonology. Finally I review evidence from studies of developmental dyslexia that demonstrate how individual differences in the functional organization of left perisylvian regions associated with phonological processes play a crucial role in impacting the development of efficient reading skills. Next, I review several learning studies which examine the impact of intervention and training on the development of reading skills in developmental dyslexia, as well as the impact of such interventions on the functional organization of cortical regions involved in reading. These initial studies represent a new research paradigm for investigating the relationship between specific interventions and specific changes in cortical activity. Despite a host of limitations of the studies conducted thus far, in theory, such paradigms could allow specific causal relationships between therapeutic interventions and changes in cortical activation patterns associated with core processing deficits in reading disability, as well as other more mild forms of reading difficulties encountered by many children.

Finally, I will consider future directions such research may take in order to help maximize the impact on current practice in education, with an emphasis on how such research might impact practice within realistic schooling environments. I will review recent work taking place in New York City public schools that involves forging a direct connection between neuroimaging studies of basic reading processes in children with a randomized controlled comparison of two school-based intervention programs.

BEYOND THE READING WARS: CHILD-INSTRUCTION INTERACTIONS IN EARLY READING ACQUISITION

Frederick Morrison
University of Michigan

We present the results of a series of studies that examine 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. Classrooms were observed in the fall, winter, and spring. Dimensions of instruction were used to describe classroom language arts activities – explicit versus implicit, teacher- versus child-managed, and word-level versus higher-order activities. Change in amount of time spent in the activity over the school year was predictive as well. Overall, the effect of instruction depended on children's fall language and reading scores. For example, children with average to low fall comprehension scores achieved greater reading comprehension growth in classrooms with more time in teacher-managed-explicit higher-order instruction (e.g., teacher-led predicting, questioning). Children with higher fall scores demonstrated stronger growth in classrooms with more child-managed explicit higher order instruction (e.g., cooperative writing opportunities). Research, classroom instruction, and assessment implications will be discussed.

WORKING MEMORY CAPACITIES IN LEARNING MATHEMATICS

Marie-Pascale Noël
Unit of Cognition and Development

The talk will be organised around two main sections. In the first one, we will present the data of different studies showing that poor working memory capacities are characteristics of dyscalculic children relative to control ones. In the second section, we will propose a tentative explanation of this pattern. We will argue that in very young children, poor working memory capacities do not favour the learning of the counting string and rather leads to weaker counting abilities (including poor level of elaboration of the counting string). This state of affair would then be related to the use of immature counting strategies in solving simple additions, which, in turn, would impede the constitution of a good arithmetical fact network. This process might be a valuable account of the poor arithmetical abilities of dyscalculic children.

DEVELOPMENTAL DYSCALCULIA: PREVALENCE AND NATURAL HISTORY

Ruth S. Shalev
Shaare Zedek Medical Center

Developmental dyscalculia is a specific learning disability affecting the acquisition of arithmetic skills. The prevalence of this cognitive handicap in school-age children is 3-7%, a figure found in countries as diverse as the United States, England, Germany, India and Israel. This prevalence is similar to that of other neurocognitive disorders such as dyslexia and ADHD but, unlike them, is 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. Dyscalculia is frequently encountered in neurological disorders such as developmental language syndromes, epilepsy, neurofibromatosis, Fragile X syndrome and Turner's syndrome.

AUDITORY PROCESSING AND DYSLEXIA: BRAIN RESPONSE TO AUDITORY-FOCUSED REMEDIATION TO DYSLEXIA

Elise Temple
Cornell University

Developmental dyslexia, an unexpected difficulty in reading, affects between 5-17% of the population. Dyslexic children (and adults) have been shown to have a disrupted neural response to phonological and rapid auditory processing. It has not been known the extent to which this disrupted response can be ameliorated through behavioral training. To explore the neural effects of behavioral training, dyslexic children underwent brain imaging (fMRI) before and after a behavioral training program that improved their reading ability. This talk will describe the changes in neural activity that were observed after behavioral training. Changes were seen in neural activity during both rapid auditory and phonological processing. These changes were both in areas normally used during these processes and in regions not normally active in control children, reflecting changes in brain function that were both normalizing and compensatory. These results suggest 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 behavioral training.

COMPUTATIONAL MODELING AND THE DEVELOPMENT OF READING SKILL

Jason Zevin
Sackler Institute for Developmental Psychobiology

Research in the experimental psychology of reading has been driven by the articulation and testing of cognitive models. In particular, computational models that can be implemented as computer programs have provided many insights into the nature of the representations and processes of skilled reading. Curiously, less research has focused on the computational basis of *how* reading skill is acquired. However, parallel distributed processing (PDP) models of reading such as those introduced by Seidenberg & McClelland (1989) are inherently developmental: A central goal of this approach to modeling is to examine how human-like behaviors can emerge from the interaction of statistical learning mechanisms with a complex environment. In this talk, I will summarize some promising results from studies that have begun to apply this computational approach to issues more directly relevant to the development of literacy.

Harm and Seidenberg (1999) presented a neural network model consisting of a set of units representing individual letters connected to a set of units representing phonological features via a set of connections and computational units. It was taught to map from spelling to sound using a statistical learning algorithm that shares some properties with current theories of how learning occurs in the brain.

A number of different methods of adding noise to the phonological representations of the model gave rise to a pattern of behavior similar to that observed in many developmental dyslexics: The model was able to read familiar words correctly, but had difficulty decoding novel "pseudowords" and unfamiliar words. Harm, McCandliss and Seidenberg (2003) used the same basic model to explore why some methods of remediation training for dyslexics are more successful than others. In particular, techniques which involve training the relationship between spelling and sound are more effective – particularly once learning to read has already begun – than methods that exclusively train phonological processing.

Analyses of the model demonstrated that explicit training on spelling-to-sound patterns at the sublexical level allowed the model to form more componential representations of words, and improved its ability to generalize its knowledge to novel pseudoword items – a critical index of decoding skill. The model also provided a possible explanation for why focusing on remediating phonology alone is less successful in children who have already begun to read. The phonological deficit in the model is not the proximal cause of reading difficulty. Rather, the effect of the phonological deficit is that it negatively impacts the model's ability to form componential representations of the *mapping* between spelling and sound – whereas the unimpaired model is able to represent regularities in this mapping at multiple levels (single letters, clusters like –OO- and –OOK), the impaired model is less able to perceive and recombine these sublexical units. Phonological remediation *before* the beginning of reading instruction can be helpful, but once less componential representations in the *mapping* between spelling and sound begin to be formed, it is more effective to remediate these directly.

In later work, Harm et al. extended this approach to the study of different basal reading materials. When the model was trained on a collection of texts which emphasized spelling-to-sound similarities among words, generalization performance was much better than a condition in which the same model was trained on a corpus that emphasized variety in the type of text presented.

Both studies demonstrate the importance of stressing spelling-to-sound relationships in teaching reading. More importantly, they demonstrate how i*n silico* experiments of this type can complement empirical research by providing computational explanations of the acquisition and use of reading skill that are broadly consistent with our basic understanding of learning in neural systems. These initial successes suggest that increased collaboration between computational modelers and educators can foster both theoretical and practical advances. Simulation models can be directly analyzed to assess the degree to which their representations are componential or holistic, in a way that is not possible with human subjects. Furthermore, the models never tire of testing, and can be run on many more test stimuli and in many more training conditions than a set of subjects in a typical educational study. With this approach there is hope that the modeling work can begin to deal directly with the complexities facing real educators deciding among entire corpora of curriculum materials and activities designed to promote literacy.

References

*Harm, M. W., McCandliss, B. D., & Seidenberg, M. S., (2003). Modelling the Successes and Failures of Interventions for Disabled Readers. Scientific Studies of Reading.**7**,155-182.*

Harm, M.W. and Seidenberg, M.S. (2002) Modeling Reading Development From First Grade Text. Talk given at the Annual Meeting of the American Education Research Association, New Orleans, LA, April 2002.

Harm, M.W. & Seidenberg, M.S. (1999) Phonology, Reading Acquisition, and Dyslexia: Insights from Connectionist Models. Psychological Review, 106, 491-528.

Seidenberg, M. S. and McClelland, J. l. (1989). A distributed, developmental model of word recognition and naming. Psychological Review, 96, 523-568.