1 Neurobiological Correlates of the Language-Literacy Connection in Normal and Atypical Development

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2 Reading is a complex skill and there are many reasons why a child may have difficulty learning to read.

Reading Disability has at its core a deficit in the phonological component of language.

3 Studies have consistently found phonological processing abilities to play a critical role in learning to read. *(Report of the National Reading Panel, 1998).*

The degree of phonological awareness is the single best predictor of reading success.

4 Phonological processing

“the segmental analysis of words for ordinary speaking and listening, as well as the metaphonological skills required for explicitly analyzing the sound structure of speech into the phonemic components represented by the alphabet.”

- Mody, 2003

5 Language acquisition and reading development depend on early exposure to and a full appreciation of the sound patterns of one’s language (i.e., it’s phonological characteristics)

6 Developmental Dyslexia

Approximately 10-15% of children struggle to learn to read despite adequate intelligence, motivation, and schooling, no frank neurological signs, and absence of any sensory deficits.

Developmental Dyslexia results from a breakdown in:

- Word recognition (accurate and fluent identification of real words)
- Decoding (rate of oral reading of nonwords)
- Spelling (translation of phonemic information into an integrated code)

- Lyon, Shaywitz & Shaywitz, 2003

7 Characteristic Deficits in Dyslexia

- Speech Perception under demanding conditions (e.g., categorical perception, speech in noise)
- Phonological Awareness (e.g., sound/syllable segmentation, blending, rhyme judgment).
- Verbal Memory (e.g., non-word repetition)
- Lexical Retrieval (e.g., rapid naming)

8 Impetus for Functional Neuroimaging Research in Dyslexia

- Are the brains of dyslexic individuals wired differently?

- Relevant applications of neuroimaging findings:

  * improved sensitivity and specificity of diagnosis
  * to test the efficacy of different interventions

9 Language Organization in the Brain

"No one area of the brain is devoted to a very complex function, such as 'syntax' or 'semantics'. Rather, any task or function utilizes a set of brain areas that form an interconnected, parallel, and distributed hierarchy. Each area within the hierarchy makes a specific contribution to the performance of the task."

-Fiez & Petersen, 1993

10 Language & Reading: Components and Network

- Phonology, Orthography, Semantics, Syntax, and Pragmatics
- Inferior frontal areas (speech production/articulation), temporo-parietal areas (phonologic/semantic analysis), occipito-temporal areas (word form recognition)

11 Neural Signature of Dyslexia

- Reduced activation of posterior reading circuitry in poor readers

- temporo-parietal areas
- Occipito-temporal areas

12 Some tools for investigating structure-function relationships in the brain

- EEG: electroencephalography
- MEG: magnetoencephalography
- fMRI: functional magnetic resonance imaging
- PET: positron emission tomography
- NIRS: near infra-red spectroscopy
- DTI: diffusion tensor imaging

13 Phonological processing differences in adults vs. children: MEG

- Accuracy >80% in both gps; Longer RTs in children.
- Adults (n=10; age: 20-30 yrs): significant difference ($p<0.05$) between Rhyme and Line in 150-250ms post-stimulus window
  - left STS and left IFG

- Children (n=10; age: 10-12 yrs) : significant difference ($p<0.05$) between Rhyme and Line in 250-350 ms post-stimulus window
  - left and right temporo-parietal

- The slightly later and more bilateral activation in children compared to adults suggests ongoing development of their phonological processing abilities.

14 Moving beyond Phonology:

Reading for meaning

- Reading for meaning involves a combination of
bottom-up (e.g., phonological decoding) and top-down (e.g. semantic/contextual) processes.

Aim: To explore the contribution of phonology and semantics to single-word reading in children vs. adults.

15 *Subjects*

College educated adults (n=12; mean age: 25 yrs)

Normally developing children (n=10; mean age: 10 yrs)

Task: Homophone Judgment Task involving synonym foils modeled after Perfetti & Zhang (1995), using a priming paradigm

Stimuli: 75 – 95 “target” words.

each primed by a homophone, synonym and control (unrelated) word.

PLAIN	**plane**
JET	**plane**
DOG	**plane**

;

16 Behavioral Results

- Both groups did well on the task (>85% accuracy)
- Both groups took significantly longer to reject synonym foils compared to control stimuli
- On average, children showed an SIE of 86 ms and adults showed an SIE of 24 ms.

17 Conclusions

- Both children and adults showed semantic priming effects in the time range of the N400, an ERP component associated with semantic processing.
- The larger SIE effect in children than in adults may suggest less closely harnessed phonological-semantic relations due to developmental differences in relative efficiency of phonological and semantic processes.
- Smaller SIE in adults along with less activation for the synonym condition compared with the control condition in right anterior temporal 300–500 ms post stimulus is suggestive of semantic priming
- right inferior frontal activation in adults may also reflect more successful inhibition of the interference due to a more tightly coupled phonological-semantic interface compared to that in children.

18 Summary

When phonology and semantics were forced to compete at a single-word reading level, children compared to adults showed larger SIE, prolonged semantic priming effect in left ant.

temporal area and were more influenced by the prime, despite controlling for longer RTs.

These results suggest changing relations between phonological and semantic systems over the course of reading development.

19 Subjects

- General
  - 7-12 years old
  - English as primary language
  - No history of psychological or neurological problems
  - Normal hearing
  - Normal verbal and nonverbal IQ (PPVT, TONI)
- **Poor Reader group (n = 15)**
  - Below 25th percentile on at least one reading measure
    - Woodcock Reading Mastery Tests-Revised (Word Attack, Word ID)
    - Receiving reading remediation
- **Good Reader group (n = 15)**
  - Above 39th percentile on both Woodcock subtests
  - Age-matched to poor reader group

20 Auditory Word Discrimination (oddball)

- Varied phonological contrast by manipulating degree of phonetic similarity
  - voicing, place of articulation, manner of articulation

- Poor readers may have more difficulty with a 1 phonetic feature (phonologically similar) vs. 3 phonetic feature (phonologically dissimilar) contrast.
  e.g., *bat-pat* harder than *rat-pat*

- Attended oddball paradigm:
  /pat/ as standard (n=1000)
  /bat/, /kat/, /rat/ as deviants (n=100 each)

21 Auditory word discrimination (oddball): Summary

- Similar behavioral performance across groups (no diff in accuracy;
  bat > cat > rat (both groups)
- Different brain activation patterns
  - Poor Readers:
    - Delayed and reduced left-hemisphere activation to most demanding phonological contrast (*bat-pat*), compared to good readers.
    - Overall sustained bilateral activation, stronger on the right.
  - Both groups had longer RTs to *bat* vs. *rat*
    - Only good readers differed in brain activation

22 Study 2: Auditory word discrimination in sentence context

- Reading-impaired children have normal spoken language and adequate reading comprehension
  - Context cues to compensate for impaired phonological processing abilities
- Phonological contrast on auditory comprehension
  - Auditory sentence plausibility task

23 Study 2: Auditory word discrimination in sentence context

- Subjects listened to sentences ending in words that were either semantically congruent or semantically anomalous with the preceding context.

24 Auditory word discrimination in sentence context: Summary

- Good and Poor Readers
  - Accuracy: lower on phonologically similar (PS) than phonologically dissimilar (PD) words and congruent words
  - RT: Congruent < Phono. Sim. & Phono. Dissim
- Good Readers
  - Superior coding skills aided discrimination of phonologically similar foils despite conflicting contextual cues, evident in left lateralized but delayed response relative to PD condition.
- Poor Readers
  - Greater difficulty with phonological processing evident in less activation in left STG between 200-300 ms as well as bilateral activation, stronger on the right for sentences ending in phonologically similar than phonologically dissimilar words

25

Beyond Single-Word Reading: A Model of Reading Comprehension

The meaning of a sentence :

- is a function of the meaning of its constituent words as well as the way they are syntactically combined
- entails combining information from a sequence of words or phrases, determining their syntactic and thematic relations and using one's word knowledge to construct a representation of meaning (Just et al., 1996)

26

Neural Indices of Reading Comprehension

- Semantic and Syntactic factors each impact not just independent areas but affect activation in a network of brain areas encompassing inferior frontal, temporal and parietal regions implicated in reading comprehension.

- Typically investigated using an anomaly paradigm:
  - Semantic pragmatic anomaly: N400, occurs approximately 400 ms following onset of contextually inappropriate word within a sentence.
  - Morphosyntactic anomaly: P600, occurs 600-800 ms following onset of syntactic incongruity in sentence.

27

Sentence Comprehension Task: MEG

Example of each sentence type used :

- In art class we painted a bowl. (normal)
- In art class we paints a bowl. (morphosyntactic anomaly)
- In art class we jumped a bowl. (semantic pragmatic anomaly)

Child subjects were asked to read each sentence and to press "yes" if the sentence was okay and "no" if the sentence was not okay.

Analysis: MNE source analysis.

28

Reading Comprehension: Preliminary Behavioral & MEG Results

- Significant group difference on accuracy in morphosyntactic anomaly condition accompanied by greater activation activation in occipitotemporal areas in poor readers compared to good readers.
- suggestive of poor readers' use of orthographic strategies in lieu of phonologic analysis in word recognition

29

Efficacy of Intervention: Evidence from Neuroimaging

Intensive phonological training helped reading-impaired children approximate brain activation patterns similar to those of normal controls, accompanied by improved reading ability.

-*Aylward et al., 2003; Blachman et al., 2003; Simos et al., 2002*

30 Patterns and Outcomes of Functional Disruption in Reading Disability

- Dysfluent readers show different patterns of disruption in the posterior circuits for reading depending on reading accuracy

- Support for potentially two different types of poor readers

Shaywitz et al, 2003.

31 Conclusions

- Neuroimaging research appears to validate a critical role for phonological processing in reading development and disorders.

- Important to consider the contribution of the different components of language to reading outcomes given the interaction of top-down and bottom-up processes during reading.

- Early and appropriate intervention based on robust science is key to successful remediation.