Developmental Disorders affecting language

Specific Language Impairment (SLI)

Specific Language Impairment (SLI): a developmental disorder of language in the absence of frank neurological damage, hearing deficits, environmental deprivation, or mental retardation (e.g., Bishop, 1992; Leonard, 1998).

Several factors have complicated efforts to provide a unified theory:
1) Disorder is not limited to language
2) Neural bases of disorder have been relatively ignored
3) Disorder is quite heterogeneous

(Ullman & Pierpont, 2005)

Two Previous Theoretical Frameworks (1)

Grammar-specific deficit:
- Particular aspects only (Clahsen, 1989; Gopnik & Crago, 1991; Ruz, Woods et al., 1995)
- Grammar in general (van der Lely, 1994; Ullman & Gopnik, 1999)

(+) Account for grammatical impairments in SLI
(-) Do not account for
  - broad range of language deficits, including lexical retrieval
  - non-linguistic deficits

Two Previous Theoretical Frameworks (2)

Non-linguistic processing deficit:
- Specific: working memory (Gathercole and Baddeley, 1990; Montgomery, 1995)
  - or temporal processing (Tallal and Piercy, 1978; Tallal, Miller et al., 1993)
- General (Leonard, 1998)

(+) Account for processing deficits
(-) Processing deficits do not necessarily co-occur with linguistic deficits

An Alternative View

Procedural Deficit Hypothesis (PDH): SLI largely explained by abnormalities of brain structures of the procedural memory system (Ullman & Gopnik, 1999; Ullman & Pierpont, 2005).

The PDH can account for much of the SLI data:
- The neural abnormalities in SLI
- The consistency and heterogeneity of the particular linguistic and non-linguistic deficits found in SLI

Procedural Memory System

Brain system implicated in the learning of new, and control of established, motor and cognitive skills, especially those involving sequences and rules.

Composed of a network of brain structures:
1) rooted in left frontal (BA 44/premotor)/basal-ganglia (caudate) circuits
2) also: cerebellum, inferior parietal cortex, and superior temporal cortex

(Squire and Zola, 1998; Schacter & Tulving, 1994; Ullman, 2004)
Procedural Deficit Hypothesis (PDH)

PDH: Many if not most SLI individuals are afflicted with procedural system brain abnormalities that result in grammatical and/or lexical retrieval deficits. These individuals may be characterized as having Procedural Language Disorder (PLD).

Such individuals should also show impairments of the non-linguistic functions that depend on the affected brain structures of the procedural system.

More on the PDH

- SLI heterogeneity: variability in which structures are affected
- But for most PLD: abnormalities to frontal/basal-ganglia, especially Broca’s area & caudate nucleus
- Additional heterogeneity: variability in which channels are affected
- Etiology: diverse, including genetic dysfunction (FOXP2) and early insults (e.g., auto-immune); basal ganglia are highly susceptible
- Compensation by spared declarative memory system:
  - memorize complex forms as chunks (“walked”, “the cat”)
  - learn rules explicitly (“add -ed to verb if event has occurred”)

Procedural Memory System

These brain structures also subserve other functions:

- Specific aspects of language (especially Broca’s area, caudate)
  - Grammar: rule-governed composition, across domains (syntax, morphology, phonology)
  - Lexical retrieval – but not lexical knowledge (declarative memory)
- Dynamic mental imagery – but not static mental imagery
- Working memory
- Rapid temporal processing

Hypotheses PDH vs. Previous

Unlike other explanatory hypotheses of SLI:

- PDH purports to explain a wide range of behavioral and neural data, including not only consistent patterns across SLI, but also some of the heterogeneity
- PDH is a theory about brain as well as behavior
- PDH makes predictions from independent sources of knowledge: our understanding of the brain structures and their functions

PDH Predictions

SLI population: Abnormalities of procedural system brain structures, and impairments of grammar, lexical retrieval, and the non-linguistic functions that depend on these structures, should be common in SLI individuals.

SLI individuals: These brain abnormalities and linguistic and non-linguistic deficits should co-occur within individuals.
**Empirical Evidence**

- **Neural Correlates of SLI**
  - Anatomical studies
  - Event-Related Potential (ERP) studies
- **Behavioral Evidence from SLI**
  - Language studies
    * Grammatical Profile of SLI
    * Lexical Profile of SLI
  - Studies of non-language domains in SLI
    * Functions of the procedural memory system: procedural learning, motor skills, mental imagery, working memory, rapid temporal processing
    * Functions of the declarative memory system

**Neural Correlates:**

**Anatomical Studies**

Converging evidence from structural neuroimaging, metabolic neuroimaging, post-mortem brain examination, and functional neuroimaging.

- Every study that has examined frontal regions or the basal ganglia has reported abnormalities in these structures, especially in Broca’s area and the caudate nucleus.
- Also some evidence for cerebellar abnormalities, and for atypical (a)symmetries in inferior parietal and superior temporal regions.

**ERP Studies**

- **Content words:** (Neville, Coffey, Heksher and Tallal, 1995)
  - normal children: N400s (linked to declarative memory)
  - SLI children: N400s
- **Function words (critical for grammatical processing):** (Neville et al, 1993)
  - normal children: left anterior negativities
  - SLI children: N400-like negativity
- **Musical-rule violations:** (Anteschke, Kodela, Friederici, 2005)
  - normal children: early right anterior negativities (ERAN)
  - SLI children: no ERAN

**Behavioral Evidence:**

**Language: Grammar**

- Syntax: Widespread impairments, in expressive and receptive tasks but sparing of stored aspects of syntax (argument structure)
- Morphology: Widespread impairments but sparing of stored aspects (irregulars vs. regular affixation)
- Phonology: Severe impairments, especially with non-words but repetition of real words much less impaired than of non-words

Compensatory shift to declarative memory.
- use of high-frequency phrases
- frequency effects for regulars
- compounds with regulars as well as irregulars (e.g., rats-eater)

**Language: Lexicon**

Prediction: Lexical tasks spared -- except where they depend on functions that involve the brain structures of the procedural system
- Lexical-semantic organization spared
- Word learning spared except when items presented rapidly or without contextual support
- Receptive lexical tasks spared but expressive lexical tasks (involving retrieval) impaired
- Nouns spared but verbs (may depend more on procedural system) more impaired

**Non-Language:**

**Procedural Learning Deficits**

- Adolescents, diagnosed with SLI in childhood, and age-matched typically-developing controls
- Task: Serial Reaction Time (SRT)

Results:
- SLI subjects showed learning deficit as compared to controls
- Within SLI: grammar-impaired showed learning deficit as compared to non-grammar impaired
- Within SLI: vocabulary-impaired did not show learning deficit as compared to non-vocabulary impaired

(For a summary, see Ullman and Pierpont, 2005)
### Behavioral Evidence: Non-Language: Motor Deficits

- Oral and facial apraxia, of speech and non-speech movements, especially sequences of movements
- Non-facial fine and gross motor impairments, particular for tasks involving complex sequences of movements
- SLI subjects with and without Developmental Coordination Disorder had equivalent motor praxis deficits (Hill, Bishop, Nimmo-Smith, 1998)

(For summaries, see Hill, 2001; Ullman and Pierpont, 2005)

### Behavioral Evidence: Non-Language: Imagery

- Dynamic Mental Imagery (e.g., mental rotation): impaired
- Static Mental Imagery (e.g., imaging static objects): spared

(e.g., Blighfield, 1976; Johnston and Wexman, 1983; Kahmi, 1981; Savich, 1994; see Leonard, 1998; Ullman and Pierpont, 2005)

### Behavioral Evidence: Non-Language: Working Memory Deficits

- Working memory deficits strongly associated with SLI

- Non-word repetition, which is highly dependent on working memory, is notoriously difficult for SLI children
  (Bishop, North et al., 1996; Heston and Comi-Ramadna, 2001; Gathercole and Baddeley, 1993; Kahmi and Catts, 1986; Montgomery, 1995; North, Bishop et al., 2001; Wexman, Tomblin et al., 2006)

- Non-word repetition correlates, across subjects, with performance at tasks probing grammatical processing
  (Bishop, North et al., 1996; Heston & Comi-Ramadna, 2001; Kahmi & Catts, 1986; North, Bishop et al., 2001)

### Behavioral Evidence: Non-Language: Procedural Rapid Temporal Processing Deficits

One of the most common SLI deficits is a difficulty in perceiving a sequence of stimuli presented in rapid succession, or brief stimuli

- Audition: language (e.g., syllables) and non-language (e.g., tones)
- Also found in vision and touch


### Behavioral Evidence: Non-Language: Spared Declarative Memory

Learning in declarative memory is spared:

- Verbal episodic memory spared (Dewey and Wall, 1987)
- Verbal semantic memory spared (Merriam and Libral, 1987)
- Visual episodic memory spared (Williams, Stutt et al., 2000; Dewey and Wall, 1987)

(For discussion, see Ullman and Pierpont, 2005)

### Summary

Brain and behavioral data suggest:

- **Brain:** Abnormalities of procedural system brain structures, especially Broca’s area and the caudate nucleus
- **Language:**
  - Deficits: Compositional aspects of grammar, across domains. Lexical retrieval.
  - Spared: Lexical knowledge
- **Non-Language:**
  - Deficits: Functions depending on procedural system structures
  - Spared: Functions depending on declarative memory
- **PDH**, but not previous hypotheses (deficits of grammar or of non-linguistic processing) can account for this pattern of data