

# 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; Rice, Wexler 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:

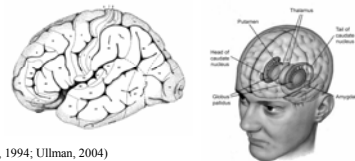
- The neural abnormalities in SLI
- The consistency *and* heterogeneity of the particular linguistic *and* non-linguistic deficits found in SLI

## PROCEDURAL MEMORY SYSTEM

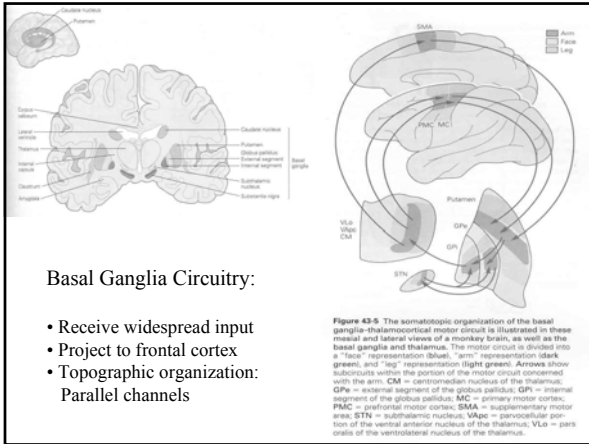
Brain system implicated in the learning of new, and control of established, motor and cognitive skills, especially those involving sequences and rules

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, 1996; Schacter & Tulving, 1994; Ullman, 2004)



## 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

(for review and discussion, see Ullman and Pierpont, 2005)

## 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.

(Ullman & Pierpont, 2005)

## 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")

(Ullman & Pierpont, 2005)

## 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

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

(Ullman & Pierpont, 2005)

## 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

(Frontal: Clark and Plante, 1998; Cohen, Campbell et al., 1989; Denays, Tondeur et al., 1989; Gallagher and Watkin, 1997; Gauger, Lombardino et al., 1997; Jernigan, Hesselink et al., 1991; Kabani, MacDonald et al., 1997; Liegeois, Connelly et al., 2002; Vargha-Khadem, Watkins et al., 1998)  
(Basal Ganglia: Tallal, Jernigan et al., 1994; Vargha-Khadem, Watkins et al., 1998; Jernigan, Hesselink et al., 1991; Watkins, Gadian et al., 1999; Liegeois, Connelly et al., 2002; Ors et al., 2005)

## NEURAL CORRELATES: ERPs

Content words: (Neville, Coffey, Holcomb and Tallal, 1993)

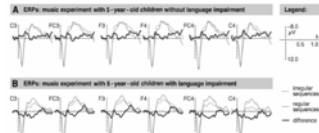
- normal children: N400s (linked to declarative memory)
- SLI children: N400s

Function words (critical for grammatical processing): (Neville et al., 1993)

- normal children: left anterior negativities
- SLI children: N400-like negativity

Musical-rule violations: (Jentschke, Koelsch, 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*)

(For a summary, see Ullman and Pierpont, 2005)

## BEHAVIORAL EVIDENCE: 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

(for a summary, see Ullman and Pierpont, 2005)

## BEHAVIORAL EVIDENCE: 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

(Tomblin et al., in press)

## 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., Inhelder, 1976; Johnston and Weismer, 1983; Kahmi, 1981; Savich, 1984; see Leonard, 1998; Ullman and Pierpont, 2005)

## BEHAVIORAL: NON-LANGUAGE: WORKING MEMORY DEFICITS

- Working memory deficits strongly associated with SLI (Botting and Conti-Ramsden, 2001; Fazio, 1996, 1998; Gathercole and Baddeley, 1993; Kirchner and Klatzky, 1985; Montgomery, 1995, 2000, 2003; Sininger, Klatzky et al., 1989; Weismer, 1996)
- Non-word repetition, which is highly dependent on working memory, is notoriously difficult for SLI children (Bishop, North et al., 1996; Botting and Conti-Ramsden, 2001; Gathercole and Baddeley, 1993; Kahmi and Catts, 1986; Montgomery, 1995; Norbury, Bishop et al., 2001; Weismer, Tomblin et al., 2000)
- Non-word repetition correlates, across subjects, with performance at tasks probing grammatical processing (Bishop, North et al., 1996; Botting & Conti-Ramsden, 2001; Kahmi & Catts, 1986; Norbury, Bishop et al., 2001)

## BEHAVIORAL: 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

(Alcock, Passingham et al., 2000; Fazio, 1998; Kracke, 1975; Tallal and Piercy, 1973; Tallal, Stark et al., 1981, 1985; Tomblin, Abbas et al., 1995)

## BEHAVIORAL: NON-LANGUAGE: SPARED DECLARATIVE MEMORY

Learning in declarative memory is spared:

- Verbal episodic memory spared (Dewey and Wall, 1987)
- Verbal semantic memory spared (Merrit and Liles, 1987)
- Visual episodic memory spared (Williams, Stott et al., 2000; Dewey and Wall, 1997)

(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