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)

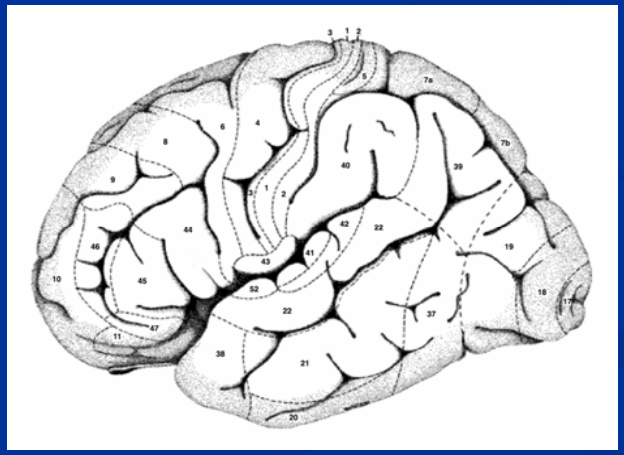
The PDH can account for much of the SLI data:

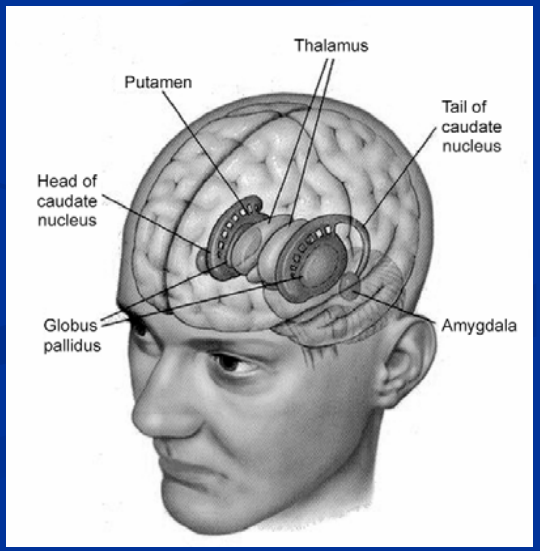
- The neural abnormalities in SLI
- The consistency *and* heterogeneity of the particular linguistic *and* non-linguistic deficits found in SLI

Procedural Memory System

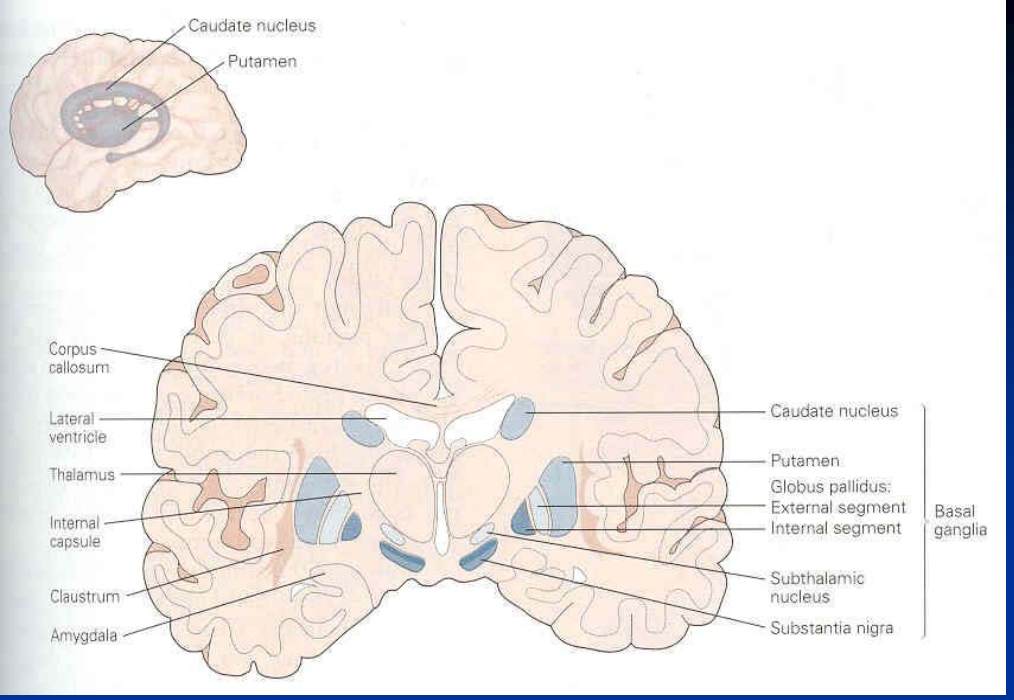
Brain system implicated in the learning of new, and control of established, motor and cognitive skills, especially those involving sequences and rules

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)



Basal Ganglia Circuitry:

- Receive widespread input
- Project to frontal cortex
- Topographic organization: Parallel channels

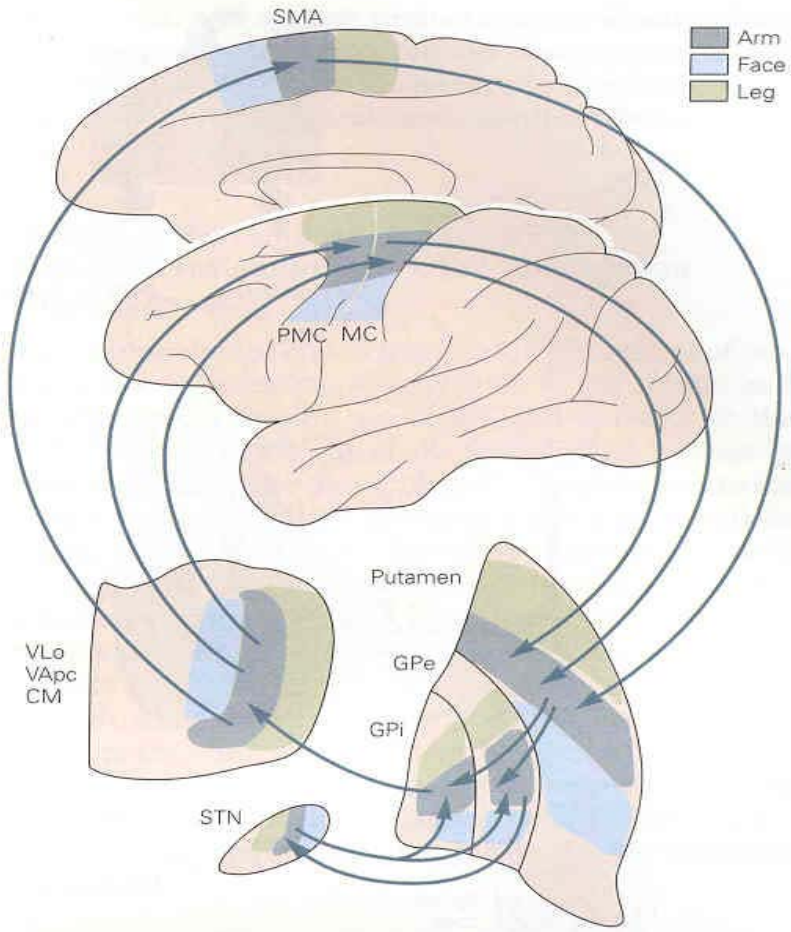


Figure 43-5 The somatotopic organization of the basal ganglia–thalamocortical motor circuit is illustrated in these mesial and lateral views of a monkey brain, as well as the basal ganglia and thalamus. The motor circuit is divided into a "face" representation (**blue**), "arm" representation (**dark green**), and "leg" representation (**light green**). **Arrows** show subcircuits within the portion of the motor circuit concerned with the arm. **CM** = centromedian nucleus of the thalamus; **GPe** = external segment of the globus pallidus; **GPi** = internal segment of the globus pallidus; **MC** = primary motor cortex; **PMC** = prefrontal motor cortex; **SMA** = supplementary motor area; **STN** = subthalamic nucleus; **VApc** = parvocellular portion of the ventral anterior nucleus of the thalamus; **VLo** = pars oralis of the ventrolateral nucleus of the thalamus.

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 *channel*s 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)

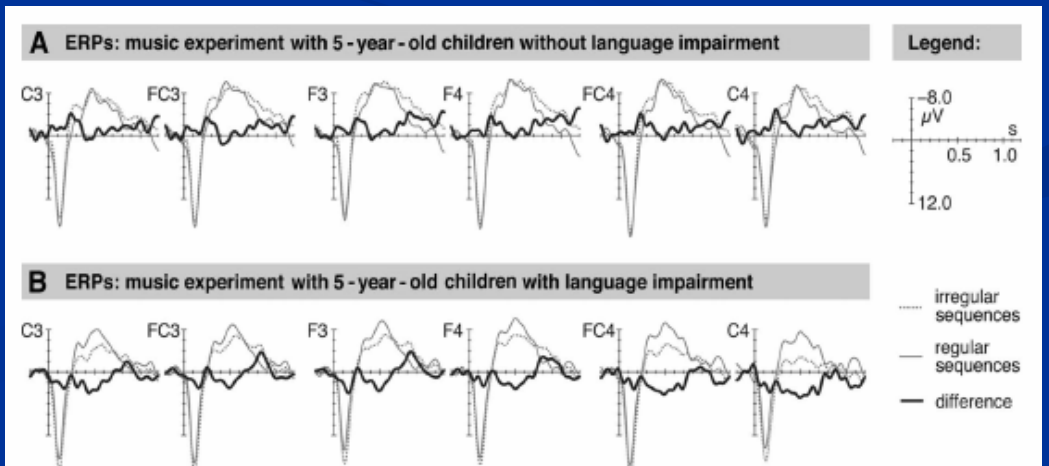
-normal children: left anterior negativities

-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, 1995,200, 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