Statistical Learning in Children with Specific Language Impairment

(Evans, Saffran & Robe-Torres, 2009)

Presented by: Natalia Bila

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Specific Language Impairment (SLI)

Definition: difficulty acquiring and using language in the absence of hearing, intellectual, emotional, or neurological impairments.

Accounts of SLI

Modular: Focus on grammatical impairments

- children with SLI are late in setting specific parameters of their grammatical system
- missing specific grammatical features
- have a representational deficit for dependent relationships

Non-Modular: Auditory perceptual, working memory, and/or speed of processing deficits

Ullman's modular account of SLI

DP Model of language acquisition

Declarative Memory: Mental lexicon

Procedural Memory: Mental grammar

- **SLI may involve impaired procedural learning**

  Evidence: abnormalities in the brain structures

  (Ullman & Gopnik, 1999; Ullman & Pierpont, 2005)

→ **adaptive reliance on declarative memory**

Implicit learning

= learning without awareness

- Includes: procedural motor learning,
  probabilistic learning of categories,
  prototype abstraction,
  statistical learning,
  artificial grammar learning.

- Learning is incremental, unconscious, and expressed through changes in the behavioral response

Related work

→ **Implicit learning might be impaired**

Serial Reaction Time Task (Tomblin et al., 2007)

- Slower learning in SLI (non-linguistic task)
- Different learning curves (SLI: slowed responses prior to the onset of rapid learning)
- grammatical (and not vocabulary) deficits correlated with poor performance

Artificial Grammar Learning (AGL) Task (Plante et al., 2002)

- language/learning disabled college students
- L/LD: showed difficulty in grammar learning (slow RTs, more false positives)

Related work

Ullman: mental lexicon is acquired via declarative memory,

not implicit memory

BUT! creating sound-meaning mappings, learning the phonological structure, and segmenting words from fluent speech is done via **implicit memory**

- implicit learning is critical in the earliest stages word learning

Related work

Statistical learning— discovering patterns of regularities over input (linguistic and non-linguistic)

Saffran et al. (1997):

- children and adults were exposed to fluent speech while performing a cover task
- both groups could learn new words after 21 minutes of exposure
- both groups showed **improvement after double exposure** over 2 days
- there is **individual variability in implicit learning** (scores ranged from 41% to 97%)

Research Questions:

- Can children with SLI implicitly **compute probabilities** of sound sequences?
- Is this ability related to the **degree of exposure**?
- Is the learning domain-specific or **domain-general?**
- How is this ability related to **vocabulary** knowledge?

Hypothesis: SLI includes deficits in domain-general implicit learning abilities

Predictions: poor learning for both speech and matched non-speech stimuli

Experiment 1

Participants

- Children with SLI and normal language controls
- Age ranges: 6.5–14.4 and 8.0–10.11

Study Design

- Listening to artificial language streams
- 21-minute exposure

Variable	SLI (n = 35)			NL (n = 78)			Comparison	
	M	*SD*	Range	*M*	*SD*	Range	*t*(110)	*P*
Age (in months)	115	21	77–172	95	21	67–154	4.15	< .001*
Leiter–Nonverbal IQ[a]	97	8	87–119	109	10	85–139	6.70	< .001*
CELF-3 ELS[b]	71	11	50–84	109	12	86–150	10.69	< .001*
CELF-3 RLS[c]	68	14	50–98	N/A	N/A	N/A		
PPVT-III[d]	89	11	66–112	109	11	87–135	8.91	< .001*
EVT[e]	81	9	61–109	104	10	85–124	11.56	< .001*

Note. For each variable, age-scaled scores have a mean of 100 and an *SD* of 15. IQ = intelligent quotient; N/A = not applicable.

[a] Leiter International Performance Scale (Roid & Miller, 1997).

[b] CELF-3 ELS = Clinical Evaluation of Language Fundamentals–3: Expressive Language score (Semel et al., 1995).

[c] CELF-3: RLS = Clinical Evaluation of Language Fundamentals–3: Receptive Language Score (Semel et al., 1995).

[d] PPVT-III = Peabody Picture Vocabulary Test, Third Edition (Dunn & Dunn, 1997).

[e] EVT = Expressive Vocabulary Test (Williams, 1997).

Stimuli

Words	Nonwords
dutaba (1.0)	batipa
tutibu (.75)	bidata
pidabu (.65)	dupitu
patubi (.50)	pubati
bupada (.42)	tapuba
babupu (.37)	tipabu

transitional probabilities

within the words - 0.37-1

between the words - 0.1-0.2

Task

- children drew pictures while listening to a continuous speech stream in the background

Test: forced-choice paradigm

e.g.: com-pu-ter vs. pu-ter-com

Experiment 1: Results

	SLI group	Control group
word learning	at chance	above chance
correlation with: - vocabulary	✗	✓ expressive and receptive
- age	✗	✓
- nonverbal IQ	✗	✗

Key question:

Are children with SLI unable to track statistical patterns due to **limited exposure** or inherent **inefficiency**?

Experiment 2

2a

- do children with SLI require greater exposure to the input to discover word boundaries?
- artificial language

2b

- how domain-specific are the learning impairments in SLI?
- tone language

Exposure duration: 42 min (instead of 21 minutes in Experiment1)
Participants: 30 children (8-10 y.o.) from Experiment 1
Controls: Matched for age and nonverbal IQ
Interval: 10-14 days between 2a and 2b

Experiment 2b

Tone words	Nonwords
GG#A (1.0)	AC#E
CC#D (.75)	F#G#E
D#ED (.65)	GCD#
FCF# (.50)	C#BA
DFE (.42)	C#FD
ADB (.37)	G#BA

- 11 pure tones
- Transitional probabilities

withing words :0.25–1.00;

between words: 0.05–0.60

- 7-minute continuous stream of tones

Experiment 2: Results

2a

- do children with SLI require greater exposure to the input to discover word boundaries?

SLI ✓ (5 words)

Controls ✓ (all 6 words)

- SLI group performance correlated with receptive vocabulary

2b

- how domain-specific are the learning impairments in SLI?

SLI ✗ (1 ‘word’)

Controls ✓ (5 ‘words’)

Experiment 2: Observations

SLI group performance:

1) above-chance (n=10) : 5 words
2) below or at chance (n=5): 2 words

How do these groups differ?

2a: higher nonverbal IQ (insignificant correlation)

2b: unclear

- **increased exposure** to the speech stimuli in Experiment 2a played a key role in the performance of the children with SLI
- unlearned sequences **did not depend on transitional probabilities**

  → word representations may be phonologically underspecified

Discussion

- Statistical learning appears to be a domain-general ability in normal developing children.
- **Statistical Learning in SLI:**

  worse performance in both linguistic and non-linguistic tasks;

  more sensitive to input features.
- **Increased exposure helps** children with SLI improve, but their performance remains less effective compared to normal developing peers.
- **Individual differences:** working memory capacity and selective auditory attention.

Key Takeaways

- Some aspects of vocabulary learning are also supported by the **implicit system.**
- Poor implicit learning may be one of the factors that cause SLI.
- Implicit learning abilities differ based on exposure, domain, and individual differences.