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SLI - A Domain Specific or Domain General Implicit Learning Deficit?

Modality-Constrained Statistical Learning of Auditory and Perceptual Motor Sequences in SLI

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Abstract
Impaired implicit procedural learning has recently been proposed as an account Specific Language Impairment (SLI). Implicit learning is not a single construct however, but a multifaceted phenomenon that is supported by a complex set of different cortical networks. Research suggests that the implicit learning impairments seen in SLI may be more domain-general than domain-specific and involve more than just the perceptual motor sensory system.

To investigate this question, a group of 28 children (ages 11.0 – 18), half with SLI and half serving as age/IQ controls, participated in two studies where statistical artificial grammar learning was compared in the auditory and perceptual motor modalities using the same underlying finite-state grammar. Both groups had less difficulty learning the perceptual motor sequences whereas the SLI group had greater difficulty than the CA group with implicit learning in the auditory modality. The SLI group also appeared to attend to qualitatively different aspects of the input stimuli as compared to the CA group in both modalities.

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Questions

1. Is implicit learning in auditory and perceptual motor modalities the same for SLI and NL controls?
2. Is implicit learning in auditory and perceptual motor modalities related to syntax comprehension in SLI and NL adolescents?

Declarative versus Implicit Memory-Learning

Declarative

- Rapid; single trial learning of "episodes" or experiences (episodic) and "meanings" (semantic); easily expressed verbally.

Implicit

- Gradual; occurs slowly over many trials or exemplars; expressed through performance; not available to conscious access. (*Knowlton & Squire, 1996*)
- Defined by a collection of different abilities.
 - Procedural Learning (*Cleeremans, 1993*)
 - Probabilistic Category Learning (*Ashby & Maddox, 2005*)
 - Statistical Sequential Learning (*Saffran, Newport, Aslin, 1996*)
 - Artificial Grammar Learning (*AGL; Reber, 1967*)
- Debate whether knowledge learned implicitly is abstract, domain general and independent of stimulus features, or domain specific and not transferable from one modality to another.
- Recent research suggests, knowledge learned implicitly is modality constrained and not transferable for typical adults. (*Conway & Christensen, 2005*)

Implicit Learning in SLI

Implicit learning impairments seen in SLI on a range of different tasks/modalities.

1. **Procedural Motor Learning:** SLI need more exposure trials than NL to learn; have qualitatively different learning curves. (*Tomblin, Mainela-Arnold, Zang, 2007; Lum, et al., 2010*)
2. **Auditory Statistical Learning:** SLI require double the exposure of NL controls to discover word boundaries. (*Evans, Saffran, Robe, 2009*)
3. **Auditory AGL:** Unlike NL controls, adults with SLI show no evidence of learning after same number of exposure trials. (*Plante, Gomez, Gerkin, 2002*)

Implicit Learning and Language SLI

Ullman proposes that grammar is learned via brain structures that support implicit procedural learning, and that Procedural Learning Deficits are the cause grammar deficits in SLI. (*Ullman & Pierpont, 2005*)

1. **Procedural Learning related to grammar knowledge in SLI** (*Tomblin, Mainela-Arnold, Zang, 2007*)
2. **Auditory Statistical Learning related to vocabulary knowledge in SLI** (*Evans, Saffran, Robe, 2009*)

Method

Participants. Twenty eight (11;0-18;0), right-handed adolescents, normal hearing, no head injury; all participants in longitudinal language study since elementary school; SLI (n=14) known history of specific language impairments; CA/IQ (n=14) no history of speech/language impairments.

Age Mos.	Leiter ¹ NV	Leiter FG ²	Leiter RP ³	Leiter SO ⁴	NEPSY IMIT ⁵	NEPSY SEQ ⁶
X(SD)	SS (SD)	SS (SD)	SS (SD)	SS (SD)	RS (SD)	RS (SD)
SLI 198 (24)	103 (15)*	10 (3)	10 (2)**	11 (3)	22 (2)**	44 (7) **

¹ Nonverbal IQ Leiter International Performance Scale-Revised (Leiter-R), (Leiter-R; Roid & Miller, 1997)

² Figure Ground Subtest (Leiter-R; Roid & Miller, 1997)

³ Repeated Patterns Subtest (Leiter-R; Roid & Miller, 1997)

⁴ Sequential Order Subtest (Leiter-R; Roid & Miller, 1997)

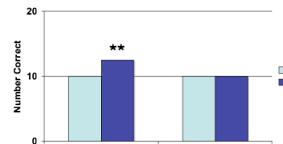
⁵ Imitating Hand Positions NEPSY: A Developmental Neuropsychological Assessment. Kirkman, Kirk, Kemp, (2007).

⁶ Manual Motor Sequences NEPSY: A Developmental Neuropsychological Assessment. Kirkman, Kirk, Kemp, (2007).

*p < .05, **p < .01

Results

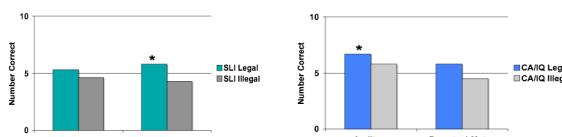
Auditory and Perceptual Motor Finite Grammar Learning (AGL)



Significant (Modality x Group) Interaction ($p < .04$)

- No Main effect of Modality or Group
- SLI no greater than chance (Auditory or Motor)
- CA/IQ significantly greater than chance Auditory ($p < .001$)

Legal & Illegal Sequences (Auditory, Perceptual Motor)



- SLI: Legal Sequences significantly greater than chance Motor ($p < .04$)
- CA/IQ: Legal Sequences significantly greater than chance Auditory ($p < .02$)

Method (cont)

Procedure

As part of larger on-going study, adolescents completed Sentence Comprehension Task (TAPS, Montgomery & Evans, 2009) and AGL Implicit Learning tasks.

AGL Training.

- Participants told they were going to learn a spy code.
- Presented with legal pairs of sequences generated from the finite state grammar (Fig.1) and asked to decide if the sequences in each pair were same/different.
- Twelve pairs presented six times in random order for a total of 72 exposures.

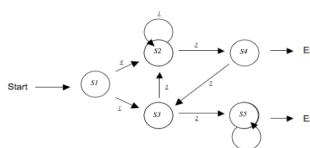
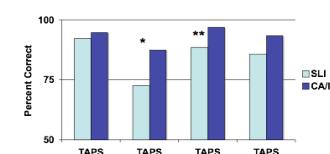


Figure 1. Finite State Grammar (Gómez & Gerkin, 1999)

Results



- SLI less accurate in comprehending Passives ($p < .01$) and Reflexives ($p < .03$) as compared to CA/IQ controls.

AGL and Syntax Comprehension:

SLI

Table 2. Correlations between Leiter Subtests, NEPSY Manual Subtests, AGL Auditory, Motor, TAPS for SLI group

Leiter	Fig Grid	Rep Pat	Seq Ord	Hand Limit	Manual Seq	AGL	
						Aud	Motor
Figure Ground						.42*	
Repeated Sequences						.47**	.16
Sequential Order							
NEPSY							
Hand Imitation						.002	.42
Manual Sequences						.59***	.56
AGL						.14	.22
Auditory						.12	.25
Motor						.12	.25
TAPS						.12	.25
Simple						.14	.25
Passives						.26	.25
Reflexives						.24	.24
Pronouns						.17	.17

* p < .05 (1-tailed), * p < .01 (1-tailed), ** p < .005 (1-tailed), *** p < .001 (1-tailed)

CA/IQ

Table 3. Correlations between Leiter Subtests, NEPSY Manual Subtests, AGL Auditory, Motor, TAPS for CA/IQ group

Leiter	Fig Grid	Rep Pat	Seq Ord	Hand Limit	Manual Seq	AGL	
						Aud	Motor
Figure Ground						.12	
Repeated Sequences						.43*	.57**
Sequential Order							
NEPSY							
Hand Imitation						.13	.67***
Manual Sequences						.59**	.35
AGL						.07	.13
Auditory						.16	.21
Motor						.16	.17
TAPS						.28	.28
Simple						.34	.34
Passives						.26	.26
Reflexives						.23	.23
Pronouns						.17	.17

* p < .05 (1-tailed), * p < .01 (1-tailed), ** p < .005 (1-tailed), *** p < .001 (1-tailed)

Summary

- Implicit Learning in Auditory and Perceptual Motor modalities, and relationship to syntax comprehension qualitatively for SLI and CA/IQ matched controls.
- SLI better at correctly classifying Legal Perceptual motor sequences; CA/IQ better at correctly classifying Legal Auditory sequences - Procedural Learning better for SLI?
- AGL and syntax comprehension:
 - No relationship in SLI group
 - For CA/IQ, Passives and Reflexives significantly correlated with AGL auditory; Pronouns significantly correlated with AGL auditory.
- For SLI, comprehension significantly correlated with Manual Motor Sequence abilities (NEPSY), and Sequential Order and Pattern Repetition Recall (Leiter).
- Future research needs to examine modality differences in implicit learning in SLI and NL and the relationship between Procedural Learning and Grammar knowledge.