

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; occur 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 & Christiansen, 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 ¹ FG ²	Leiter ¹ RP ³	Leiter ¹ SO ⁴	NEPSY ⁵ IMIT ⁵	NEPSY ⁵ 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)**
CAIQ	187(22)	113 (9)	11 (2)	12 (2)	12 (2)	24 (1)	52 (6)

¹Nonverbal IQ Leiter International Performance Scale-Revised (Leiter-R), (Leiter-R; Roid & Miller, 1997)
²Figure Ground Subtest (Leiter-R; Roid & Miller, 1997)
³Repeated Patterns Subtest (Leiter-R; Roid & Miller, 1997)
⁴Sequential Order Subtest (Leiter-R; Roid & Miller, 1997)
⁵Imitating Hand Positions NEPSY: A Developmental Neuropsychological Assessment. Korkman, Kirk, Kemp, (2007).
⁶Manual Motor Sequences NEPSY: A Developmental Neuropsychological Assessment. Korkman, Kirk, Kemp, (2007).
 * p < .05, ** p < .001

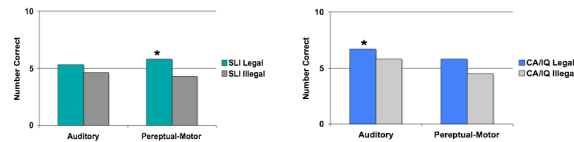
Results

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)
- CAIQ significantly greater than chance Auditory (p < .001)

Legal & Illegal Sequences (Auditory, Perceptual Motor)



- SLI: Legal Sequences significantly greater than chance Motor (p < .04)
- CAIQ: 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.

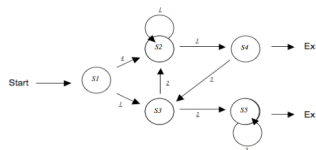
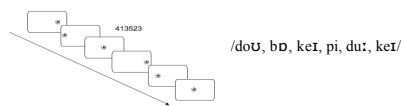


Figure 1. Finite State Grammar (Gómez & Gerkin, 1999)

Stimuli

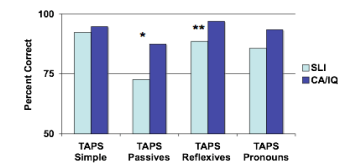
- **Perceptual motor:** Participants touched a soccer ball on a TouchScreen
- **Auditory:** Participants heard sequences of novel words via headphones



AGL Test.

- Total of 20 novel sequences (10 legal, 10 illegal) from same finite state grammar.
- Participants presented with novel sequences one at a time and asked to decide if novel sequences were part of the spy code.

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 Letter Subtests, NEPSY Manual Subtests, AGL Auditory, Motor, TAPS for SLI group

	Letter				NEPSY		AGL	
	Fig Grnd	Rep Pat	Seq Ord	Hand Imit	Manual Seq	Aud	Motor	
Letter Figure								
Ground Repeated Sequences	.42*							
Sequential Order	.47**	.16						
NEPSY Hand Imitation	.002	.42	-.39					
Manual Sequences	.59***	.56	.366	.18				
AGL Auditory	-.14	.22	-.12	.52***	.07			
Motor	.122	.017	-.15	.22	.05			
TAPS Simple	-.14	.24	.56***	-.19	.006	-.07	-.25	
Passives	-.05	.67**	.36	.29	.46**	-.15	-.17	
Reflexives	.25	.45**	.25	.21	.20	.12	-.19	
Pronouns	.03	.23	.55**	.38	.17	-.01	-.06	

*p < .06 (1-tailed), ** p < .05 (1-tailed), *** p < .01 (1-tailed)

CAIQ

Table 3. Correlations between Letter Subtests, NEPSY Manual Subtests, AGL Auditory, Motor, TAPS for CAIQ group

	Letter				NEPSY		AGL	
	Fig Grnd	Rep Pat	Seq Ord	Hand Imit	Manual Seq	Aud	Motor	
Letter Figure								
Ground Repeated Sequences	-.12							
Sequential Order	.43*	.57**						
NEPSY Hand Imitation	-.13	.67***	.22					
Manual Sequences	.59**	.35	.34	.34				
AGL Auditory	-.07	.13	.38 ¹	.05	-.13			
Motor	-.09	-.16	-.21	-.16	-.17			
TAPS Simple	.28	.14	.34	.02	.17	.38 ¹	-.07	
Passives	-.23	.28	.04	.26	-.10	.36 ¹	-.58**	
Reflexives	-.26	-.06	-.26	-.23	-.24	-.13	.51**	
Pronouns	-.06	.17	.1	.28	-.2	.43* ²	.29	

¹p = .08 (1-tailed), ²p < .06 (1-tailed), * p < .05 (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 motor; 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.