

## BACKGROUND

There is partial overlap in the structural language abilities observed in a subgroup of children with Autism Spectrum Disorders (ASD+LI) and in children with Specific Language Impairment (SLI) (e.g., Kjelgaard & Tager-Flusberg, 2001; Lindgren et al., 2009). Whether these similarities arise from a shared etiology has been hotly debated (e.g., Taylor et al., 2014; Whitehouse et al., 2008; Williams, Botting, & Boucher, 2008).

Deficits in procedural/implicit learning and memory have been proposed as a mechanism contributing to language impairment, separately, for ASD (Romero-Munguía, 2008; Ullman, 2004) and SLI (Ullman & Pierpont, 2005). No study has directly compared ASD+LI and SLI on the same implicit learning task.

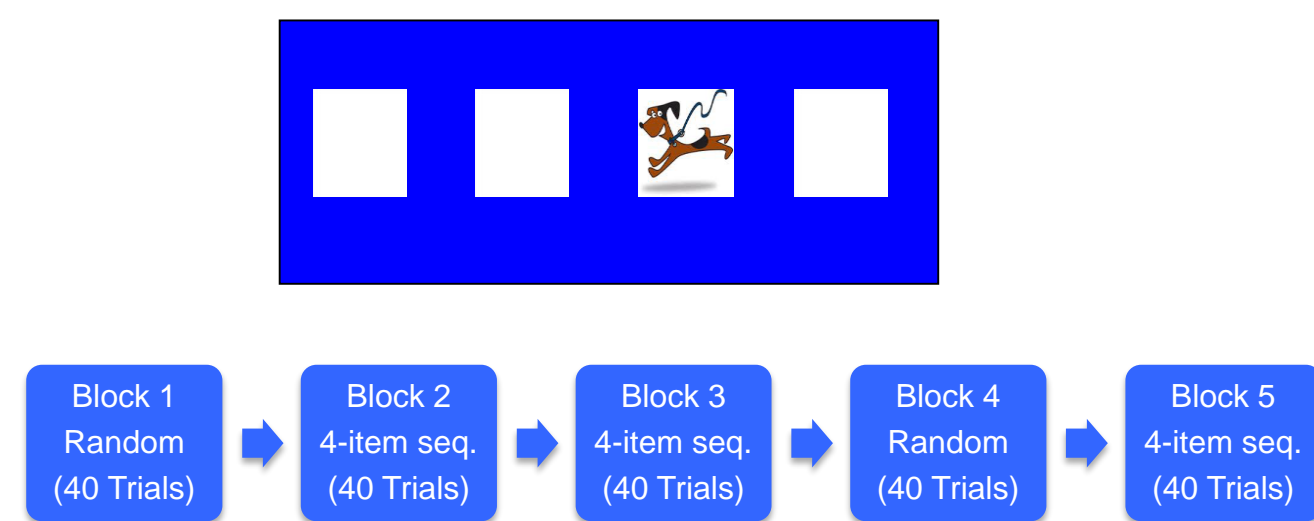
Only two studies have examined implicit learning in children with ASD+LI. Gordon & Stark (2007) reported that they were able to learn 4-step visual sequences when given 6 times the exposure as TD children of the same age. Klinger & Dawson (2001) found deficits in implicit category formation.

Previous studies have generally shown impaired visual sequence learning in children with SLI compared to TD peers (Hsu & Bishop, 2014; Lum et al., 2012; Tomblin et al., 2007), yet a few studies found intact abilities (Gabriel, Meulemans, et al., 2013; Lum & Bleses, 2012).

## RESEARCH OBJECTIVES

- To investigate implicit learning abilities in children with ASD+LI or with SLI in comparison to TD children of similar age and NVIQ
- To clarify whether proposed implicit learning deficits are shared across children with ASD+LI and children with SLI

## Visual implicit sequence learning



**Serial Reaction Time task (SRT; Thomas & Nelson, 2001).** Participants press a button on a response box that corresponds to the location of a dog. Unbeknownst to the child, on some blocks of the experiment, the dog follows a repeating 4-step-sequence and on others movement is random.

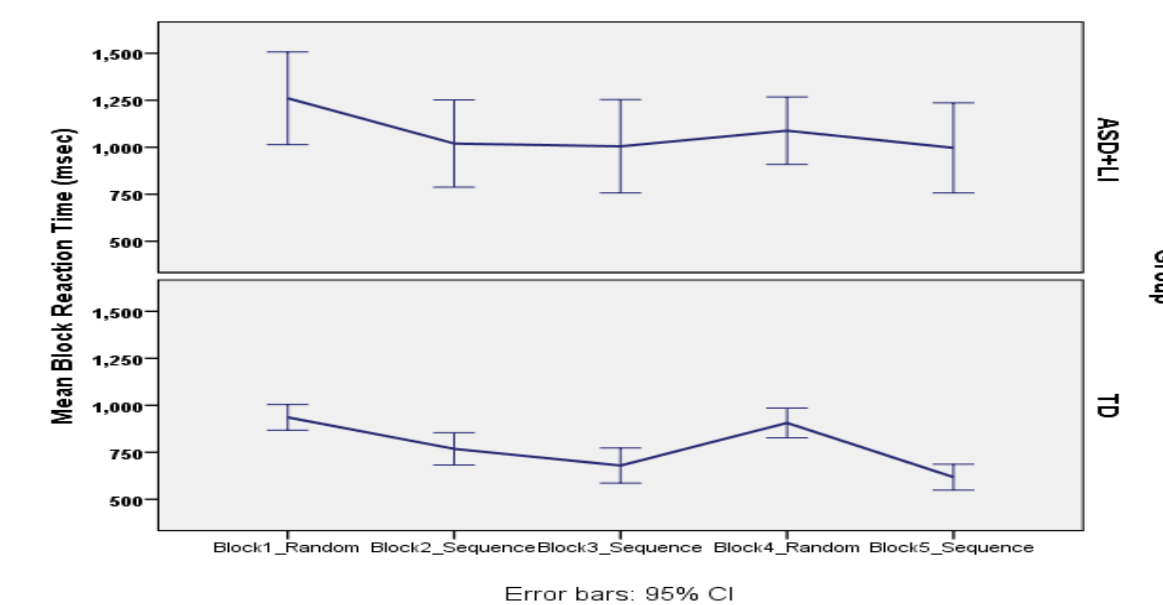
Sequence learning is indicated by significantly faster reaction times in block 5 (sequence) relative to block 4 (random). This was measured by a **sequence learning score** (mean of block 4 – mean of block 5)/(mean of block 4 + mean of block 5).

After the task we asked participants if they had noticed a pattern that helped them “catch the dog” and to replicate it, providing a measure of **explicit knowledge of the sequence**.

## ASD+LI vs. TD

Characteristics	ASD+LI (n=19)	TD (n=19)	p-value
CA (Y.M)	8.05 (1.3) 6 - 10	7.5 (.9) 6 - 9.8	.07
NVIQ (Leiter-3)	101.47 (14.4) 83 - 141	107.26 (1217) 95 - 148	.19
<sup>1</sup> CELF-4 Recalling Sentences	3.74 (1.97) 1 - 7	10.95 (2.53) 8 - 16	<.01
PPVT Receptive vocabulary	82.89 (12.2) 59 - 113	114.16 (17.48) 85 - 150	<.01
<sup>2</sup> Phonological awareness	-.76 (1.27)	.12 (.88)	.02

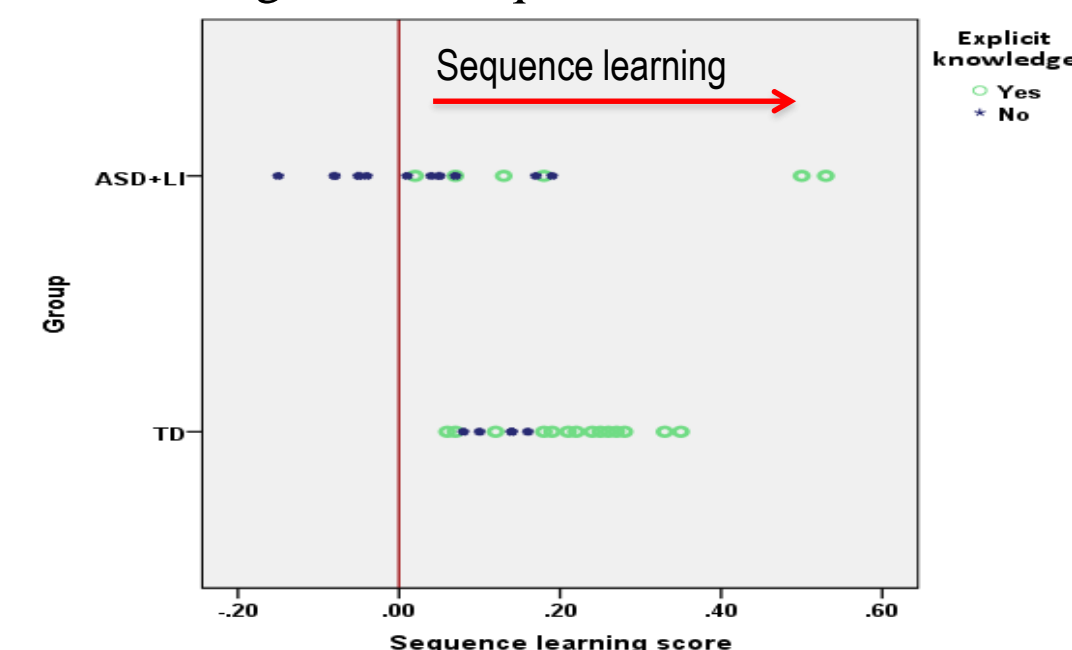
<sup>1</sup> Language impairment was defined by scores of at least 1SD below the mean/ 7 or below (Thordardottir et al., 2011; Tomblin & Zhang, 1999) on this subtest (CELF-4; Semel, Wiig, & Secord, 2003).  
<sup>2</sup> Phonological awareness was measured by the *Auditory Analysis Test* (Rosner & Simon, 1971). Z scores were calculated on accurate phoneme or syllable omissions in this task. Negative scores indicate lower number of correct omissions than the mean score of the control TD group.



The **sequence learning score** in the ASD+LI group ( $M = 0.08$ ) was significantly lower than in the TD group ( $M = 0.19$ ),  $t(36) = -2.41$ ,  $p = .02$ ,  $r = 0.37$ , demonstrating **less sensitivity to the change from random to sequence blocks in ASD+LI**.

The TD group responded significantly faster on block 5 than 4 ( $t(18) = 9.34$ ,  $p < .01$ ,  $r = .91$ ). The ASD+LI group did not ( $t(18) = 1.57$ ,  $p = .12$ ,  $r = .34$ ), **indicating that the TD group learned the sequence while the ASD+LI group did not**.

Reliably more TD children (14 of 19) than ASD children (6 of 19) demonstrated explicit knowledge of the sequence. Only ASD participants who demonstrated implicit learning also showed explicit knowledge of the sequence.



## DISCUSSION

Our findings demonstrate impaired implicit learning of even very short sequences in ASD+LI. Based on Gordon & Stark (2007) increased exposure to 4-step sequences (144 repetitions x 6 days) would result in eventual learning.

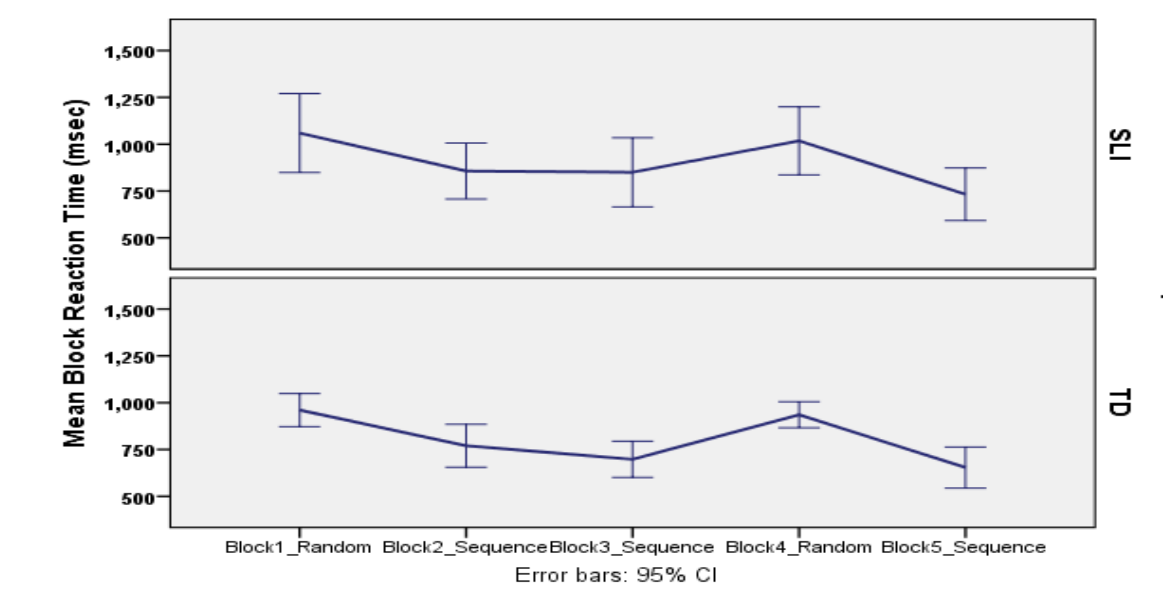
The relationship between implicit and explicit measures suggest that the task taps implicit learning, but this becomes explicit knowledge by the end of the task for some participants.

Our results confirm proposed implicit learning deficits in children with ASD+LI (Romero-Munguía, 2008; Ullman, 2004).

## SLI vs. TD

Characteristics	SLI (n=14)	TD (n=14) <sup>1</sup>	p-value
CA (Y.M)	7.2 (1.2) 5 - 9	7.2 (.11) 6.1 - 8.8	.93
NVIQ (Leiter-3)	105.07 (7.8) 92 - 125	105.07 (6.74) 95 - 120	.95
<sup>2</sup> CELF-4 Recalling Sentences	4.86 (2.21) 1 - 7	11 (2.15) 8 - 14	<.01
PPVT Receptive vocabulary	95.36 (18.16) 76 - 146	109.21 (13.47) 85 - 142	.03
Phonological awareness	-1.12 (.89)	.1 (.84)	<.01

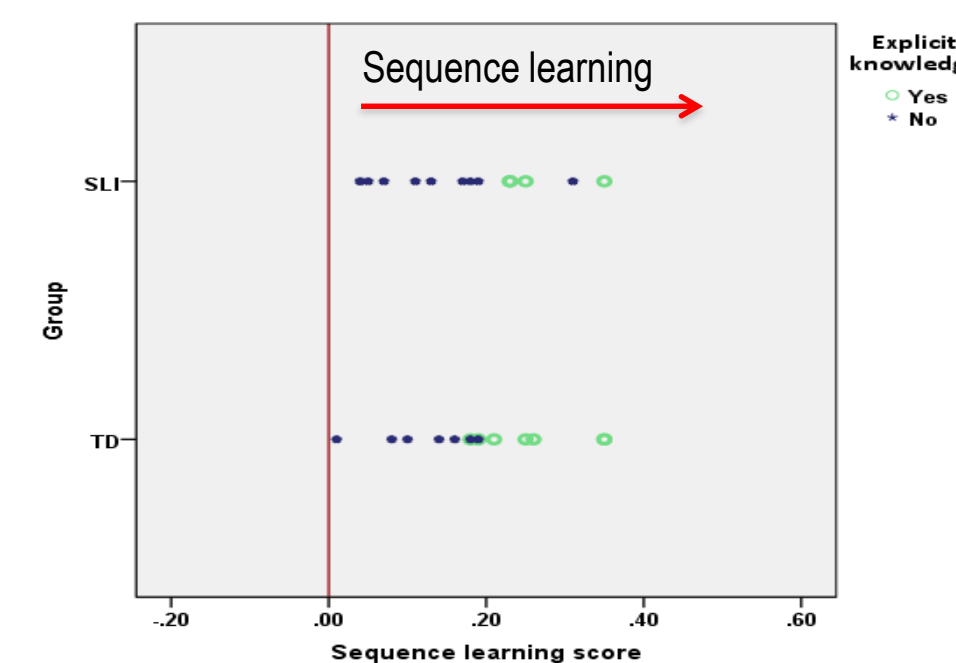
<sup>1</sup> Typically-developing children were selected to match SLI participants and were not identical to the sample in the previous panel.  
<sup>2</sup> Language impairment was defined by scores of at least 1SD below the mean/ 7 or below (Thordardottir et al., 2011; Tomblin & Zhang, 1999) on this subtest (CELF-4; Semel, Wiig, & Secord, 2003).



Similar **sequence learning scores** were observed in the SLI group ( $M = .17$ ) and the TD group ( $M = .19$ ),  $t(26) = .58$ ,  $p = .57$ ,  $r = .11$ ; they were **both sensitive to the change from random to sequence blocks**.

Both **the SLI group** ( $t(13) = 16.31$ ,  $p < .001$ ) and **the TD group** ( $t(13) = 8.65$ ,  $p < .001$ ) responded significantly faster on block 5 than 4 indicating that they **both learned the sequence**.

Similar proportions of children in the SLI group (4 of 14) and the TD group (7 of 14) showed explicit knowledge of the sequence. While all children demonstrated implicit learning, those with higher **sequence learning scores** were those who also demonstrated explicit knowledge of the sequence.



## DISCUSSION

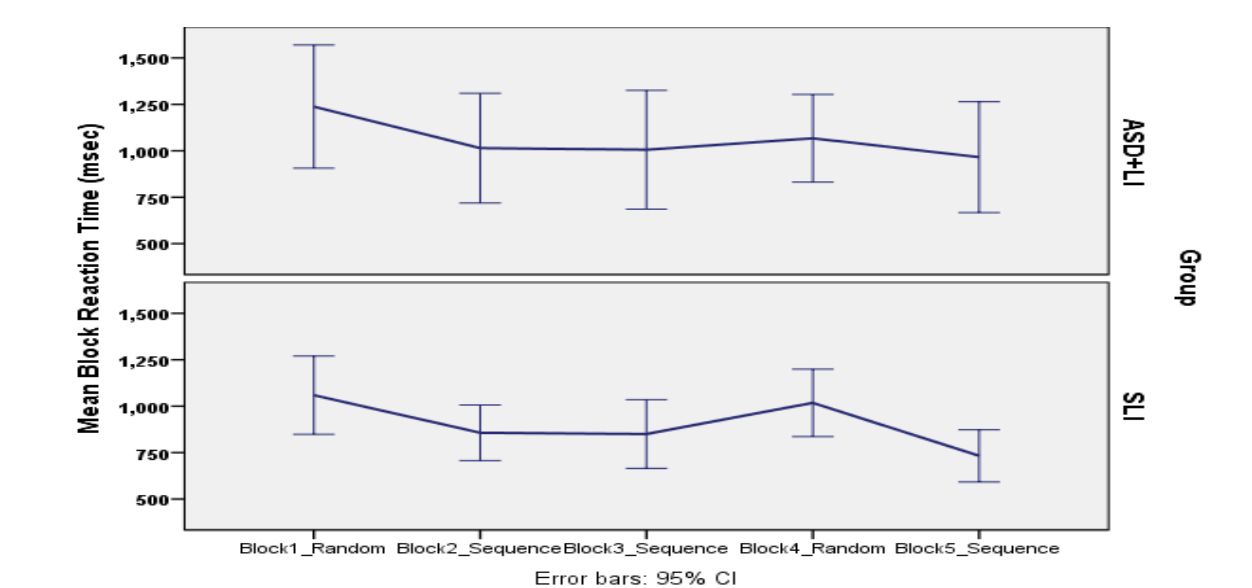
Our findings of 4-step sequence learning are in line with studies showing intact implicit learning in SLI of 8-step sequences that were repeated 8 times over 12 blocks (e.g., Gabriel et al., 2011). However, several studies indicate impaired 10-step sequence learning in children with SLI (e.g., Tomblin et al., 2007; Lum et al., 2010).

Taken together, there is support for intact implicit learning of shorter sequences (4- to 8-step) in SLI, with impairments appearing for longer (10-step) sequences with out extended exposure.

## ASD+LI vs. SLI

Characteristics	ASD+LI (n=14) <sup>1</sup>	SLI (n=14)	p-value
CA (Y.M)	8 (1.3) 6 - 9	7.2 (1.2) 5 - 9	.09
NVIQ (Leiter-3)	102.79 (9.7) 91 - 123	105.07 (7.8) 92 - 125	.5
CELF-4 Recalling Sentences	3.50 (2.03) 1 - 6	4.86 (2.21) 1 - 7	.1
PPVT-Receptive vocabulary	83.85 (13.69) 59 - 113	95.36 (18.16) 76 - 146	.08
Phonological awareness	-.57 (1.26)	-1.12 (.89)	.20

<sup>1</sup> Due to matching procedures the sample of ASD+LI is not identical to that in the first comparison.



Larger **sequence learning scores** were observed in the SLI group ( $Mdn = .18$ ) than in the ASD+LI group ( $Mdn = 0.05$ ),  $U = 52.5$ ,  $p = .04$ ,  $r = -0.4$ , demonstrating **less sensitivity to the change from sequence to random blocks in ASD+LI**.

The **SLI group** responded significantly faster on block 5 than 4, indicating that they **learned the sequence** ( $T = 0$ ,  $p < .001$ ,  $r = .88$ ) **while the ASD+LI group did not** ( $T = 30$ ,  $p = .17$ ,  $r = .27$ ).

Similar proportions of children with ASD+LI (5 of 14) and SLI (4 of 14) showed explicit knowledge of the sequence.

## IMPLICATIONS

The **current findings reveal impaired implicit learning of short sequences in ASD+LI in contrast with intact learning in SLI, despite similar NVIQ and language skills and age**.

This difference in implicit learning ability supports the position that ASD+LI and SLI do not share etiology (e.g., Williams et al., 2013, Whitehouse et al., 2008) despite overlap in language skills.

Domain-general implicit learning contributes to language acquisition in the typical case (Kidd, 2012; Shafto, Conway, Field, & Houston, 2012) and may contribute to the language impairment in ASD+LI (Ullman, 2004). If implicit learning contributes to language impairment in SLI it appears to be in a more subtle way than for ASD+LI.

Our measure of implicit learning did not correlate with any language measures, but future work should compare implicit learning with performance on dynamic tasks of phonological or syntactic learning. Previous studies have found relationships between implicit visual sequence learning and performance on phonological awareness (Tomblin et al., 2007) and grammar in children with SLI (Hedenius et al., 2011; Sengottuvel & Rao, 2013).