Multimodal Statistical Learning in Children with Autism Spectrum Disorder

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Introduction

- Statistical learning (SL), the ability to detect and extract regularities from inputs, plays a key role in language development in typically developing children (TD) (Saffran et al., 1996).
- SL has been proposed as one mechanism for language impairment in Autism Spectrum Disorders (ASD) (Walenski et al., 2006).
- However, individuals with ASD were found to perform similarly, worse, or even better than TD in previous SL studies (Arciuli & Conway, 2018).
- Furthermore, SL, traditionally considered as a domain-general ability, is recently suggested to vary across stimuli types (Siegelman & Frost, 2015).
- Whether SL in specific domains relates to language impairment in ASD remains unknown.

Current Study:
Does sensitivity to statistical information in linguistic and non-linguistic domains differ in TD vs. ASD?

Overall Procedure

Familiarization
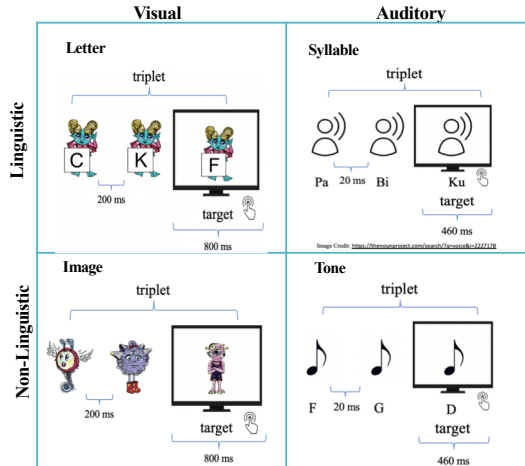
- Experiments are hosted on https://cogscigame.co
1. **Grammaticality Judgment Task** (Rice, Hoffman & Wexler, 2009)
2. **SL task:**
   - Familiarization phase:
     - Target detection cover task
     - Each triplet is repeated 24 times in Visual and 48 times in Auditory
     - Reaction time collected through keypress before, on, or after target
   - Testing phase:
     - 32 trials of two-alternative forced choice (accuracy collected)
     - 4 foils for each triplet

Statistical Learning in TD vs. ASD

Participant Demographics

	TD N = 21	ASD N = 31	P
Sex (Female/Male)	13/8	11/20	0.11
	Mean (SD)	Mean (SD)	P
Age	9.29 (2.09)	8.42 (2.21)	0.16
SCQ	2.21 (1.58)	19.44 (8.58)	<0.001***

SCQ: Social Communication Questionnaire

Mixed-level modeling on Accuracy

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	-0.37	0.17	41.30	-2.14	0.04
GroupTD	**0.93**	**0.29**	**42.82**	**3.24**	**0.002****
Syllable	0.20	0.21	40.90	0.94	0.35
Image	0.21	0.18	39.60	1.16	0.25
Tone	0.25	0.24	44.99	1.05	0.30
GroupTD:Syllable	-0.38	0.37	46.02	-1.02	0.32
GroupTD:Image	-0.57	0.30	42.66	-1.89	0.07
GroupTD:Tone	-0.61	0.40	45.43	-1.53	0.13
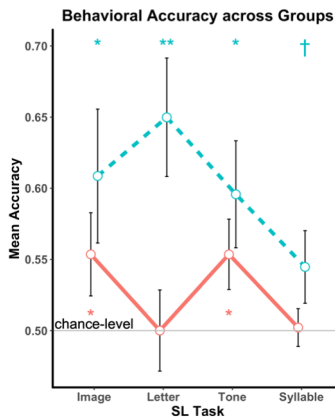
One-tailed †p < 0.08; * p < 0.5, ** p < 0.01, *** p < 0.001;
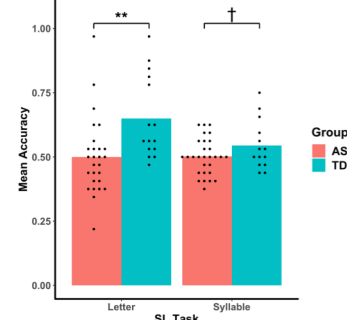
Mean Accuracy	TD	P	ASD	P	TD vs. ASD
Image	0.61 (0.19)	0.017*	0.55 (0.15)	0.039*	0.16
Letter	0.65 (0.16)	0.0015**	0.50 (0.15)	0.50	0.0031**
Tone	0.60 (0.15)	0.011*	0.55 (0.13)	0.020*	0.47
Syllable	0.54 (0.10)	0.052†	0.50 (0.07)	0.44	0.077†

Summary:
- TD are above chance across domains. **ASD are only above chance for non-linguistic SL.**
- TD have higher accuracy than ASD in linguistic (**Letter** and **Syllable**) SL.

Online Measure:
Reaction Time Slope = Scaled Reaction Time/ Number of Hit Trials

Linear Mixed-Effects Model:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.00	0.01	40.54	0.46	0.65
GroupTD	-0.03	0.02	40.78	-1.61	0.12
Syllable	-0.01	0.01	41.12	-1.26	0.22
Image	-0.01	0.01	40.89	-1.21	0.23
Tone	-0.01	0.01	40.55	-0.58	0.56
GroupTD:Syllable	0.02	0.02	44.50	1.15	0.26
GroupTD:Image	**0.05**	**0.02**	**44.26**	**2.66**	**0.01***
GroupTD:Tone	0.03	0.02	42.09	1.53	0.13

Note: Significant interaction is mainly driven by Letter vs. Image in TD.
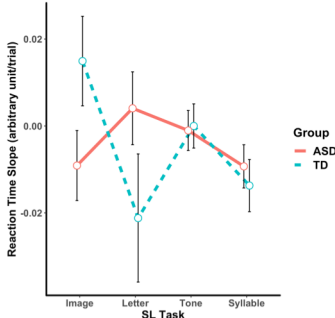
Summary:
- Significant group by Letter vs. Image SL reaction time slope interaction.
- In TD, reaction time for target triplets decreases **faster** in **visual linguistic** than in visual non-linguistic.

Individual Differences
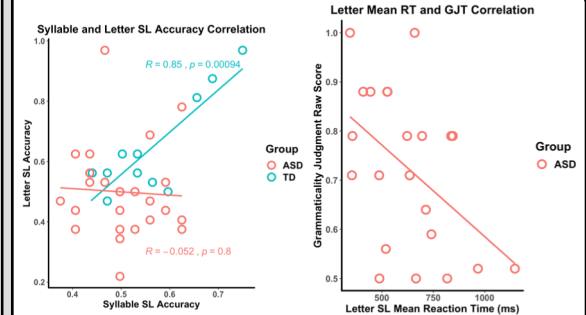
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.52	0.05	10.79	<0.001
Letter	-0.03	0.09	-0.27	0.79
GroupTD	-0.29	0.10	-2.85	0.01
GroupTD:Letter	**0.54**	**0.16**	**3.32**	**0.002****

Summary:
- Syllable SL accuracy was positively correlated with Letter SL accuracy in TD, but not in ASD.
- Better grammatical ability is related to quicker RT in Letter SL in ASD.

Conclusion

- SL across linguistic and non-linguistic domains is better in TD than in ASD. However, **children with ASD are particularly impaired in linguistic SL.**
- Children with ASD showed a lack of advantage in real-time implicit learning of linguistic SL within the visual domain.
- The disassociation between auditory and visual linguistic SL in ASD may suggest an atypical developmental pattern of spoken and written language acquisition.
- Slower RT in letter SL is related to poorer grammatical ability in ASD (ongoing data collection in TD).

Reference

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Acknowledgement