Statistical Learning in Reading Development and Reading Impairment

Zhenghan Qi[1,2], An Nguyen[1], Ola Ozernov-Palchik[2], Sara Beach[2], Sidney May[2], Joanne Arciuli[3], John Gabrieli[2]

[1] University of Delaware; [2] Massachusetts Institute of Technology; [3] University of Sydney
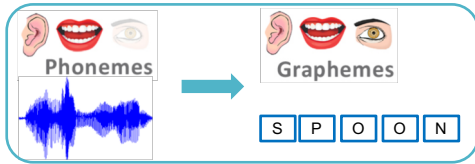
Introduction

- Statistical learning (SL), the implicit ability to detect and extract regularities from inputs, plays a key role in spoken language development (Saffran et al., 1996; Evans et al., 2009).
- Reading development, however, relies on efficient cross-modal mapping of phonemes and graphemes.

- Auditory SL might support the acquisition of phonological skills, while visual SL might support the acquisition of transitional probabilities between letters. Both ASL and VSL might support learning about the mapping between phonemes and graphemes.
- It has been proposed that dyslexia stems from fundamental deficits in extracting regularities (Ahissar, 2007).
- However, the relative importance of visual and auditory SL in reading development and reading impairment has not been evaluated.

Current Study:
Is sensitivity to statistical information in the visual and auditory modalities is equally important for reading development (Expt. 1) and reading impairment (Expt. 2)?

Overall Procedure
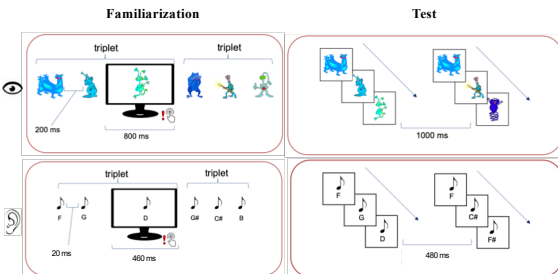
- Experiments are hosted on https://cogscigame.co
- Familiarization phase:
  - Target detection cover task
  - Each triplet is repeated 24 times in VSL and 48 times in ASL.
- Testing phase:
  - Two-alternative forced choice task
  - 4 foils for each triplet
  - 32 test trials

Expt. 1: Statistical Learning and Reading Skills

| Participants	Children	Adults	Difference
N (F:M)	36 (20:16)	36 (25:11)	n.s.
Age (Years)	12.2 (2.4)	24.0 (5.0)	p < 0.001
Nonverbal IQ	115.6 (16.1)	106.4 (12.1)	n.s.
Reading Fluency	120.0 (10.1)	123.6 (13.9)	n.s.
Cronbach's alpha	Children	Adults	All
VSL	0.86	0.89	0.87
ASL	0.79	0.82	0.75

Note:
- Group mean and standard deviation in parentheses.
- Nonverbal IQ: KBIT-2 Matrices
- Reading Fluency: Woodcock-Johnson III Test of Achievement Sentence Reading Test

Spearman Correlation	ASL Accuracy	Sentence Reading	Age	IQ
VSL Accuracy	0.16	0.22[†]	0.16	0.18
ASL Accuracy		0.50***	0.09	0.15
Reading Fluency			0.03	0.31**
Age				-0.35**

[†] p < 0.1; ** p < 0.01; *** p < 0.001; underlined correlation: significant after Bonferroni correction.

Summary: (Qi et al., 2018)
- Lack of correlation between ASL and VSL.
- No relationship between age and SL (range: 8 - 33 years old).
- Individuals' reading fluency is more strongly associated with ASL accuracy than with VSL accuracy after controlling for nonverbal IQ.
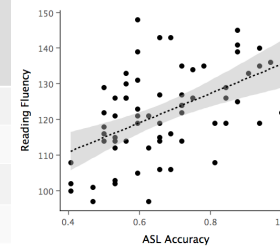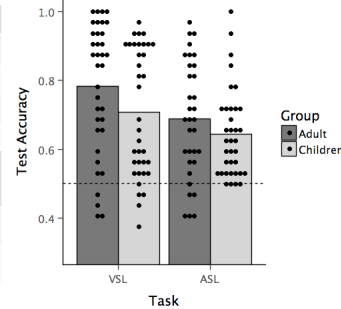
Expt. 2: Statistical Learning in Reading Impairment

Participants	Dyslexia*	Typical	Difference
N (F:M)	17 (12:5)	24 (13:11)	n.s.
Age (Years)	26.5 (7.8)	25.6 (5.9)	n.s.
Nonverbal IQ	107.2 (12.9)	116.4 (11.3)	p = 0.03
Word Identification	87.2 (11.2)	109.4 (6.6)	p < 0.001
Word Attack	75.6 (7.3)	102.7 (8.2)	p < 0.001
Sight Word Efficiency	89.4 (11.2)	109.2 (11.5)	p < 0.001
Phonemic Decoding	82.5 (7.5)	105.6 (7.0)	p < 0.001

*: Dyslexia is defined as individuals who score below 90 in at least two of the four reading tasks (in blue).

Dyslexia group showed specific impairment in ASL, but not in VSL.
ANCOVA, controlling for IQ:
- VSL: F(1,32) = 0.004, p = 0.95
- ASL: F(1,32) = 6.179, p = 0.02
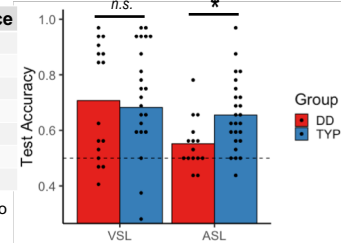
Expt. 2: Individual Differences

Spearman Correlation	WRMT-3		TOWRE-2	
	Word ID	Word Attack	Sight Word Efficiency	Phonemic Decoding
Typical				
VSL Accuracy	0.06	-0.09	-0.12	-0.04
ASL Accuracy	0.31	-0.27	0.14	-0.21
Dyslexia				
VSL Accuracy	-0.12	-0.08	0.07	0.13
ASL Accuracy	0.52*	0.58*	0.37	0.52*

* p < 0.05.

Summary:
- Adults with dyslexia show specific weakness in ASL, not VSL.
- Within the dyslexia group, word-level reading skills are only associated with ASL accuracy, but not VSL accuracy.

Conclusion

- Both experiments found weak association between ASL and VSL accuracy, suggesting individuals vary in their abilities to learn statistical regularities across sensory modalities.
- Cross-sectional data suggest little age-related effect on SL performance, at least after 8 years old. However, a longitudinal study is necessary to confirm this (Arciuli & Conway, 2018).
- Both sentence-level reading comprehension and word-level reading skills are more strongly related to auditory SL than to visual SL abilities.
- Poor capacity to detect and extract statistical patterns in the auditory domain may impair phonological development and subsequently result in atypical reading development that characterize dyslexia.

Reference

1. Ahissar M (2007): Dyslexia and the anchoring-deficit hypothesis. Trends Cogn Sci. 11: 458–65.
2. Evans JL, Saffran JR, Robe-Torres K (2009): Statistical learning in children with specific language impairment. J Speech, Lang Hear Res. 52: 321–335.
3. Qi Z, Araujo YS, Georgan WC, Gabrieli JDE, Arciuli J (2018): Hearing matters more than seeing: a cross-modality study of statistical learning and reading ability. Sci Stud Read. Doi: 10.1080/10888438.2018.1485680
4. Saffran JR, Aslin RN, Newport EL (1996): Statistical learning by 8-month-old infants. Science (80-). 274: 1926–1928.
5. Arciuli J, Conway CM (2018): The Promise – and Challenge – of Statistical Learning for Elucidating Atypical Language Development. Curr Dir Psychol Sci. 1–7.