Examining the Association between Statistical Learning and Language Abilities in School-Aged Children

Nicolette Noonan, Marc Joanisse, and Lisa Archibald

Western
UNIVERSITY · CANADA

Author #1, Nicolette Noonan: *no conflict of interest or financial disclosures*

Author #2, Dr. Marc Joanisse: *no conflict of interest or financial disclosures*

Author #3, Dr. Lisa Archibald: *no conflict of interest or financial disclosures*

How do humans learn language?

Why do some children struggle to learn or use language?

What differentiates a good and poor language learner?

Statistical Learning

"The discovery of patterns in the input" (Reber, 1967)

- Computation of transitional probabilities (TPs)
- May underlie some aspects of language learning
    - Native-language phonemes, words, syntax, word-object labels
      Domain-general learning mechanism
- Domain-general phenomenon
    - Linguistic, non-linguistic auditory, visual, and tactile sequences
    - Exhibited in non-human animals

Statistical Learning and Language Outcomes

- Statistical language (SL) learning related to language processing abilities (TD sample) (Misyak & Christiansen, 2012)

- Impaired statistical learning in DLD

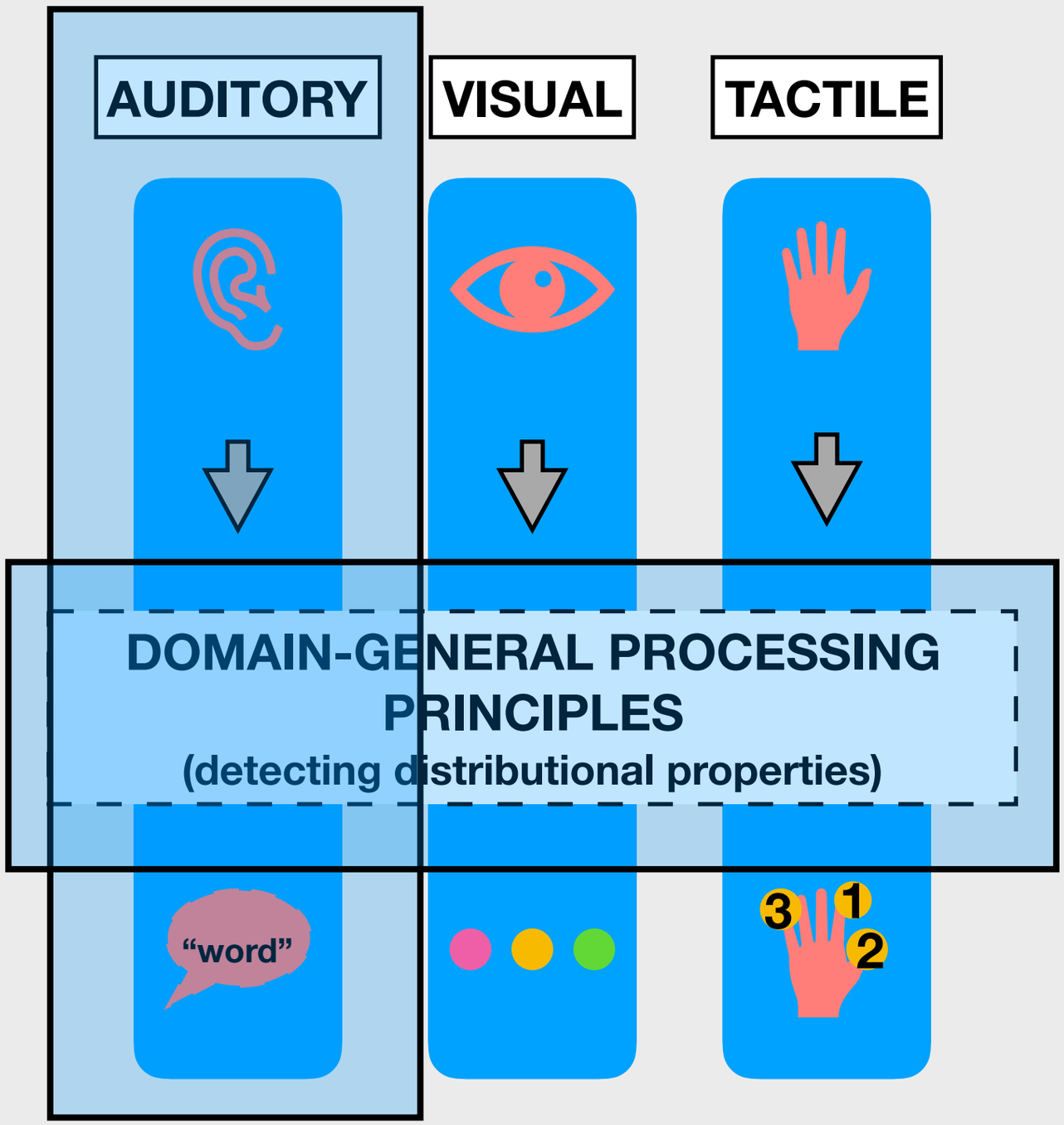
  - Verbal and non-verbal auditory stimuli (see Lammertink et al., 2017)

    - SL deficit related to language abilities (Evans et al., 2009; Mainela-Arnold & Evans, 2014)

      - Possible working memory involvement

- Also, DLD deficits in non-linguistic procedural learning tasks (e.g., Lum et al., 2014; Obeid et al., 2016)

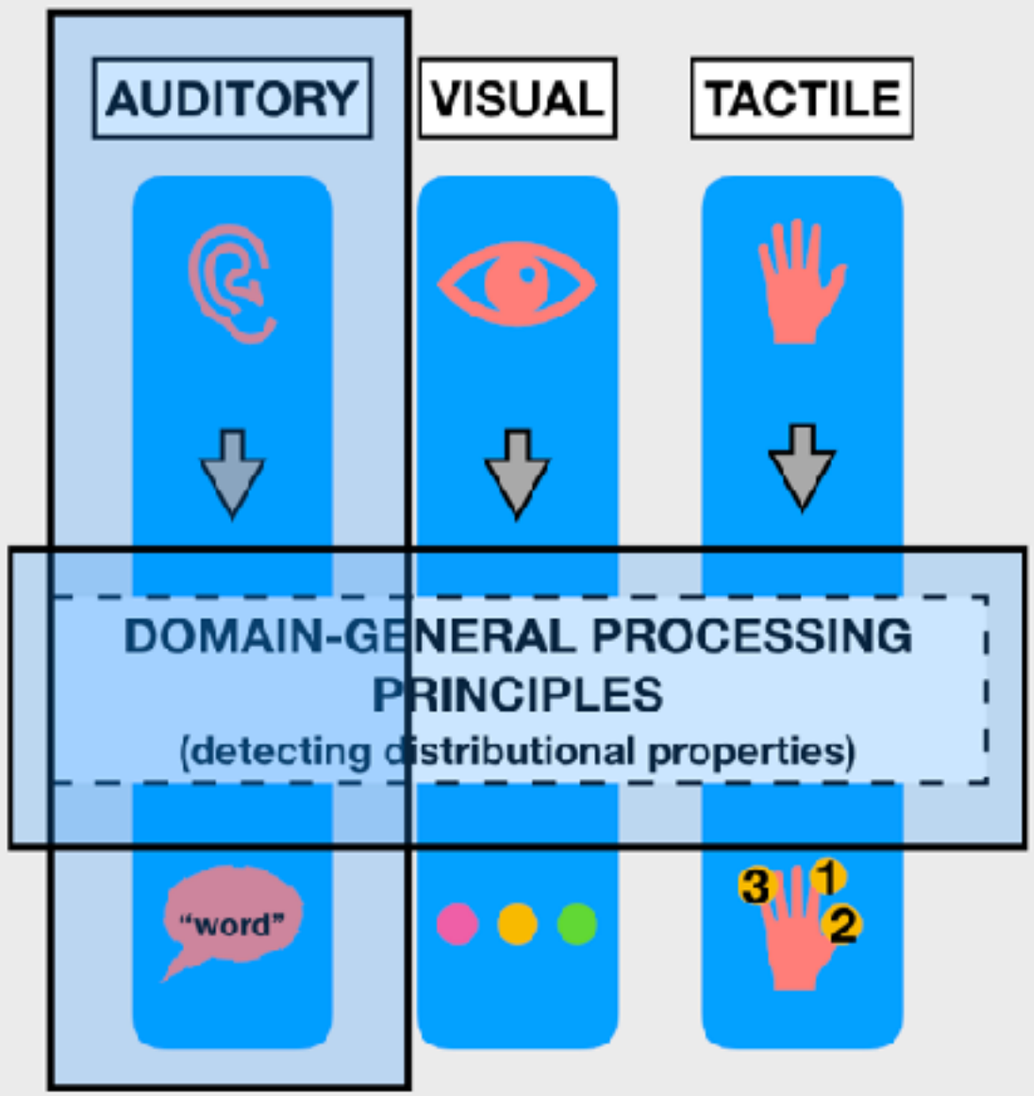
Domain-Specific or Domain-General?



Frost et al. (2015)

Research Questions

1. Is SL impaired generally in DLD?
    - Statistical language learning (SLL) task
    - Visual statistical learning (VSL) task
2. Are SL abilities related to language or other cognitive abilities?
    - Language measures
    - Working memory



Participants

	TD	DLD
***n* = 23**	12	11
Age	7.33 (1.33)	7.33 (0.94)
CELF-CLS	100.00 (11.52)	**66.18 (7.90)**
Expressive Vocab.	101.67 (6.76)	**89.09 (10.30)**
Receptive Vocab.	94.50 (18.49)	85.00 (13.34)
Working Memory (AWMA)	96.42 (15.52)	**83.32 (11.94)**
WASI Block Design	52.82 (10.59)	**43.11 (6.97)**
WASI Matrix Reasoning	54.82 (12.05)	**41.11 (9.88)**

Bolded values: DLD < TD, $p < .05$

Statistical Language Learning (Word Segmentation)

…pa tu bi tu ti bu ba bu pu bu pa da du ta ba pi da di…

Saffran et al., (1997)

Statistical Language Learning (Word Segmentation)

TP = 0.167

…pa tu bi tu ti bu ba bu pu bu pa da du ta ba pi da di…

TP = 1.0

Transitional probabilities (TP)
Within: 1.0-0.33
Between: < 0.2

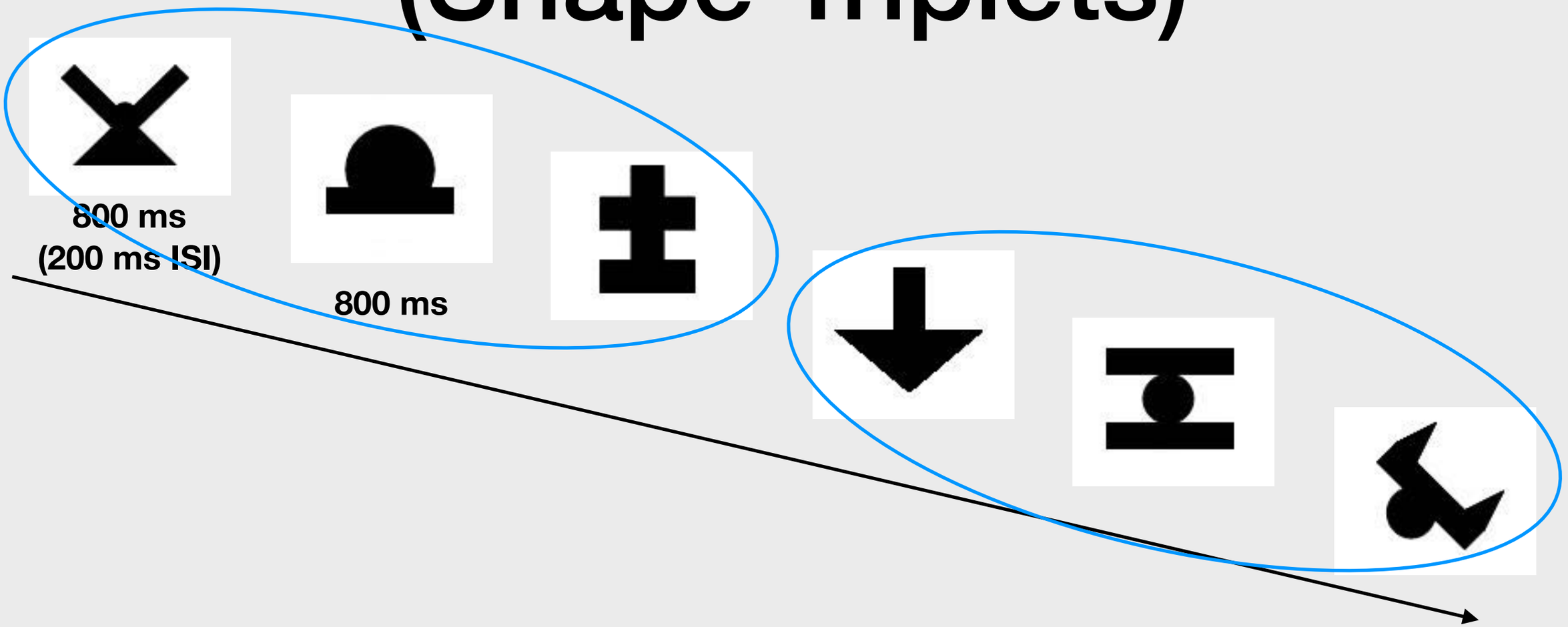
21 minutes
(360 tokens/word)

Naturally-produced speech

36 test items: 2AFC
word vs nonword
pa tu bi vs pu ba ti

Saffran et al., (1997)

Visual Statistical Learning (Shape Triplets)



5 triplets
24 tokens/triplet

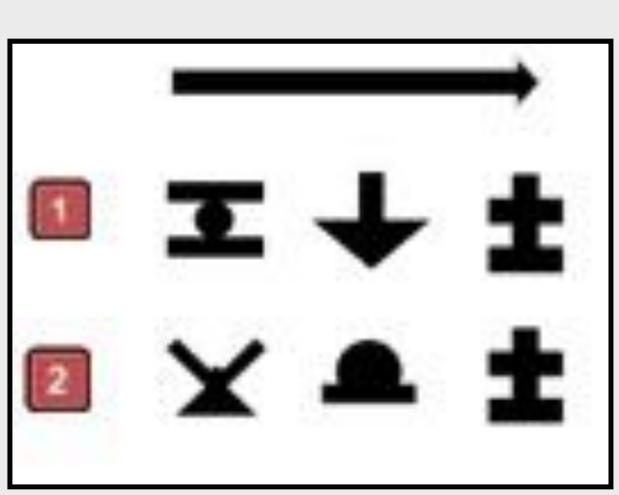
Transitional probabilities
Within: 1.0-0.33
Between: < 0.2

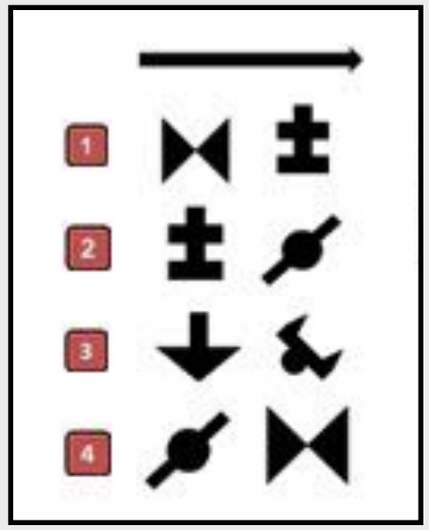
Siegelman et al, (2016)

Visual Statistical Learning Test (Shape Triplets)

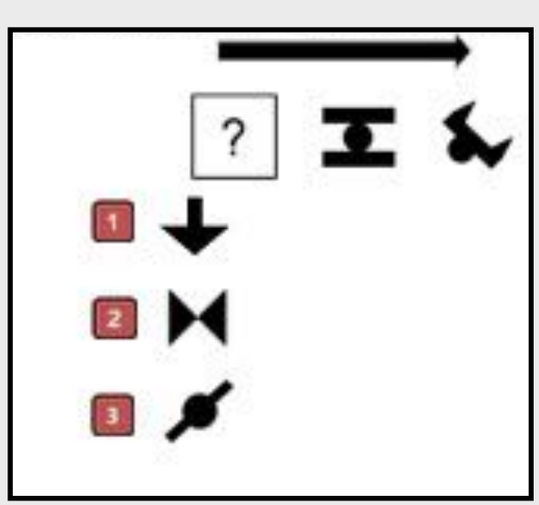
35 items

Pattern Recognition



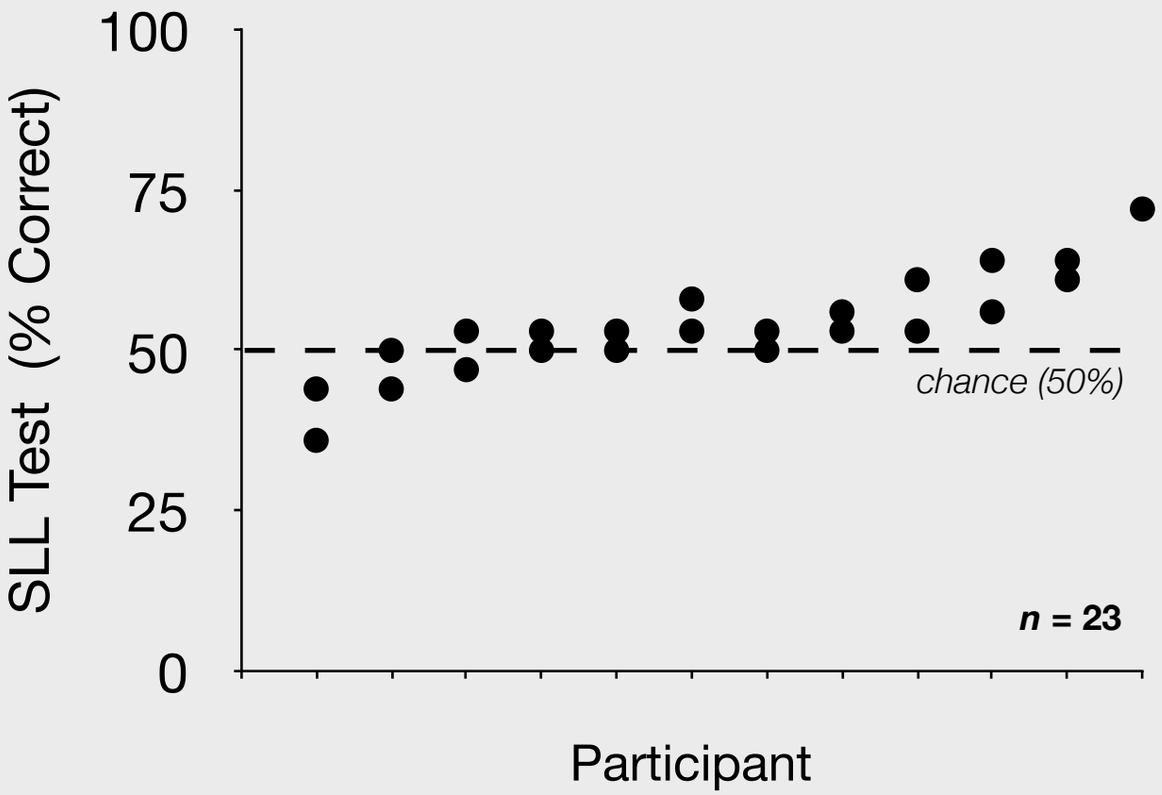


Pattern Completion



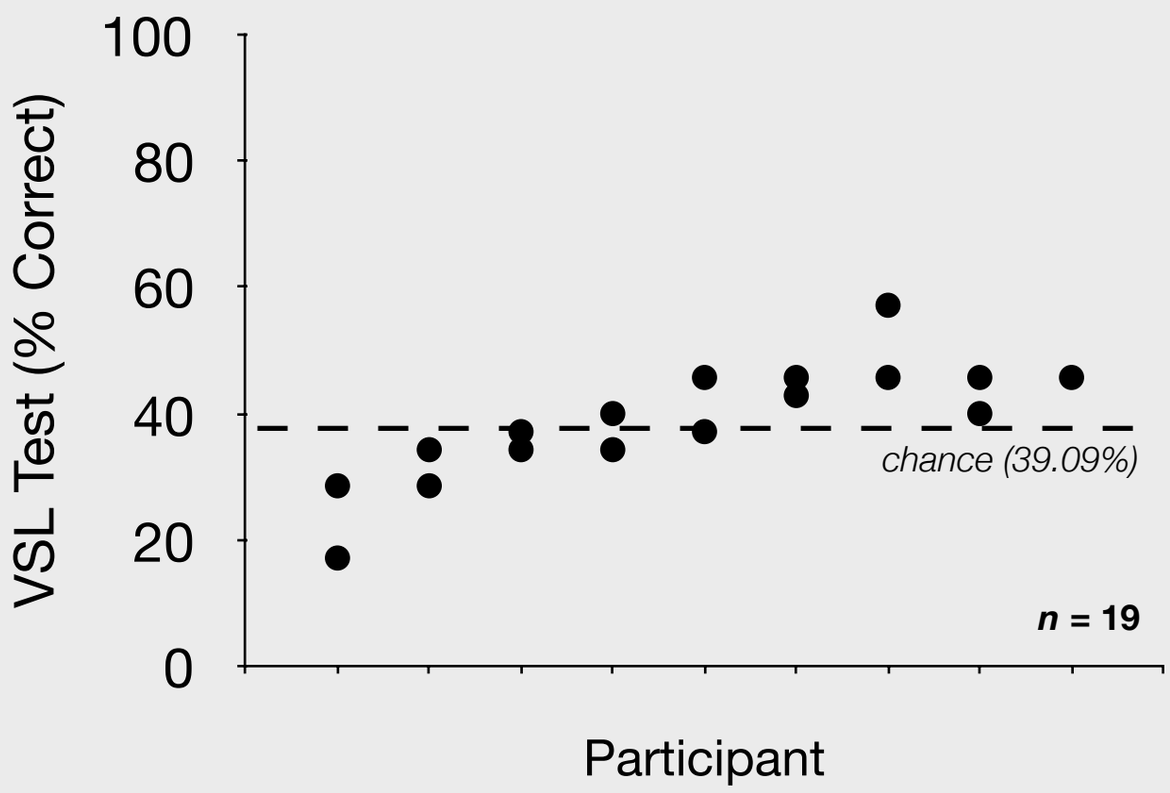
Statistical Learning Scores (Sample)

Statistical Language Learning



Group above-chance
(*M* = 53.65%; p = .032)

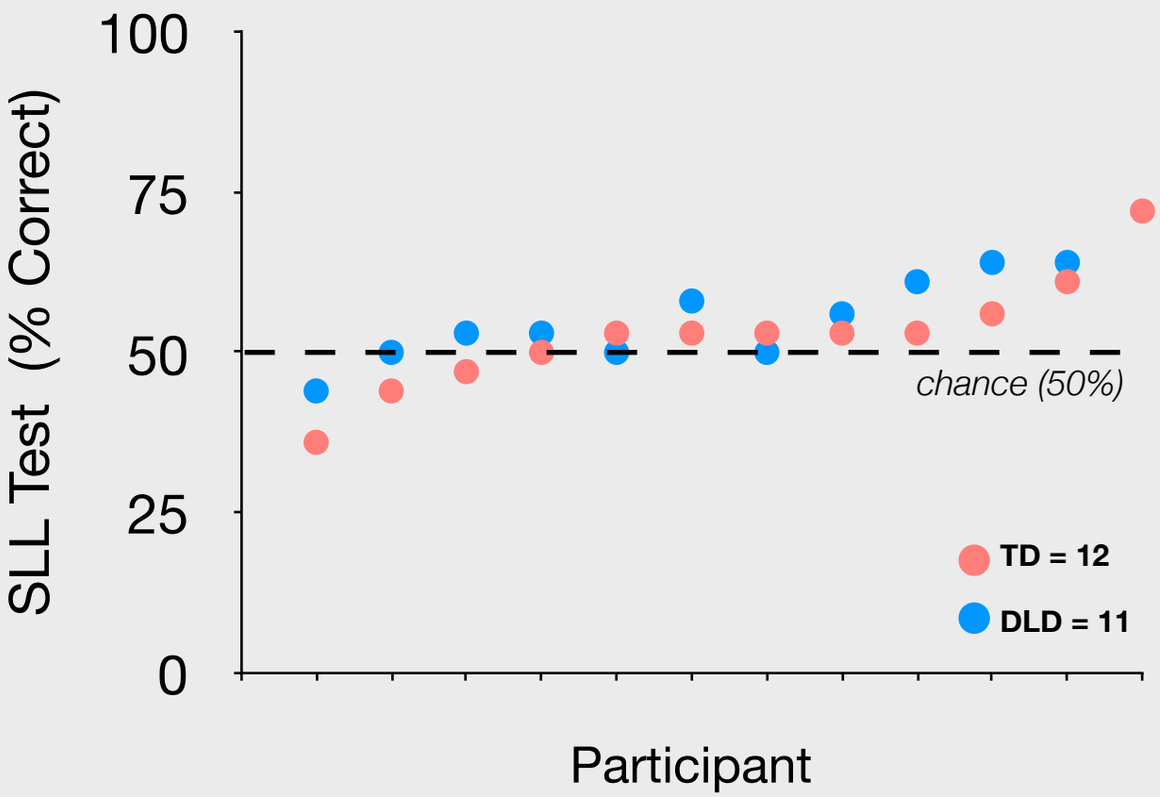
Visual Statistical Learning



Group not above-chance
(*M* = 39.09%; p = .032)

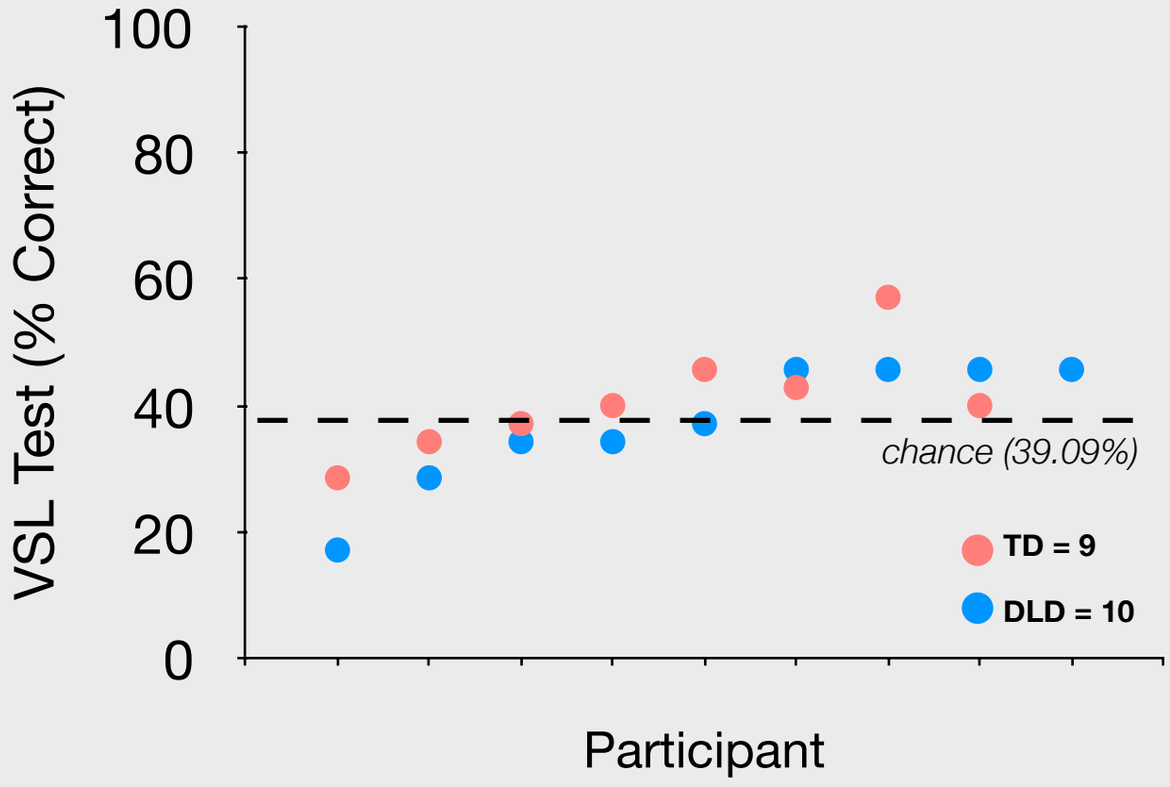
Statistical Learning Scores
(TD vs DLD)

Statistical Language Learning



DLD and TD did not differ (p = .497)
DLD marginally above-chance (p = .032)
TD not above-chance (p = .330)

Visual Statistical Learning



DLD and TD did not differ (p = .256)
Neither group above chance (p > .272)

Interim Summary

- No TD/DLD difference on either statistical learning task
    - DLD marginally above-chance on the SLL task
- SLL and VSL scores not associated with age or other cognitive measures
- SLL and VSL scores not associated with each other

Critiquing Statistical Learning Outcome Measures

Statistical Language Learning

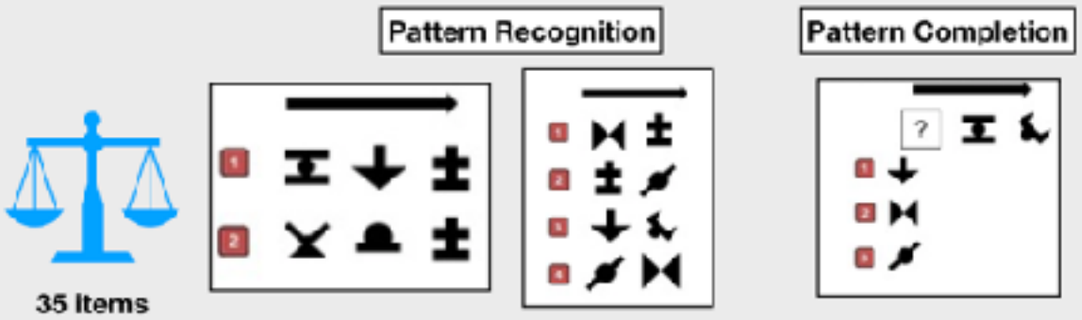
…pa tu bi tu ti bu ba bu pu bu pa da du ta ba pi da di…

21 minutes
(360 tokens/word)

36 test items: 2AFC
word vs nonword
pa tu bi vs pu ba ti

Naturally-produced
speech

Visual Statistical Learning



Critiquing Statistical Learning Outcome Measures

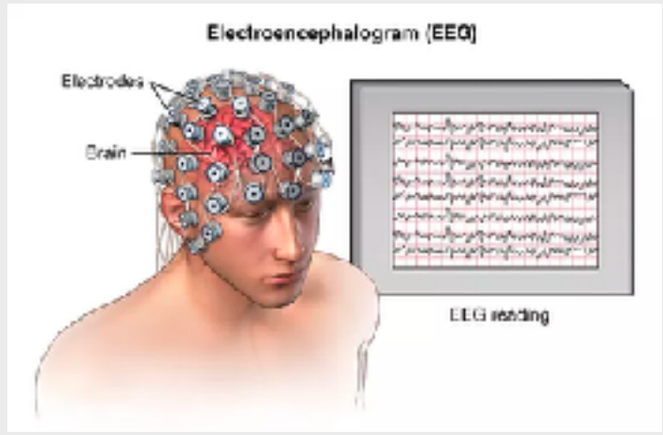
- **Mean success rate (% correct) may not reflect individual differences** (Siegelman et al., 2016)
    - Limited number of test trials
    - Group at chance-level performance
- **Explicit measures may underestimate total learning**
    - Explicit stimulus recognition does not correlate with implicit measures (Batterink et al., 2015)

Critiquing Statistical Learning Outcome Measures

- **Possible solution: Measure ERPs <u>during</u> statistical learning**

  - Implicit measure with high temporal resolution, high number of trials

  - Measures sensitivity to distributional regularities on-line



- ERPs reveal sensitivity to “words” in SLL tasks and differentiate good and poor statistical learners (e.g., Abla et al., 2006; de Diego Balaguer et al., 2007; Sanders & Newport, 2002)

Measuring ERPs Online during Statistical Language Learning

- Examined responses to **word-final** syllables
- Compared "**low**" and "**high**" statistical leaners
    - May show different responses to distributional regularities

…pa tu bi tu ti bu ba bu pu bu pa da du ta ba pi da di…

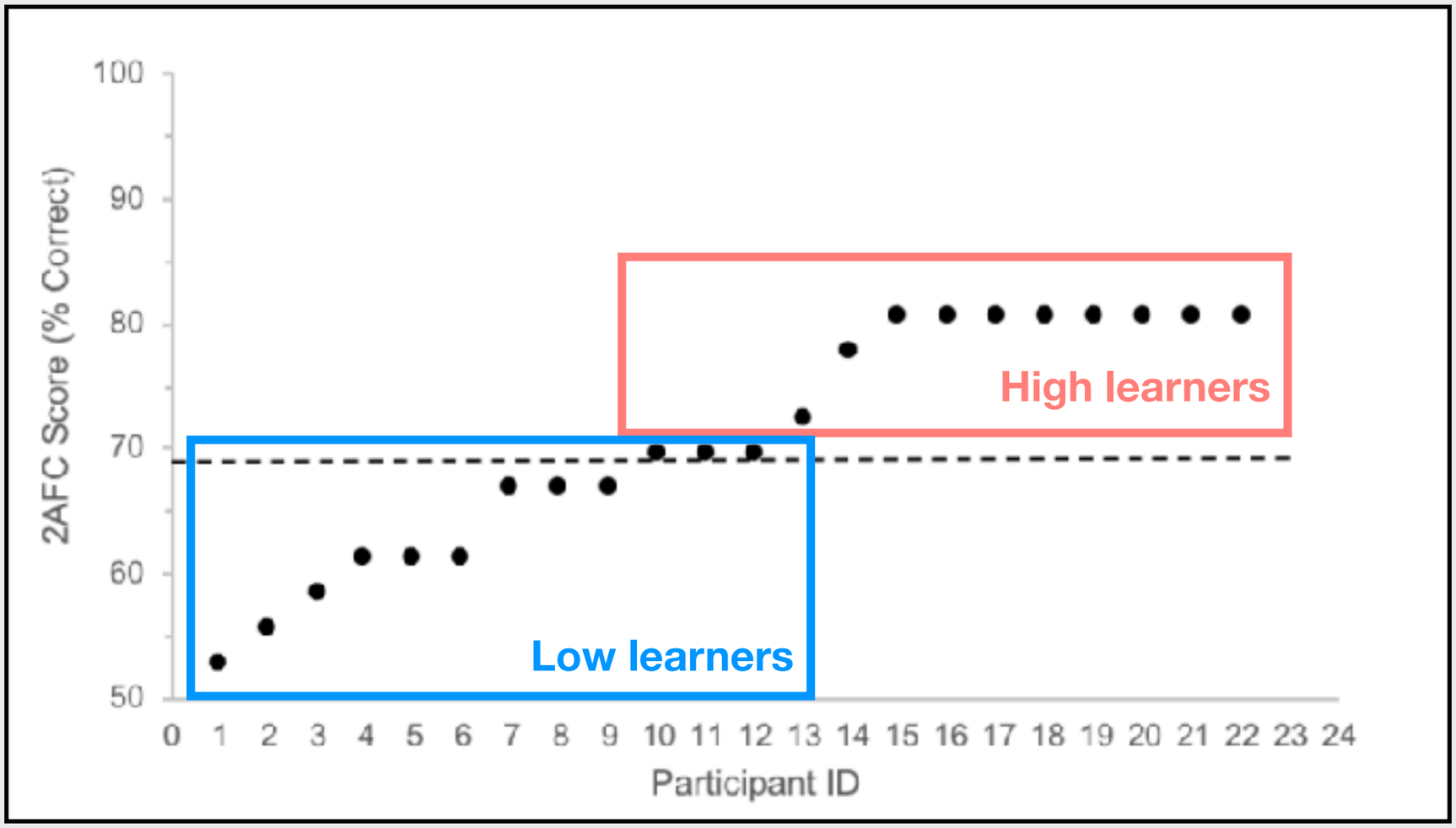
21 minutes
(360 tokens/word)

36 test items: 2AFC
word vs nonword
pa tu bi vs pu ba ti

Naturally-produced
speech

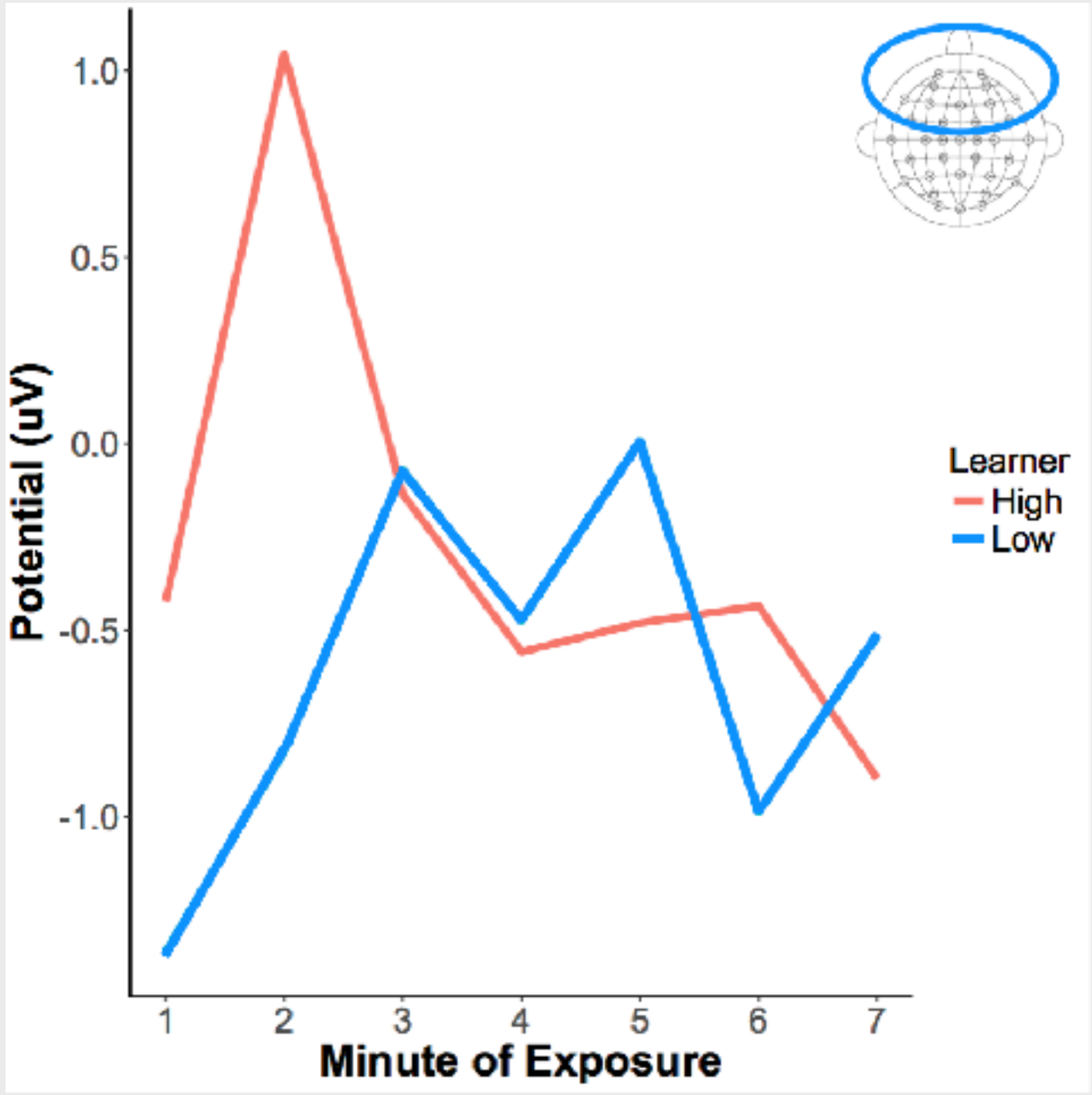
Saffran et al., (1997)

Comparing ERPs between "Low" and "High" Statistical Learners



High learners: *M* = 79.04%, *n* = 10 adults
Low learners: *M* = 63.42%, *n* = 12 adults

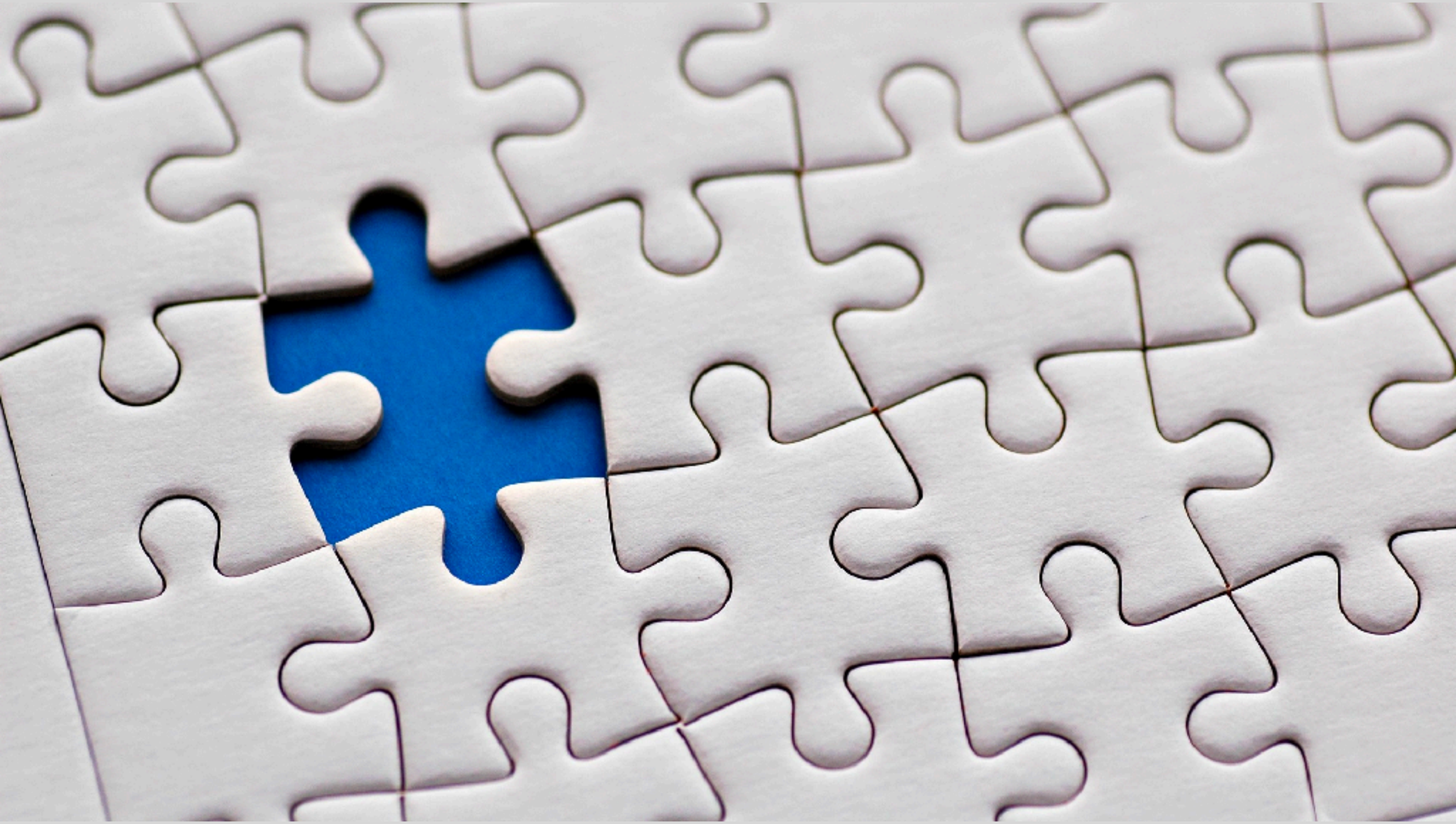
Comparing ERPs between "Low" and "High" Statistical Learners



- **High learners:** Early P200 response to word-final (expected) syllables, dissipates over exposure
  - Matching to information already stored in memory (Curran & Dien, 2003; Evans & Federmeier, 2007; Luck & Hillyard, 1994; Misra & Holcomb, 2003)
  - Rapid extraction of transitional probabilities (Cunillera et al., 2009; de Diego Balaguer et al., 2007)
- **Low learners:** Gradual increase in P200 response, lower amplitude overall
  - Lack of sensitivity to transitional probabilities
  - Mis-segmentations? Inattention? (Herning et al., 1985)

Conclusions

- Verbal and visual statistical learning did not differ between TD and DLD groups
  - Failure to replicate previous work (Evans et al., 2009)
  - Unable to answer the domain-general vs. domain-specific question
    - Statistical learning not associated with other cognitive and linguistic measures
- However, implicit measures can differentiate between groups
  - In adults, ERPs to word-final syllables differentiated “low” and “high” statistical learners
    - May help differentiate children with low language skills from TDs
  - Other implicit measures (RTs) have also shown promising results (e.g., Batterink et al., 2015)



Thanks to:

Dr. Lisa Archibald

Dr. Marc Joanisse

Data Collection:
Silvina Antunes
Alex Cross
Joel Kang
Kathy Kaye
Ren Lohmann
Natalie Pitch
Ellen Sparling

A special thank-you to the schools, children, and families who participated in this study

NSERC CRSNG

OGS
Ontario Graduate Scholarship Program

Western
The Brain and Mind Institute