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Modeling visuo-attentional exploration trajectories of new words during orthographic learning by dyslexic readers

Emilie Ginestet, Julien Diard and Sylviane Valdois

INTRODUCTION

Monitoring eye movements during novel word repeated reading provides online information of orthographic learning (Nation et al., 2017). Dyslexic individuals show orthographic learning difficulties (Martens & de Jong, 2008), but no study examined the evolution of their eye movement patterns during learning. Furthermore, few behavioral data explore the role of visual attention on orthographic learning (Marinelli et al., 2020). BRAID-Learn (a computational model of orthographic learning) predicts that visual attention affects orthographic learning (Ginestet et al., 2022).

OBJECTIVES

- Investigate eye movement patterns during learning in developmental dyslexia
- Evaluate whether visual attention abilities affect orthographic learning
- Model the role of attention in orthographic learning

BEHAVIORAL EXPERIMENT

Participants

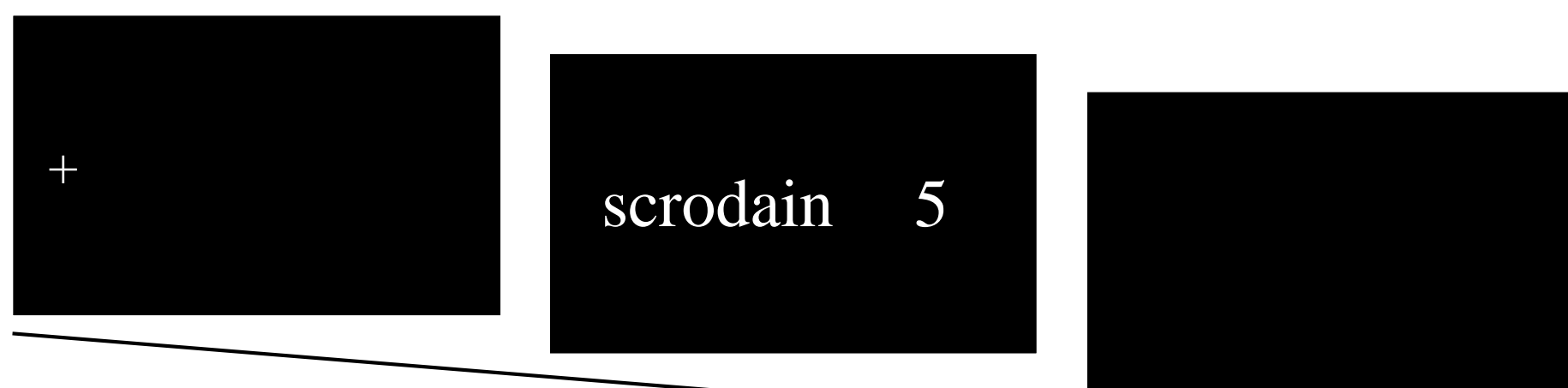
French young adults with normal vision: 46 Skilled Readers (SR; data from Ginestet et al., 2019) and 30 DYSlexic readers (Dys; new data)

Material

- ☐ 30 legal 8-letter pseudo-words (PW) containing ambiguous graphemes
 - ☐ 30 8-letter words
- } 3 lists of mixed items: 10 PWs and 10 Ws

Protocol

Exposure Phase: Oral Reading with Eye Movement Recording

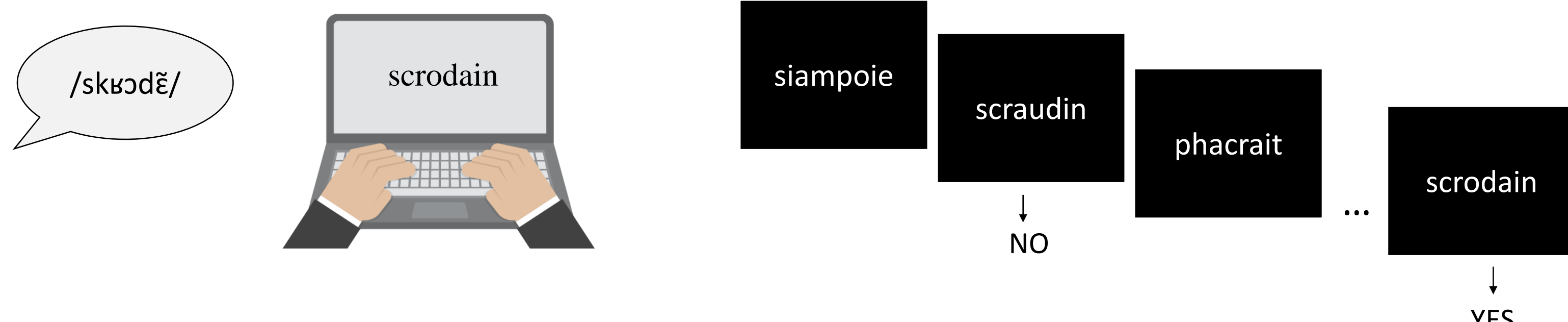


Each item (PW or W) is randomly presented 1, 3 or 5 times (180 trials). Eye movements are monitored.

Orthographic Learning Assessment: Surprise Memory and Recognition Tests

PW Spelling-to-Dictation

Orthographic Decision



Visual-Attention Span (VAS): a measure of multi-element simultaneous processing

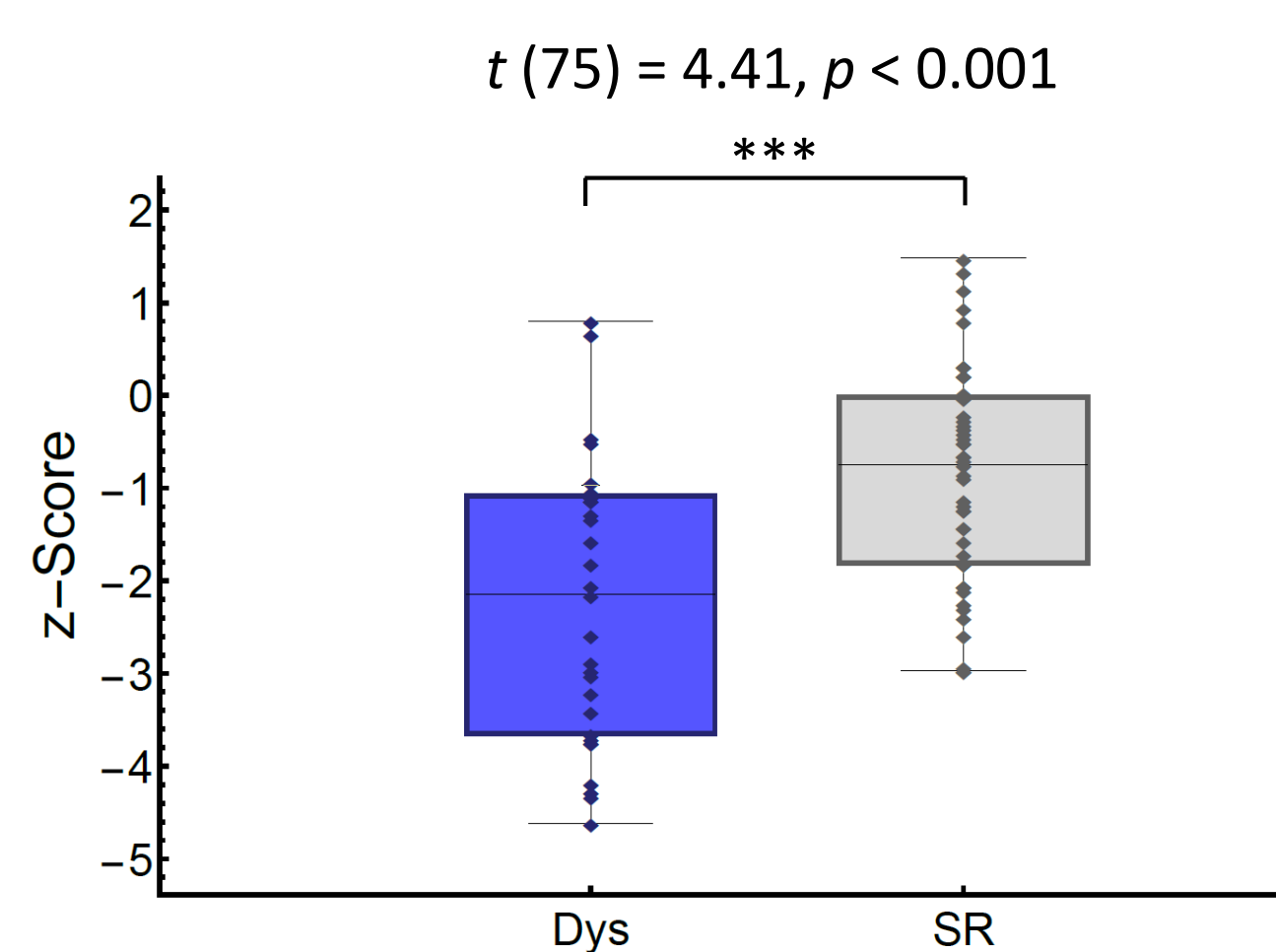
Whole and partial report – 6-consonant strings presented for 200 ms

R F D H S T

Behavioral Results

Differences in VAS skills

VAS for dyslexic participants is lower than for skilled readers

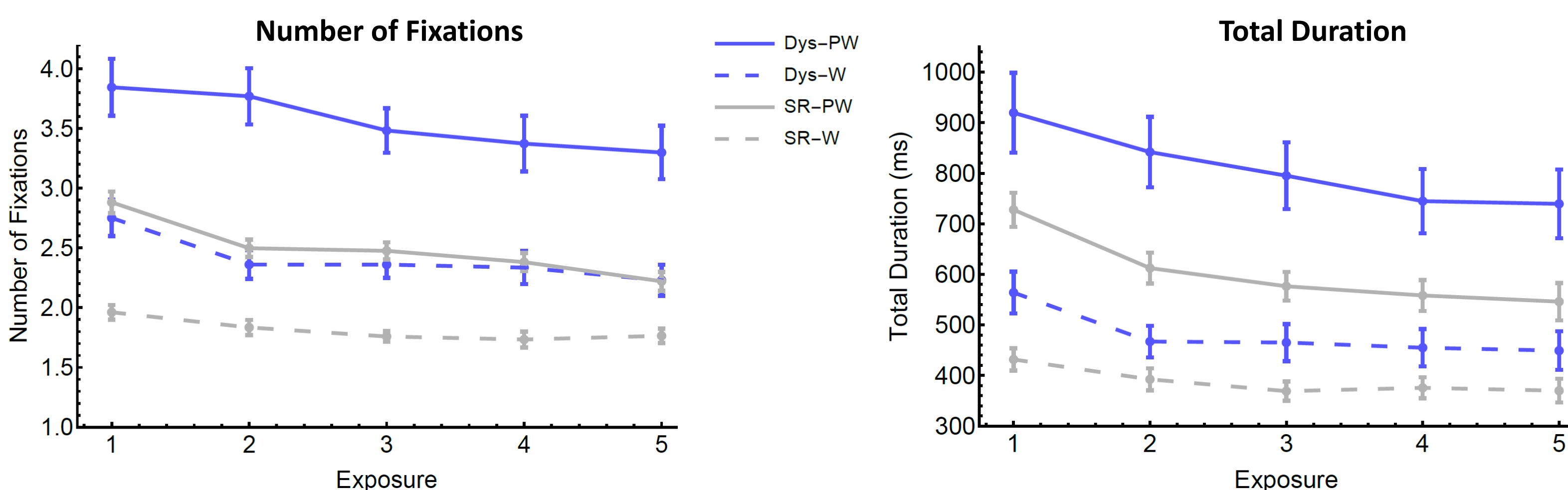


Differences in orthographic learning

Exposures	PW Spelling-to-Dictation				Orthographic Decision			
	% correct		RTs (s)		% correct (YES responses)		RTs (ms)	
Group	Dys	SR	Dys	SR	Dys	SR	Dys	SR
1	8.7 (9.4)	11.5 (8.7)	12.5 (10.0)	6.2 (3.4)	51.3 (20.4)	53.1 (15.8)	1933 (871)	1225 (469)
3	11.7 (10.2)	17.4 (15.0)	8.9 (4.9)	5.3 (2.1)	70.0 (17.8)	71.0 (16.8)	1844 (893)	1104 (419)
5	19.0 (17.7)	21.5 (15.6)	7.2 (3.7)	5.0 (1.6)	83.9 (10.7)	79.1 (12.9)	1664 (711)	1011 (266)

- Significant exposure effect on spelling and orthographic decision in both groups
- Spelling-to-dictation and orthographic decision performance are similar
- ➔ **Similar orthographic learning occurred in both dyslexics and skilled readers**
- Longer RTs for Dys than SR in both tasks
- Higher accuracy and shorter RTs in orthographic decision for participants with higher VAS; no VAS effect on spelling performance
- ➔ **Some evidence for a link between VAS and orthographic learning**

Differences in eye movements during implicit learning



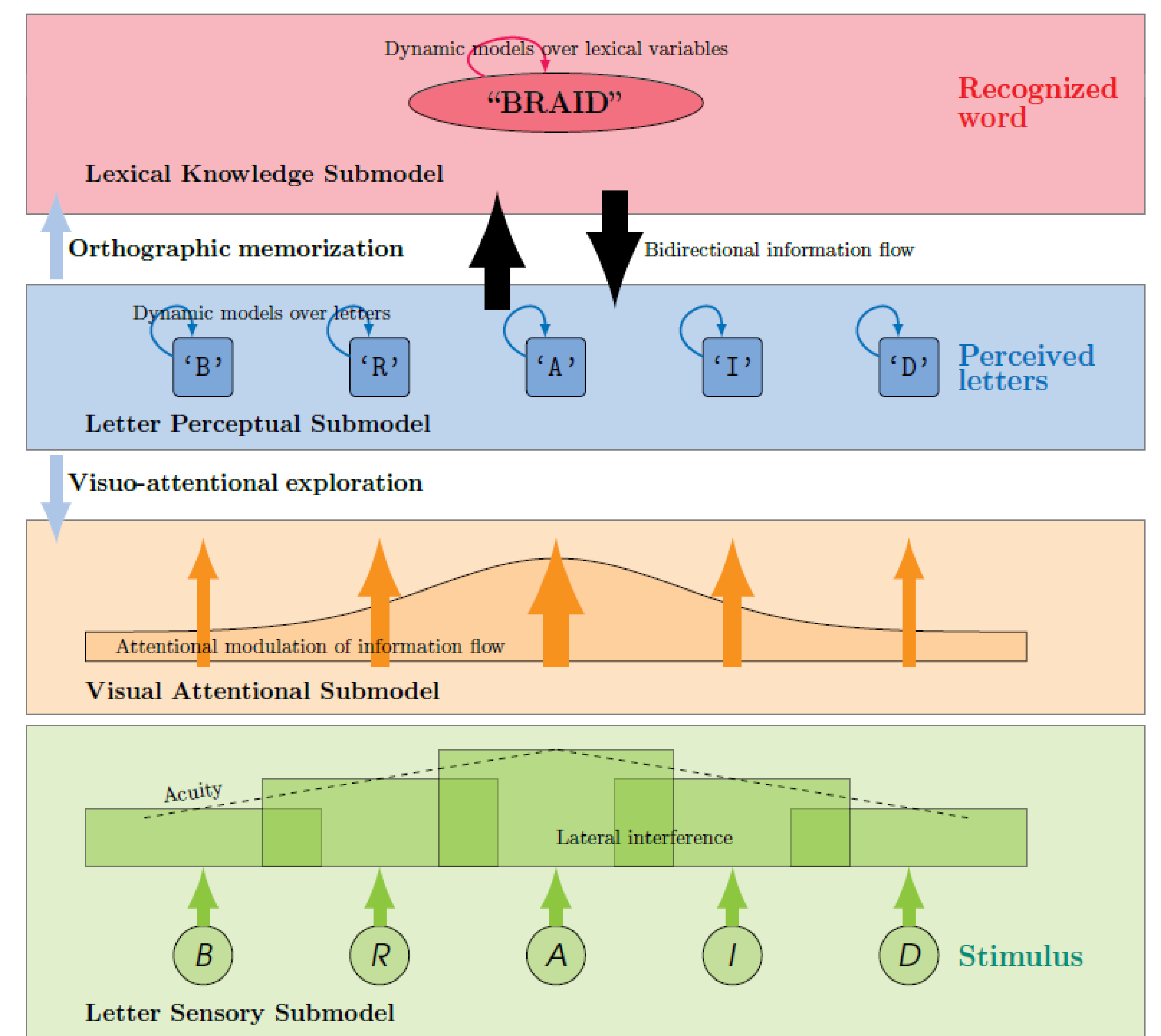
- Higher number of fixations on PWs for Dys than SR even after 5 exposures
- Similar cross-exposure improvement in the two groups
- Larger second exposure effect in SR than Dys for the PWs on both measures
- ➔ **The evolution of eye movement behaviors is slower for Dys than for SR suggesting that orthographic learning differs in the two groups**
- Shorter total duration for participants with higher VAS
- Sharper decrease of total duration across exposures for participants with higher VAS
- ➔ **VAS influences visual processing of PWs during implicit orthographic learning**

SIMULATIONS with the BRAID-Learn MODEL

BRAID-Learn is a computational model of orthographic learning. As an extension of the visual word recognition model BRAID, it is a hierarchical probabilistic model composed of 5 sub-models represented by colored rectangles on the figure.

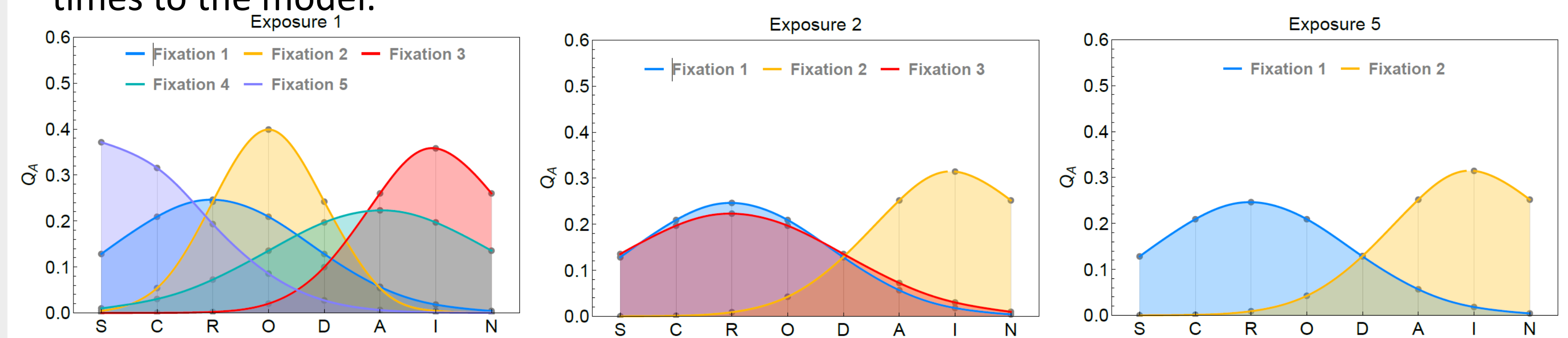
To model orthographic learning in BRAID-Learn, we assume that:

- **Visual attention and gaze displacements** are chosen to optimize the accumulation of perceptual information about letters, so as to construct a new orthographic memory trace
- **Perceptual representation** results from bottom-up (sensory processing) and top-down (lexical prediction) influence
- Word familiarity modulates the amount of **top-down lexical influence** (e.g., for non-words, lexical prediction is suppressed)



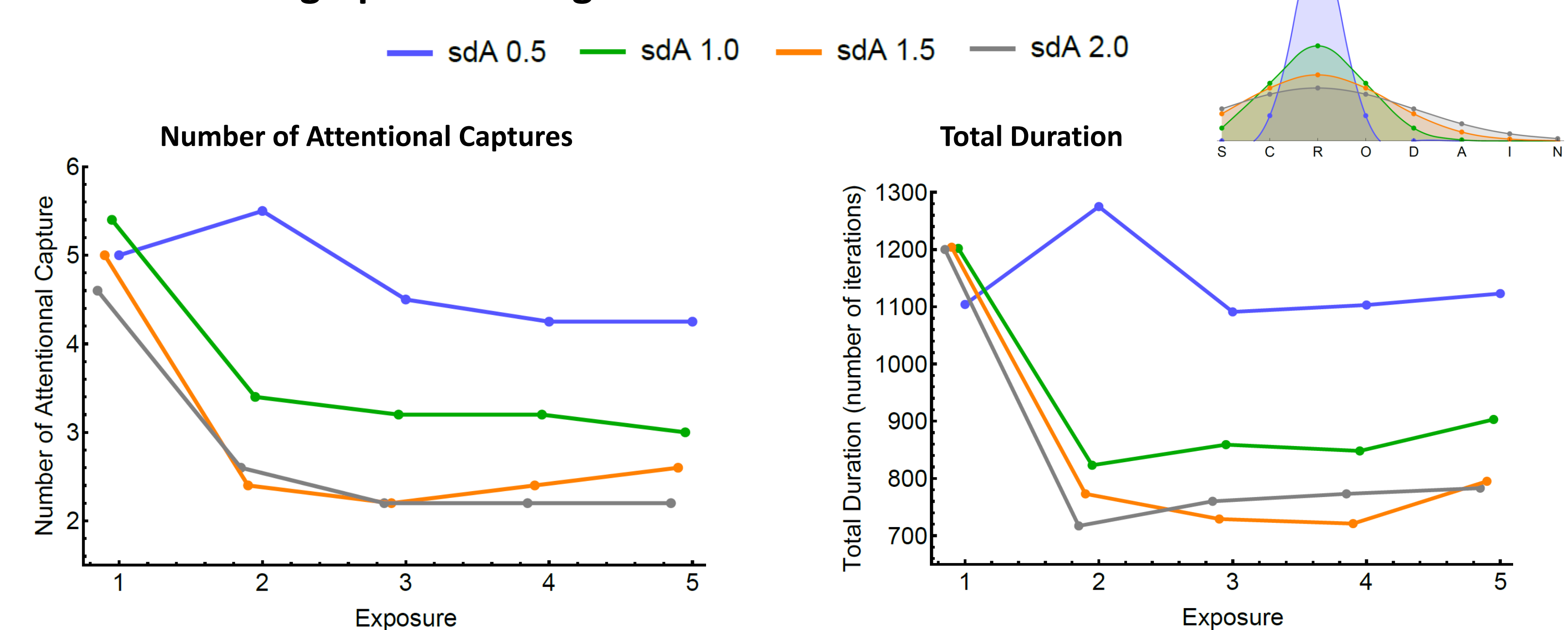
Visuo-Attentional Exploration Mechanism

Illustration of the learning process for the French pseudo-word "SCRODAIN" presented 5 times to the model.



Simulation Results

Effect of the dispersion of the attentional distribution (sdA parameter) during simulated orthographic learning of PWs: an illustration on 5 items



- Higher number of attentional captures and total duration for lower sdA even after 5 exposures
- Larger second exposure effect for higher sdA on both measures induced by a sharper decrease of number of attentional captures and total duration for sdA ≥ 1.0
- ➔ **The evolution of simulated eye movement behaviors during orthographic learning of PWs is influenced by the dispersion of the attentional distribution**

SUMMARY AND DISCUSSION

In this study, we first provide **new behavioral data on dyslexic readers** and describe their eye movement behavior during orthographic learning. Results suggest that: 1/ **dyslexic readers solve the speed/accuracy trade-off differently**, with longer RTs to reach similar performance level, because of their limits on visual processing, and, 2/ **VAS affected visual processing of PWs during learning and performance in their further recognition**.

We then used BRAID-Learn to simulate the evolution of eye movement behavior during orthographic learning of PWs. **Simulation results obtained are consistent with behavioral data suggesting a link between sdA and the VAS behavioral measure**.