The Role of Procedural Learning for Emergent Reading: Insights from Côte d'Ivoire

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Introduction

Here we ask, if procedural learning contributes to reading development similarly for both older and younger emergent readers?

Procedural Learning	Declarative Learning
Supports the discovery of patterns and structure	Supports arbitrary connections between form and meanings.
Reaches adult like capacity by age 10 (Finn et al., 2016).	Develops throughout adolescents (DiGiulio et al., 1994)
Associated with skill learning in early childhood through repeated exposures to patterns	Associated with learning in later childhood and adulthood through rote memorization
Associated with phonological processing (i.e. phonological awareness*)	Associated with Vocabulary

*Phonological awareness is the knowledge about the segmental nature of speech and is a vital skill for emergent reading

Reading in Côte d'Ivoire -
- Children may enter school between the ages of 4-12
- Prevalent absences, repeating grades is frequent

We hypothesize that procedural learning (PL) supports phonological awareness (PA) and emergent reading and that this support is consistent over development, not dependant on the child's age

Specific predictions- Even for older first time readers, PA is still vital to emergent reading. If older emergent reading relies on PA, which is supported by Pl, then emergent reading should be linked to PA and PL regardless of the age of the learner.

Methods and Materials

Language Assessments-
(Woodcock et al., 2001; Jasinska et al., 2020)
Vocabulary
  o Antonym
  o Synonym
Phonological Awareness
(Mousty et al., 1994; Yopp,1995)
  o Segmentation
  o Initial phoneme deletion

Literacy Assessments-
(RTI International, 2009; Gove & Wetterberg, 2011)
Reading
  o 100 letters & letter combinati
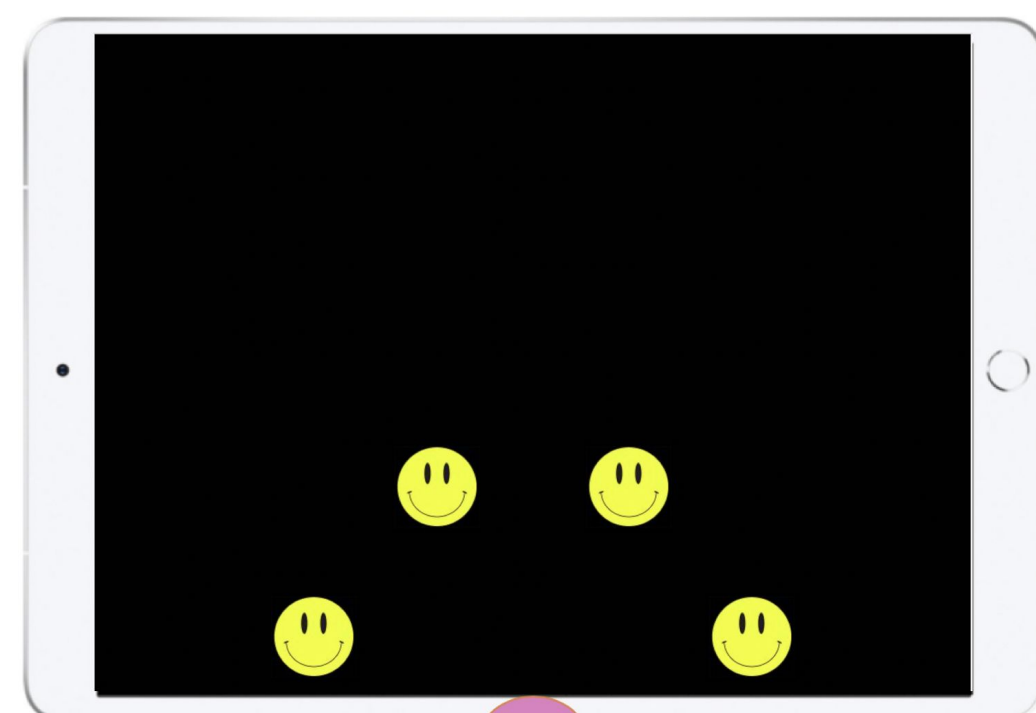 o 50 common French words
  o 50 Non-Word Read

Serial Reaction Time-
(Nissen & Bullemer, 1987)
 80 Random trials
400 Sequences trials
80 Random trails

Figure 1. Example of spatial array of stimuli for the SRT Task

Results

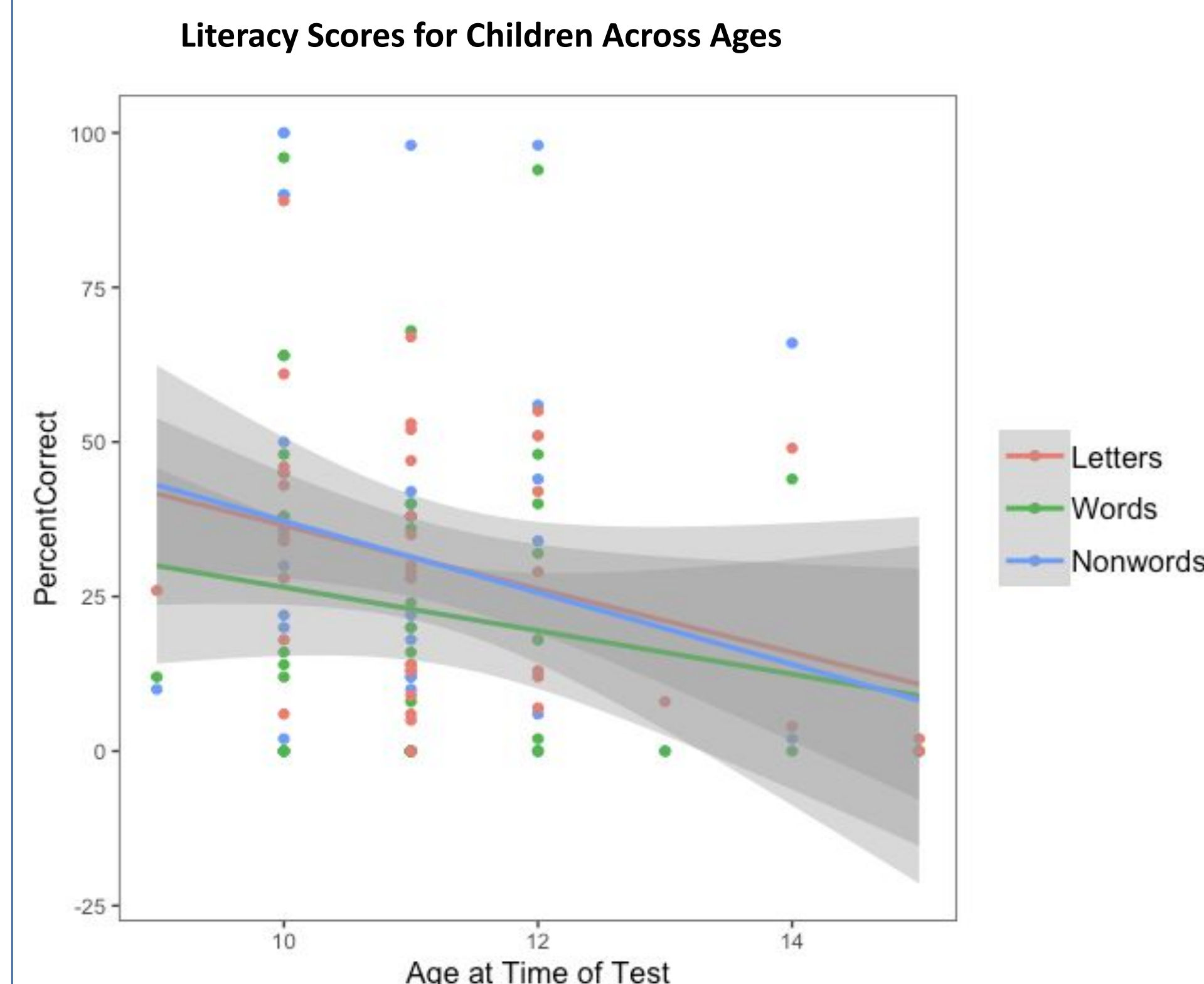### Literacy Scores for Children Across Ages

Figure 2. Scatterplot of reading scores for percent correct across three reading tests (Letters, Words, and Nonwords) at the time of testing.

	Scores			
Test	M	SD	Min.	Max.
Letter Reading	31.29	21.58	0	89
Word Reading	15.82	16.4	0	50
Nonword Reading	11.73	13.64	0	48

Younger children were better readers compared to older children: Letter Reading (β =-5.14, t(1,40)=-2.22, p=0.03). Older children had poorer PA ($r(42)$=-0.28, p=0.07)

Participants

Fifty-one children ages 9-15 years (M=10.16, SD=1.51) participated in language and literacy assessments, SRT tasks. Older children were more likely to start school late and repeat more grades

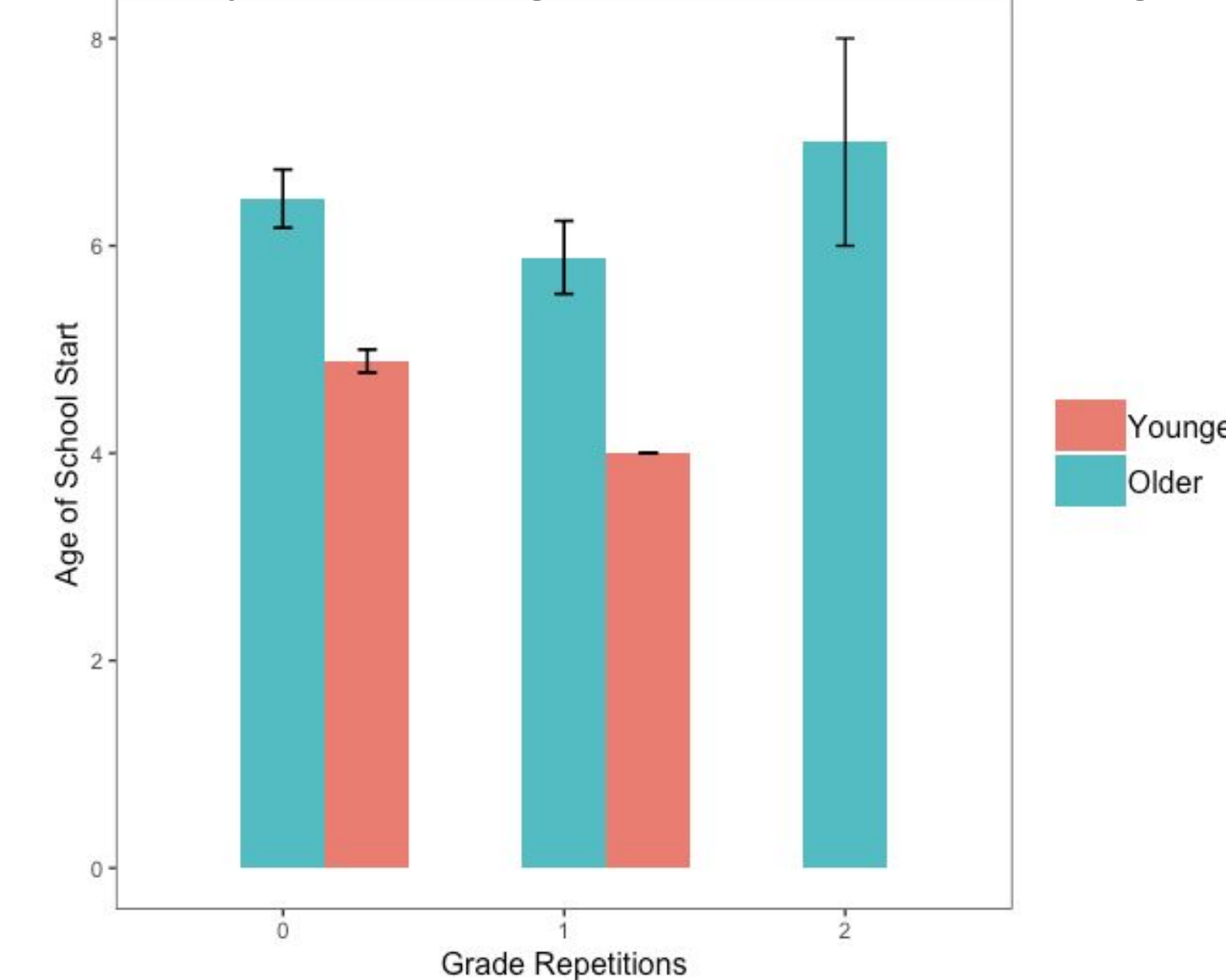### Grade Repetitions and Age of School Entrance Across Ages

Figure 3: The number of grade repetitions at age of age at school enrollment for older versus younger students.

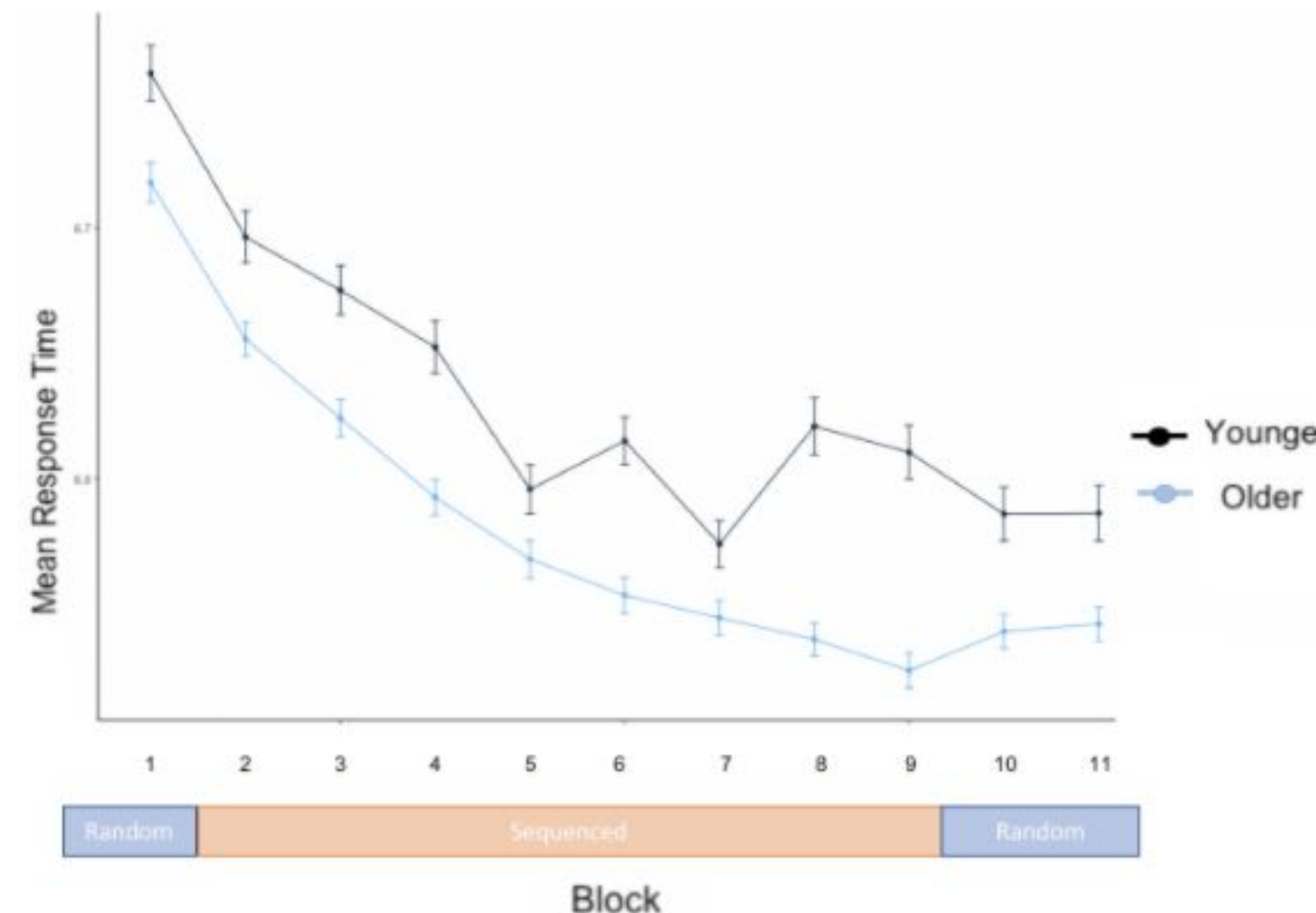### Mean Reaction time for older and Younger Children in the SRTT

Figure 4: The mean reaction time for younger (9-10 years of age) or older (11-15 year of age) the SRTT at each block.

Older children had better PL ($r(41)$=0.36, p=0.02). **PL scores did not predict PA.**
There was no interaction between age and PL for reading. There was a significant interaction between PL and PA
At 1 SD above mean for PL, PA predicted letter reading. Meaning that the the relation between phonological awareness and letter reading was stronger for children with better procedural learning

Predictor	Letter Reading b(SE)	Word Reading b(SE)	Nonword Reading b(SE)
Age	-0.95 (2.48)	-4.34 (2.18)	2.33 (1.96)
Procedural Learning	-256.41 (163.10)	-200.59 (143.85)	-5.64 (128.97)
Phonological awareness	8.41 (8.07)	7.17 (7.12)	14.70 * (6.38)
Vocabulary	1.38 * (0.62)	-0.28 (0.55)	0.84 . (0.49)
Age:Procedural Learning	17.34 (14.34)	8.82 (12.65)	-4.01 (11.33)
Age:PA	-0.51 (0.74)	-0.35 (0.65)	-1.21 * (0.58)
PL:PA	35.04** (11.65)	8.73 (10.27)	6.81 (9.21)
PL: Vocabulary	-12.40 (8.89)	4.90 (7.84)	4.24 (7.03)
Fit	R^2=0.66*** Adjusted R^2=0.57	R^2 =0.55** Adjusted R^2=0.43	R^2=0.43 ** Adjusted R^2= 0.31

Note. A significant *b*-weight indicates the semi-partial correlation is also significant. *b* represents unstandardized regression weights.

'***' indicates p <.001. '**' indicates p < .01. '*' indicates p < .05. '.' indicates p <.1

Discussion

Older children had better PL but worse PA. We found, however, that **PL was not associated with PA**. Factors such as late age at school enrollment and grade repetition might contribute to poorer PA in spite of a stronger capacity for PL among older children, as the relationship between reading and PA is reciprocal (Wagner & Torgesen, 1987)

With better PL the PA was able to support letter reading, which suggests that PL might support decoding only after the metalinguistic knowledge of PA has become more automatic, supporting previous findings (Earle et al., 2020).

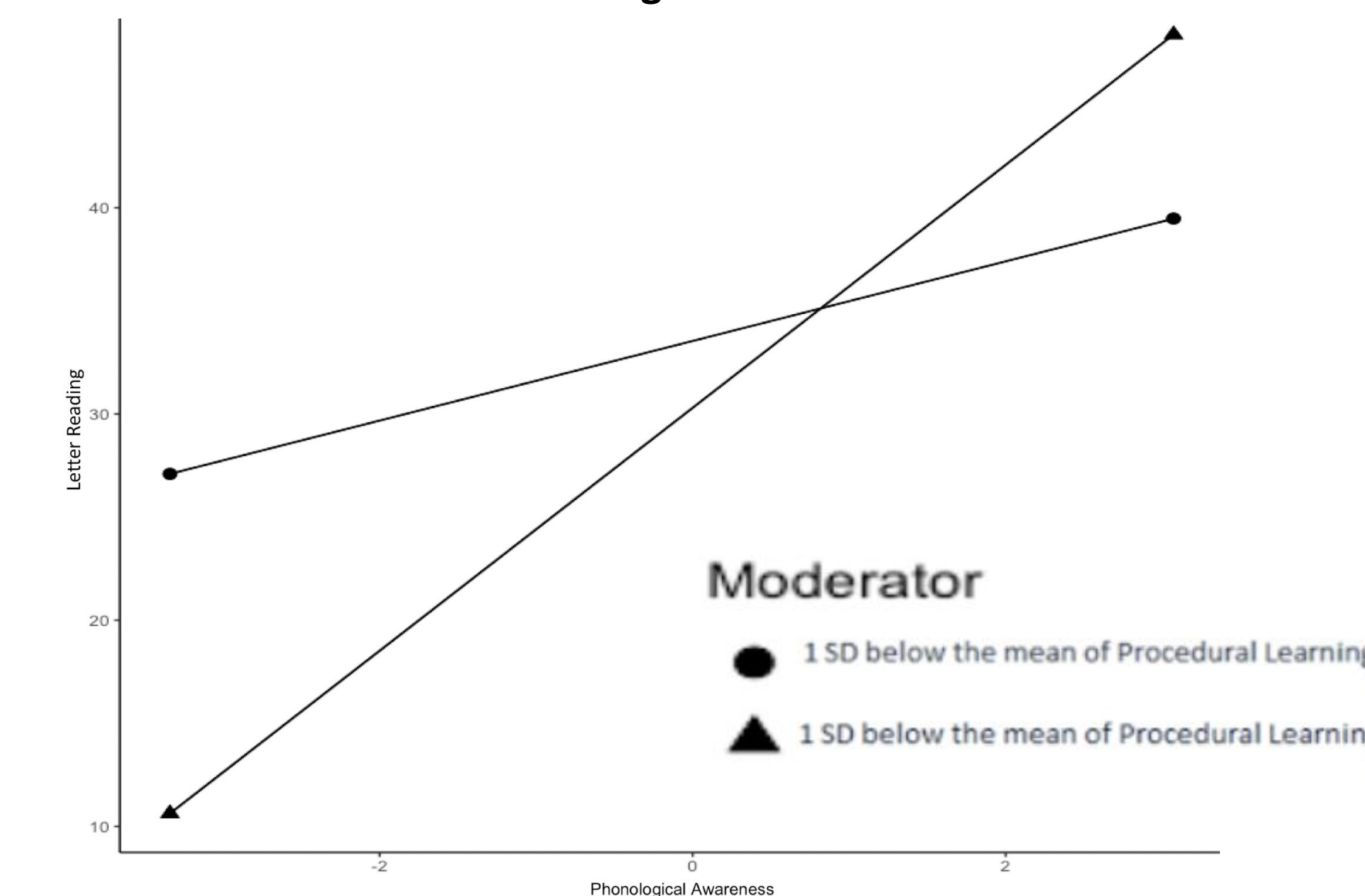### Interaction of Phonological Awareness and Procedural Learning

Figure 5: Simple slope analysis of letter reading's relation to phonological awareness at different levels of procedural learning.

Conclusions

PL contributes to reading through supporting PA's relation to literacy. This support does not depend on the child's age. Thus, our hypothesis is supported. PL supportss emergent reading similarly for both older and younger children.

We found that PL improves with age which suggests that within the same classroom are children at differing stages in their memory development, We also found that older children have poorer PA and were poorer readers, this underlines the need for more work in LMIC contexts where older children are emergent readers.

Future Directions

What is the role of school and home environment?
What is the contribution of declarative memory to reading?

References
1. DiGiulio, D. V., Seidenberg, M., O'Leary, D. S., & Raz, N. (1994). Procedural and declarative memory: A developmental study. Brain and Cognition, 25(1), 79-91.
2. Earle, F. S., Del Tufo, S. N., Evans, T. M., Lum, J. A., Cutting, L. E., & Ullman, M. T. (2020). Domain-General Learning and Memory Substrates of Reading Acquisition. Mind, Brain, and Education.
3. Factbook, C. I. A. (2012). The World Factbook. Central Intelligence Agency.
4. Finn, A. S., Kalra, P. B., Goetz, C., Leonard, J. A., Sheridan, M. A., & Gabrieli, J. D. (2016). Developmental dissociation between the maturation of procedural memory and declarative memory. Journal of Experimental Child Psychology, 142, 212-220.
5. Gove, A., & Wetterberg, A. (2011). The Early Grade Reading Assessment: Applications and interventions to improve basic literacy.
6. Hung, Y. H., Frost, S. J., Molfese, P., Malins, J. G., Landi, N., Mencl, W. E., ... & Pugh, K. R. (2019). Common neural basis of motor sequence learning and word recognition and its relation with individual differences in reading skill. Scientific Studies of Reading, 23(1), 89-100.
7. Jasinska, K. K., & Petitto, L. A. (2018). Age of Bilingual Exposure Is Related to the Contribution of Phonological and Semantic Knowledge to Successful Reading Development. Child Development, 89(1), 310-331.
8. Jasinska, K., Akpe, Y.H., Blahoua, A., Zinszer, B., Yoffo, K., Mulford, K., Curran, E., Ball, M.C., Tanoh, F. (2020). Evaluating Children's Native Language Abilities in Côte d'Ivoire: Introducing the Ivorian Children's Language Assessment Toolkit for Attié, Abidji, Baoulé, and Bété. Manuscript submitted for publication
9. Mousty, P., Leybaert, J., Alegria, J., Content, A., & Morais, J. (1994). BELEC: Batterie d'évaluation du langage écrit. Laboratoire de psychologie expérimentale, Université libre de Bruxelles.
10. Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. Cognitive psychology, 19(1), 1-32.
11. Pugh, K. R., Landi, N., Preston, J. L., Mencl, W. E., Austin, A. C., Sibley, D., ... & Molfese, P. (2013). The relationship between phonological and auditory processing and brain organization in beginning readers. Brain and language, 125(2), 173-183
12. RTI International. (2009). Manuel pour l'évaluation des compétences fondamentales en lecture. (Early Grade Reading Assessment toolkit, French adaptation). Adaptation by L. Sprenger-Charolles. Prepared for the US Agency for International Development under the EdData II project, Task Order 3, Contract No. EHC-E-01-03-00004-00. Research Triangle Park, North Carolina: RTI International.
13. Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. Cognition, 92(1-2), 231-270.
14. Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. Psychological bulletin, 101(2), 192.
15. Woodcock, R. W., McGrew, K. S., & Mather, N. (2001a). Woodcock-Johnson III. Itasca, IL: Riverside Publishing.
16. Yopp, H. K. (1995). Yopp-singer test of phoneme segmentation. Reading Teacher, 49(1), 20-29.

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