Architectures and Mechanisms of Language Processing (AMLaP) -- Berlin, Germany, September 6-8, 2018

Syntactic and semantic processing in poor comprehenders: Evidence from eye-tracking and computational modeling

Luca Campanelli[1,2], Nicole Landi[1,3], & Julie A. Van Dyke[1]

[1]Haskins Laboratories; [2]The Graduate Center, CUNY; [3]University of Connecticut

Introduction

- Individuals identified as Poor comprehenders (PC) have significant difficulty in the domain of reading comprehension despite typical intellectual ability and word reading skill
- The majority of previous work has utilized offline (standardized) assessments of comprehension skills, leaving the source of comprehension deficits in PC poorly understood (Landi & Ryherd, 2017)
- The present eye-tracking study addressed those limitations by employing two methods for directly querying the syntactic representation created during comprehension:

1. We employed the phenomenon of retrieval interference to query whether individuals assign appropriate syntactic structures to embedded clauses. Constituents with similar syntactic and semantic encodings can lead to construction of incorrect dependencies, reflected in increased reading times and poor accuracy (Van Dyke, 2007)
2. We employed syntactic surprisal derived from different language models to assess the nature of readers' linguistic representations as they are computed during reading (Brennan et al., 2016; Hale, 2014)

Participants

- N = 51 (28 female) native speakers of American English
- No reported history of learning or cognitive impairments
- Decoding scores >= 90 and P-IQ in the normal range (to ensure effects were not due to word-reading deficits or low nonverbal abilities)

	Mean (SD)	Min-Max
Age	16.9 (1.6)	13.2-19.7
P-IQ	105 (15.2)	83-140
Decoding	107 (9.6)	90-124
Reading Comp.	101 (19)	70-146

Assessments

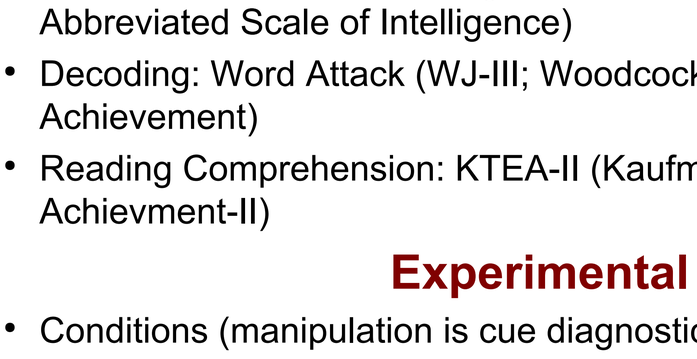
- Performance IQ: Block Design and Matrix Reasoning (WASI; Weschler Abbreviated Scale of Intelligence)
- Decoding: Word Attack (WJ-III; Woodcock-Johnson-III Tests of Achievement)
- Reading Comprehension: KTEA-II (Kaufman Test of Educational Achievment-II)

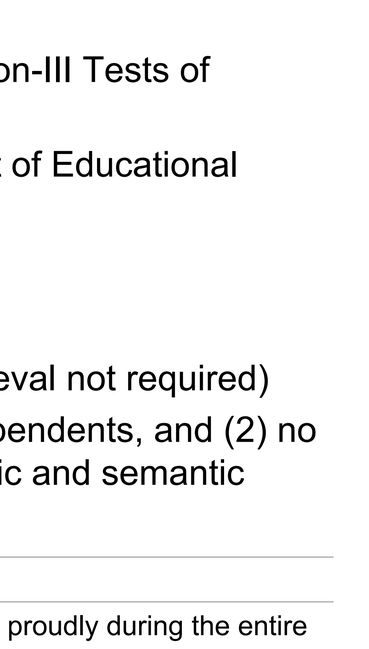
Experimental task

- Conditions (manipulation is cue diagnosticity):
  - (1) Control condition (adjacent dependents; retrieval not required)
  - → Conditions (2-4) all have five words between dependents, and (2) no distractor, (3) a syntactic distractor, (4) a syntactic and semantic distractor

Condition	Sentence
1. NoLoad	The shirt was colorful and the **father smiled** proudly during the entire game.
2. LoNoIn	The **father** with the very colorful shirt **smiled** proudly during the entire game.
3. LoSyIn	The **father** who the colorful *shirt* pleased **smiled** proudly during the entire game.
4. LoSySeIn	The **father** who the colorful *clown* pleased **smiled** proudly during the entire game.

Results: Comprehension questions



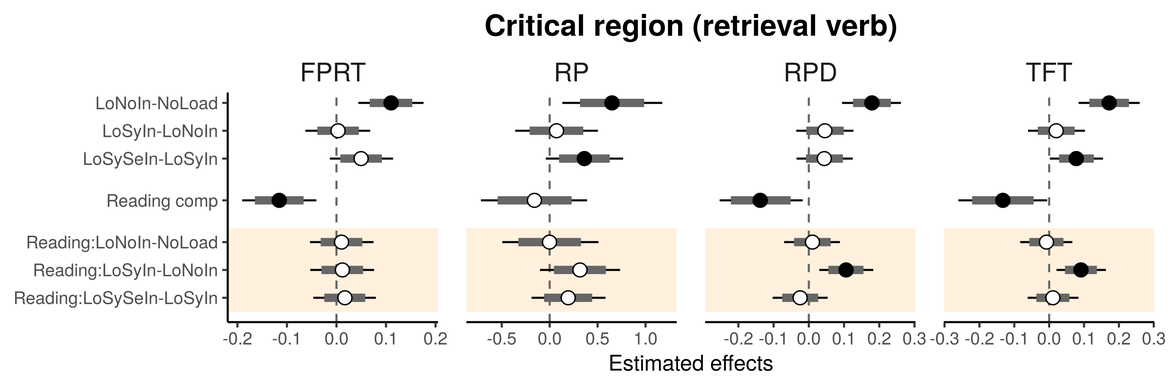


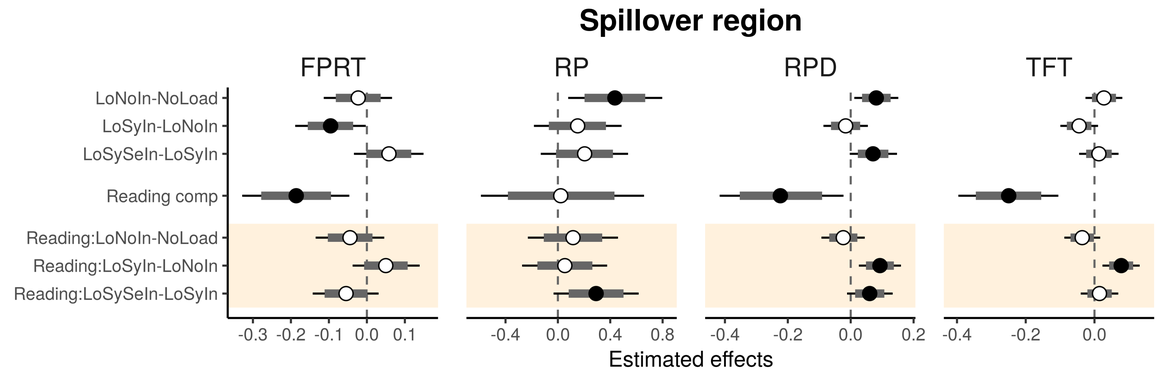
Note. Top graph: 80% (inner) and 95% (outer) uncertainty intervals. Filled points indicate significant effects. Right graphs: estimated ACC and RT by condition for 5th and 95th percentiles reading scores.

Key results

- Semantic interference: comparable effect in all readers
- Negative effect of syntactic interference greater in good than poor readers (for ACC, p = .054)

Results: Eye-tracking





Note. FPRT = first pass reading time; RP = regression probability; RPD = regression path duration; TFT = total fixation time.

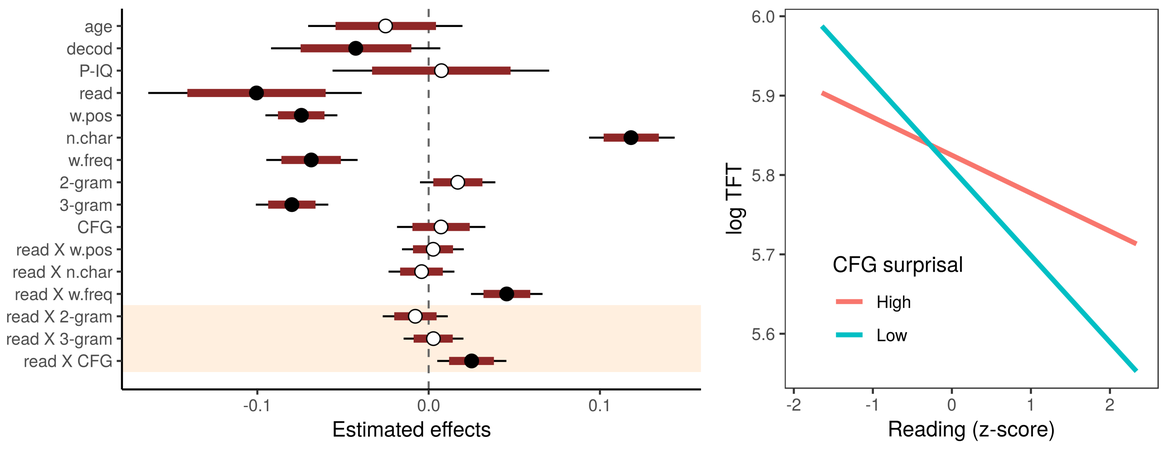
Key results

- Negative effect of syntactic interference greater in good than poor readers (RPD and TFT at both critical and spillover regions)
- Semantic interference effect greater in good than poor comprehenders (RP and RPD at the spillover region)

Computational modeling

Surprisal derived from different language models was used to predict eye movement data (TFT) for whole sentences (except first and last word):

- **n-gram** $P(W_n|W_{n-1})$: linear, word-to-word dependencies
- **CFG** (Context-Free Grammar; grammar rules + lexicon): hierarchical syntactic representations



Key results

- Effects of 2- and 3-gram comparable in all readers
- CFG better model for good than poor readers

Discussion

- Poor readers use the same memory retrieval mechanisms as skilled comprehenders (Johns et al., 2015): the semantic interference effects were comparable in all participants both offline (ACC and RT) and online at the critical region -- note RP and RPD at the spillover region
- The negative effect of syntactic interference was consistently stronger in good than poor comprehenders (PC), pointing to impaired syntactic processing in PC. When the grammatical role of the distractor noun is correctly encoded, it matches the retrieval cue of the main verb, thus generating memory interference and leading to a relative performance disadvantage for skilled readers compared to PC
- The computational modeling results further point to impaired syntactic processing as a key distinguishing component for comprehension skill. Phrase structure grammar (CFG) better modeled the reading pattern of skilled readers than that of poor comprehenders

Key References

Johns, C. L., Matsuki, K., & Van Dyke, J. A. (2015). Poor readers' retrieval mechanism: Efficient access is not dependent on reading skill. Language Sciences, 6, 1552.

Landi, N., & Ryherd, K. (2017). Understanding specific reading comprehension deficit: A review. Language and Linguistics Compass, 11(2), e12234.

Van Dyke, J. A. (2007). Interference effects from grammatically unavailable constituents during sentence processing. Journal of Experimental Psychology: Learning, Memory, and Cognition, 33(2), 407–430.

Hale, J. T. (2014). Automaton theories of human sentence comprehension. Sanford, California: CSLI.

Brennan, J. R., Stabler, E. P., Van Wagenen, S. E., Luh, W.-M., & Hale, J. T. (2016). Abstract linguistic structure correlates with temporal activity during naturalistic comprehension. Brain and Language, 157–158, 81–94.

Contact

Luca Campanelli,
campanelli.l@gmail.com

Acknowledgments

This material is based upon work supported by the National Institutes of Health, Grants No. HD-073288 and P01 HD01994