

# Eye-Movement Patterns Reveal Effects of Reading Skills on On-line Language Processing

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# Motivation

- Most models of eye movements in reading assume that **lexical properties (e.g., word frequency and length)** are the primary determiners of the eyes' progress in reading text (Joseph, Nation, & Liversedge, 2013; Reichle et al., 2013);
- Our interests:
  - Effects of reading skill differences on eye movement patterns in reading;
  - Interactions between reading skills and lexical properties.

# Research Questions

- Given that not everyone's experience and skills are the same:
  - Do eye movement patterns in reading connected text **co-vary with conventional measures of reading skills?**
  - Do effects of lexical properties on eye movements **interact with reading skill differences?**

# Participants

- 46 native English speakers (age range = 16 -24; mean = 20.58; SD = 2.25).
- **Wide range of individual differences:**
  - Adult education program, community college;
  - Or no enrollment at all.
- Pre-screened to ensure ability to read simple sentences with comprehension.
- Continuous sampling of individuals, **not extreme groups** based on particular reading skills.

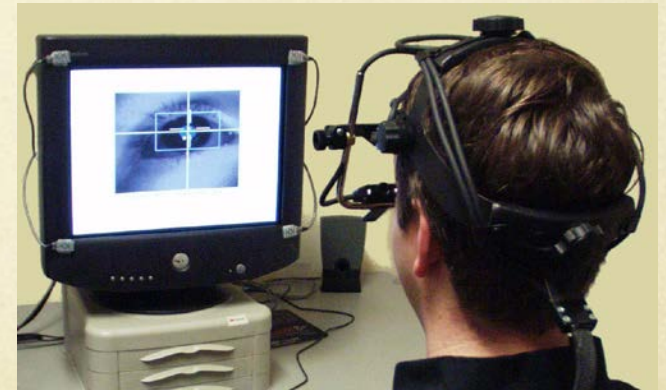
# Components of Reading Skills

Name	Label
Vocabulary	<b>ppvt.raw:</b> Peabody Picture Vocabulary Test
	<b>wasi.v.raw:</b> Wechsler Abbreviated Scale of Intelligence
Decoding	<b>wid.raw:</b> Word Identification Test
	<b>watt.raw:</b> Word Attack in Woodcock Reading Mastery
Reading Comprehension	<b>piat.r.raw:</b> Print Sentence Comprehension Test
	<b>gort.comp:</b> Passage Comprehension Test
Print experience	<b>MRT:</b> Magazine Recognition Test
	<b>ART:</b> Author Recognition Test
Visual Working Memory	<b>corsi:</b> Block-Tapping Test
Oral Reading Fluency	<b>gort.fluen:</b> Gary Oral Reading Fluency Test
Listening Comprehension	<b>piat.l.raw:</b> Listening Sentence Comprehension Test
Verbal Working Memory	<b>sspan.corr:</b> Verbal Working Memory Test

(cf. Braze, Tabor, Shankweiler, & Mencl, 2007)

# Task

- Participants **covertly read sentences**, shown one by one in a monospace font on a computer monitor, **clicked a button when done**, and **answered a comprehension question** in about 30% of trials (mean accuracy = 91.32%, SD = 6.7).
- Eye movements were recorded with an Eyelink II head-mounted device (sampling rate = 250 Hz).



# Materials

- 28 simple sentences:
  - E.g., “One of the lawyer's best clients always paid his bills early.”
- 44 sentences with embedded clauses:
  - E.g., “The waiter had told the customer that the pies were fresh.”
- No manipulation of words in sentences.

# Lexical Properties

- Lexical property measures (based on COCA database (Corpus of Contemporary American English)):

Name	Label
Current word length	$Len_w$
Current word frequency	$Freq_w$
Previous word length	$Len_{w-1}$
Previous word frequency	$Freq_{w-1}$
Next word length	$Len_{w+1}$
Next word frequency	$Freq_{w+1}$



# Particulars of the Data

- Data of 44 subjects for analyses (data of two subjects were removed due to incomplete data):
  - 320 content words.
  - 12,957 eye-movement observations.

# Eye-movement (EM) Measures

- **First-pass reading time:** Summed durations of first-pass fixations on current word.
- **First-pass regression incidence:** Whether or not there is a backward eye-movement from the current word.
- These measures reflect the early stages of lexical processing and textual integration (Kuperman & Van Dyke, 2013).

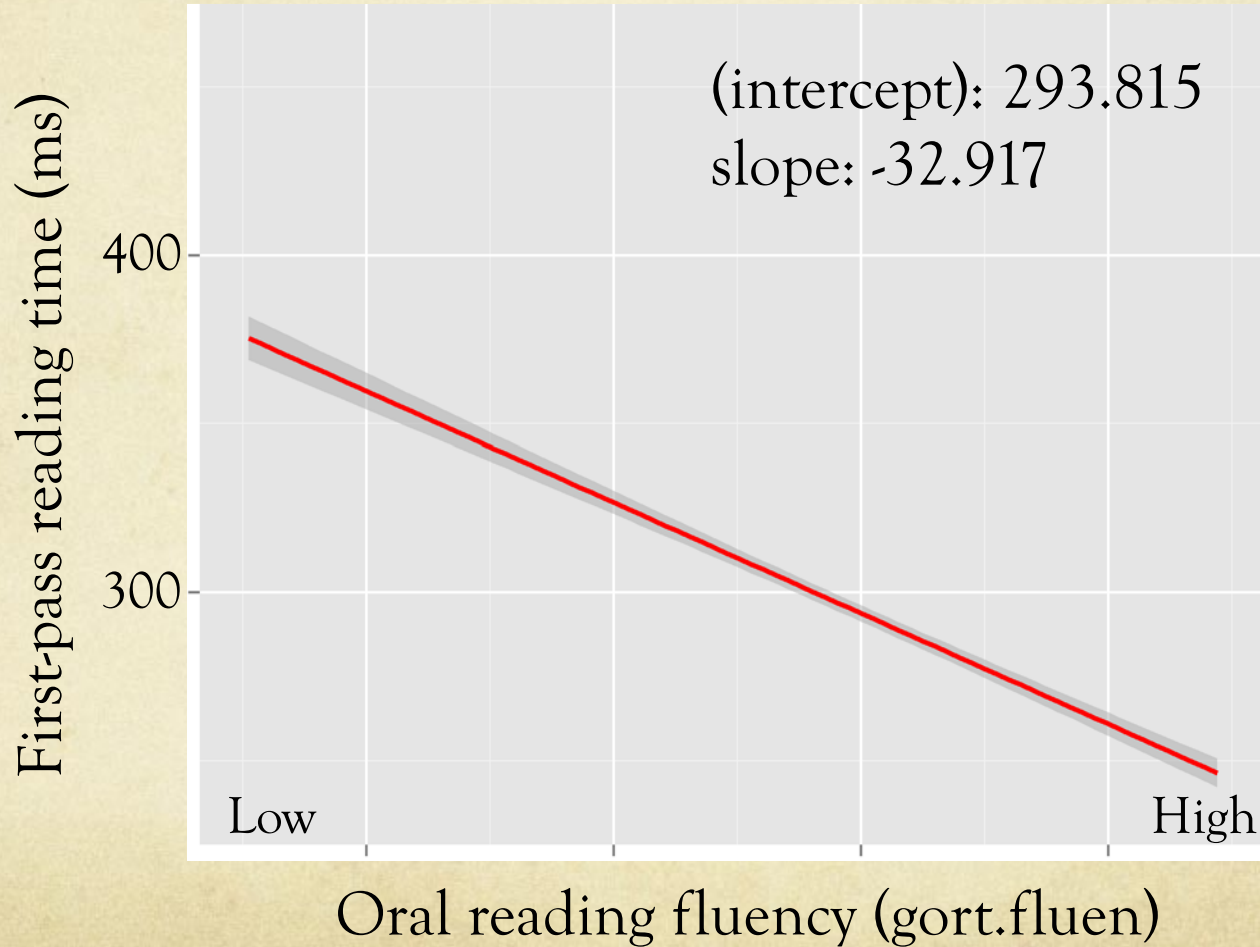
# Statistical Analyses

- Mixed effects linear (Quené & van den Bergh, 2008) or logistic regression (Jaeger, 2008).
- **Lexical properties analyses:**
  - EM measures  $\sim$  lexical properties;
  - Main effects of lexical properties on eye-movement measures (Joseph et al., 2013; Kuperman & Van Dyke, 2011; Valle, Binder, Walsh, Nemier, & Bangs, 2013).
- **Individual differences analyses:**
  - EM measures  $\sim$  lexical properties + reading skills + lexical properties : reading skills.

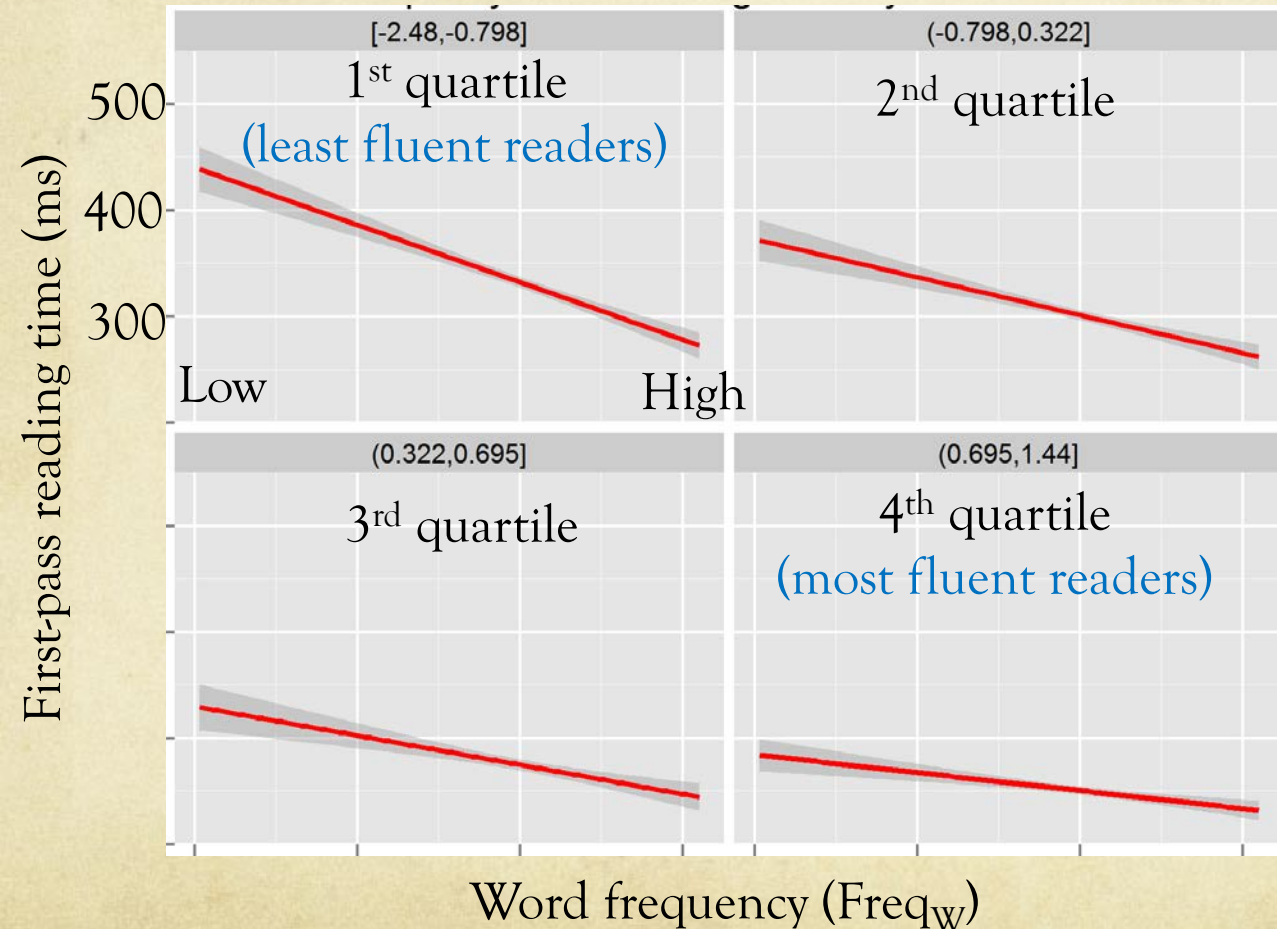
# Individual Differences Analyses

EM measures	Reading skills	$\beta$	SE	t	p<
First-pass reading time	<i>gort.fluen</i>	-21.99	10.13	-2.17	.05
	<i>gort.fluen</i> : $Freq_W$	5.71	1.53	3.73	.001
	<i>printexp</i> : $Freq_W$	5.37	1.80	2.98	.005
	<i>piat.l.raw</i> : $Freq_W$	-3.41	1.25	-2.73	.01
	<i>printexp</i> : $Len_W$	-2.99	.89	-3.36	.01
	<i>decod</i> : $Len_W$	-3.92	.86	-4.54	.001
	<i>sspan.corr</i> : $Len_W$	2.57	.71	3.64	.001
	<i>corsi</i> : $Len_W$	-1.56	.67	-2.34	.05

# Oral Reading Fluency



# Oral Reading Fluency x $Freq_W$

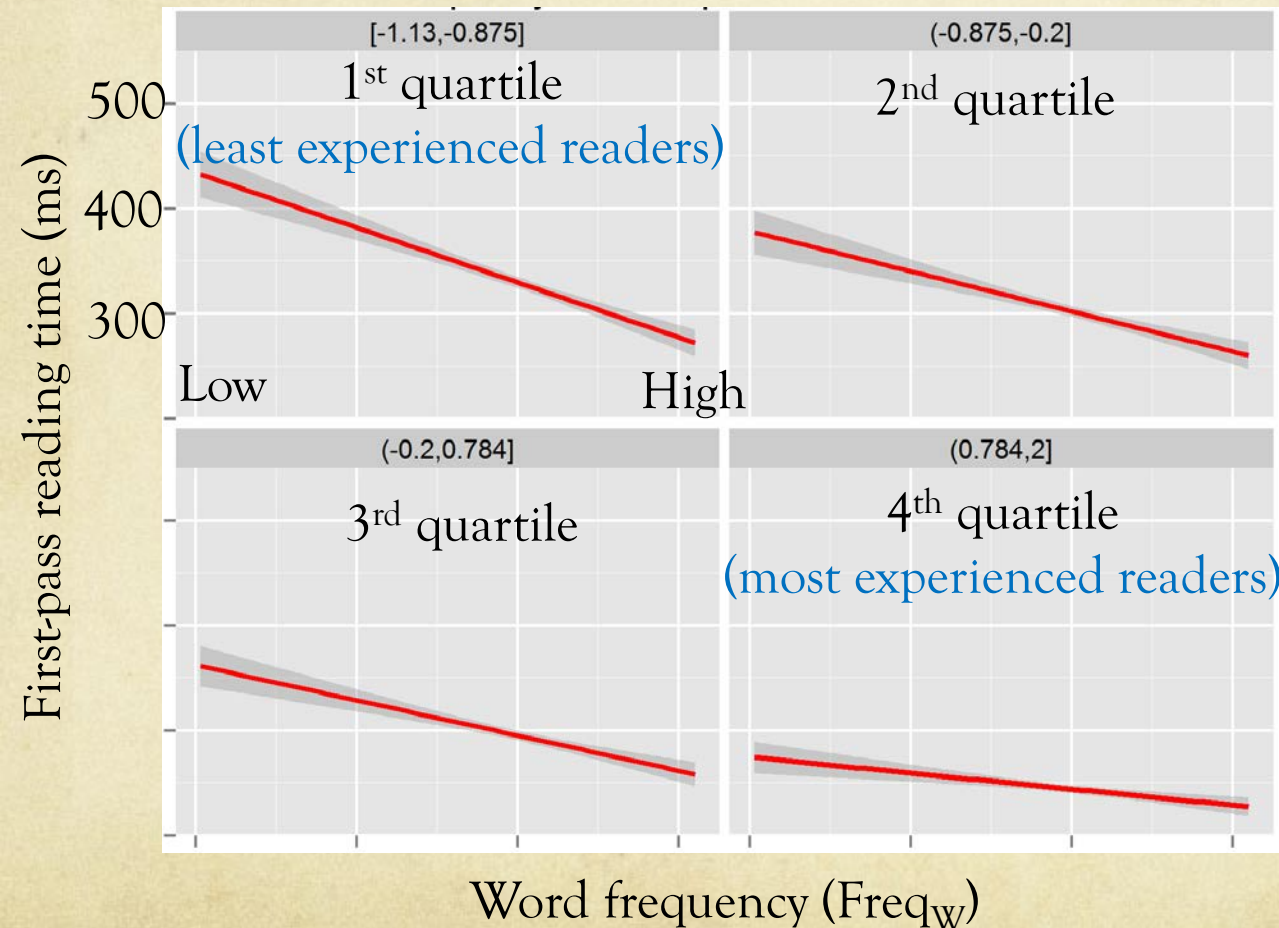


Q	slope	intercept
1 <sup>st</sup>	-27.002	332.243
2 <sup>nd</sup>	-17.855	301.490
3 <sup>rd</sup>	-13.768	275.005
4 <sup>th</sup>	-8.461	250.819

Monotonic drop of slopes and intercepts;

Fluent readers are least sensitive to  $Freq_W$ .

# Print Experience x Freq<sub>w</sub>

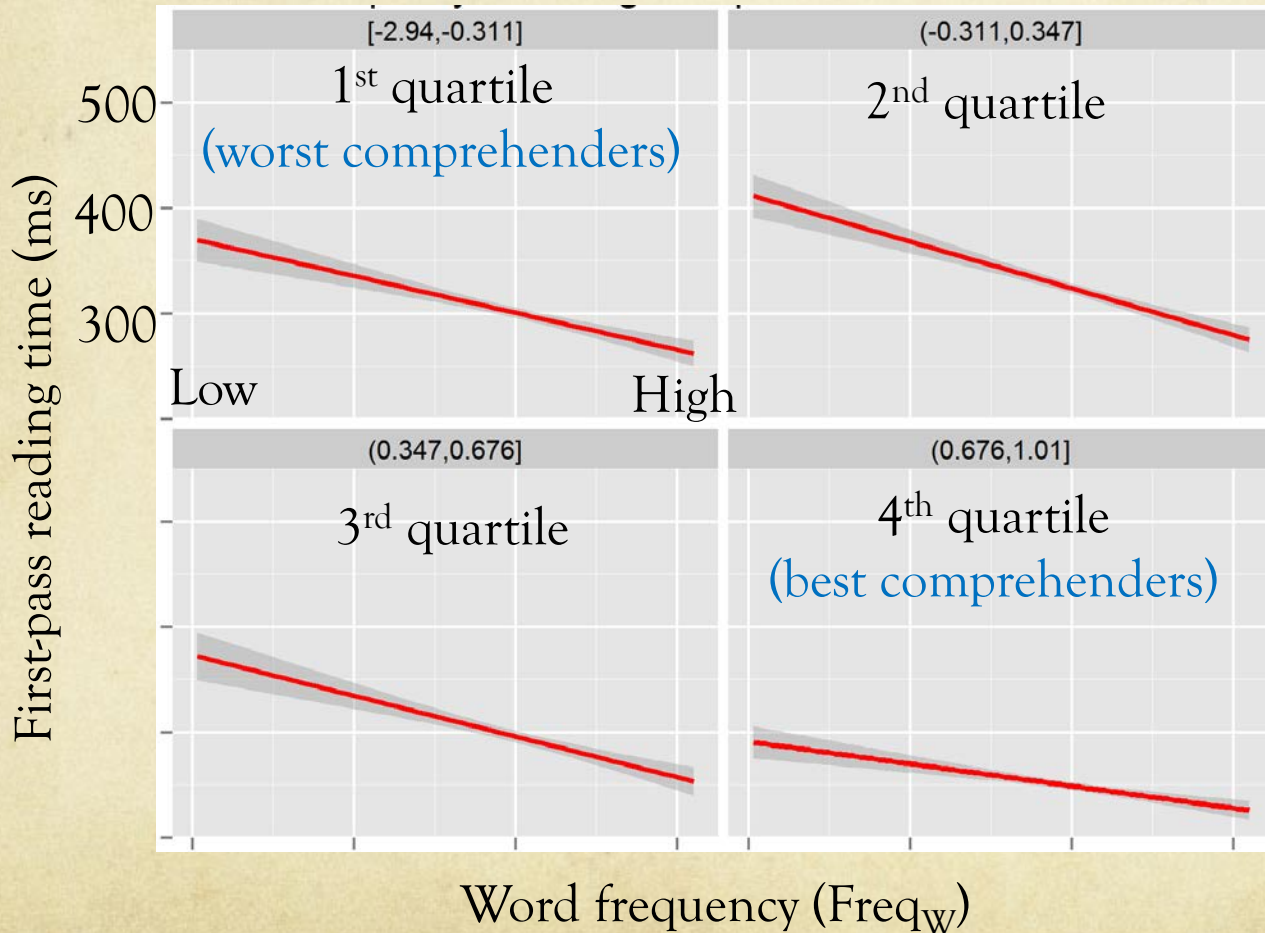


Q	slope	intercept
1 <sup>st</sup>	-26.113	329.759
2 <sup>nd</sup>	-19.108	302.296
3 <sup>rd</sup>	-16.758	295.430
4 <sup>th</sup>	-7.629	244.388

Monotonic drop of slopes and intercepts;

Experienced readers are least sensitive to Freq<sub>w</sub>.

# Listening Comprehension x $Freq_W$



Q	slope	intercept
1 <sup>st</sup>	-17.491	300.869
2 <sup>nd</sup>	-22.203	324.147
3 <sup>rd</sup>	-19.307	296.115
4 <sup>th</sup>	-10.515	249.274

Non-monotonic drop of slopes and intercepts;

Good comprehenders are least sensitive to  $Freq_W$ .



# Conclusions

- Readers having **poor component reading skills** (e.g., oral reading fluency, print experience, comprehension) are **more sensitive to lexical properties** during reading.
- Interactions between reading skills and lexical properties on eye-movements show **monotonic or non-monotonic effects**.
- Variations in conventionally measured reading skills can predict on-line reading behavior → A further indicator of their validity and relevance for reading models, reading instruction, and reading remediation.

# Future Directions

- Relationship between reading skill differences and online oral reading behaviors;
- Abilities to deal with comprehension challenges due to syntactic or pragmatic anomalies.

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