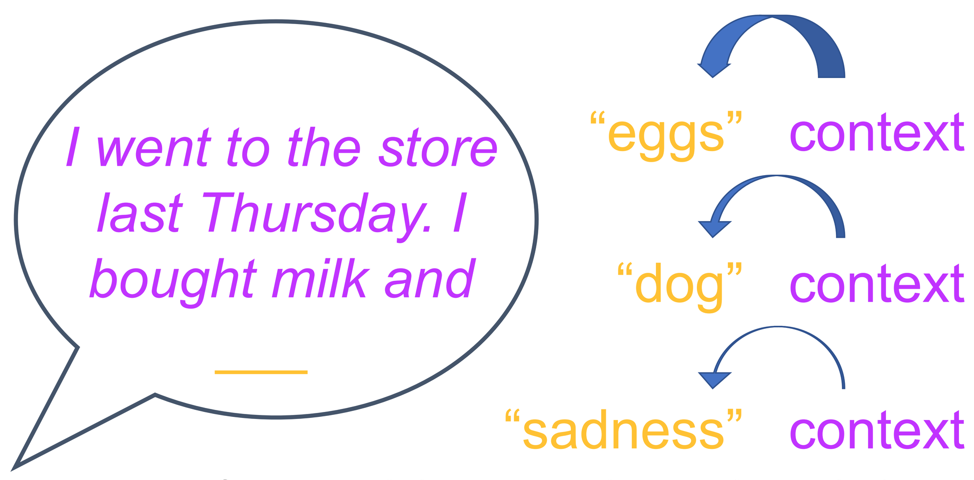
Lexical predictability in schizophrenia: A computational approach to quantifying and understanding thought disorder

Victoria Sharpe[1], Sabrina Ford[2], Samer Nour-Eddine[1], Lena Palaniyappan[2,3] & Gina Kuperberg[1,4]

[1]Tufts University; [2]Robarts Research Institute, Western University, Ontario;
[3]Douglas Mental Health University Institute, McGill University; [4]Department of Psychiatry, Massachusetts General Hospital

INTRODUCTION

- Natural speech provides objective, quantifiable data that can potentially serve as a clinical biomarker for schizophrenia & give insight into mechanisms underlying disordered speech
- **Lexical predictability**: probability that a given word will be produced based on its prior context
  - In healthy adults, is amongst the best predictors of behavioral processing and neural activity[a,b,c,d]
  - Important role in effective communication[e,f]



- We used the predictive language model GPT-3[d] to quantify word-by-word predictability of natural speech from people with schizophrenia and healthy controls, asking whether:

a) relative to healthy controls, lexical predictability is reduced in the language produced by patients,
b) patients are relatively more impaired in using global versus local context to produce upcoming words, and
c) these abnormalities are linked to clinical ratings of positive thought disorder

METHOD

Data Collection

- 70 patients recruited during their first episode of psychosis[g,h]
- 36 healthy controls [g,h]
- 1-minute descriptions of 3 different pictures from the Thematic Apperception Test → 3 unique transcripts per participant
- Participant utterances extracted
  - spellings and punctuation standardized

	Patients	Controls
Age	22.24(SD = 4.37)	21.52(SD = 3.32)
Sex	F: 14; M: 56; NB: 0	F: 12; M: 24; NB: 0
Mean Utterance Length (in words)*	72.80 (SD = 51.74)	94.60 (SD = 56.76)
PANSS Total*	25.48 (SD = 6.86)	8.00 (SD = 0.00)
TLI Total*	1.56 (SD = 1.38)	0.30 (SD = 0.40)
TLI Disorganization*	1.00 (SD = 1.21)	0.16 (SD = 0.26)
TLI Impoverishment*	0.56 (SD = 0.70)	0.14 (SD = 0.25)

* Indicates a significant difference between groups

Data Processing

GPT-3 "davinci-002" predictability was computed for each word of each participant utterance

- First, we gave GPT-3 all available context for each word
- We then manipulated context length within words by giving the model prior contexts ranging from 1 to 50 words in length for each word

Data Analysis

- Excluded disfluencies and function words
- LMERs w/ maximal random effects structures
  - Predictability & Context Length log-transformed
  - Modeled subject-, utterance-, and word-level confounds

"They look like they're farmers…"
"look like they're farmers…"
"like they're farmers…"
"they're farmers…"

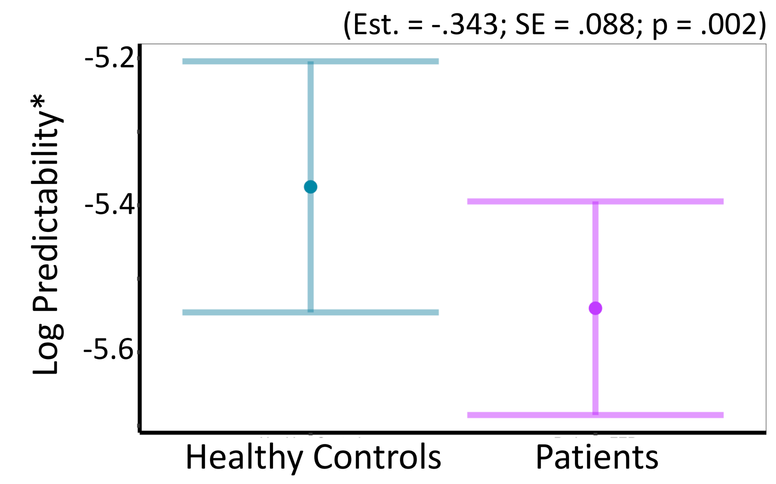
P("look" | "They")

Word	P_1wd	P_2wds	P_3wds	P_4wds	…
They	-	-	-	-	-
look	0.0001	-	-	-	-
like	0.1510	0.1700	-	-	-
they're	0.0002	0.0004	.1812	-	-
farmers	0.0002	0.0003	0.0004	0.0005	-
…	…	…	…	…	…

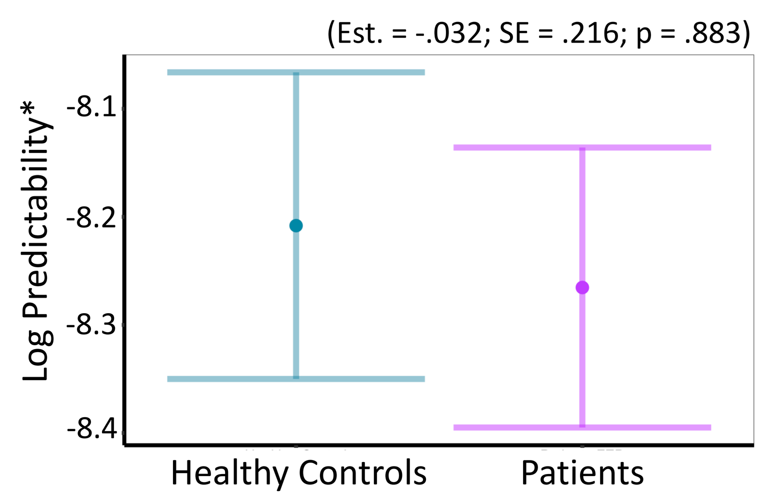
P("farmers" | "look like they're")

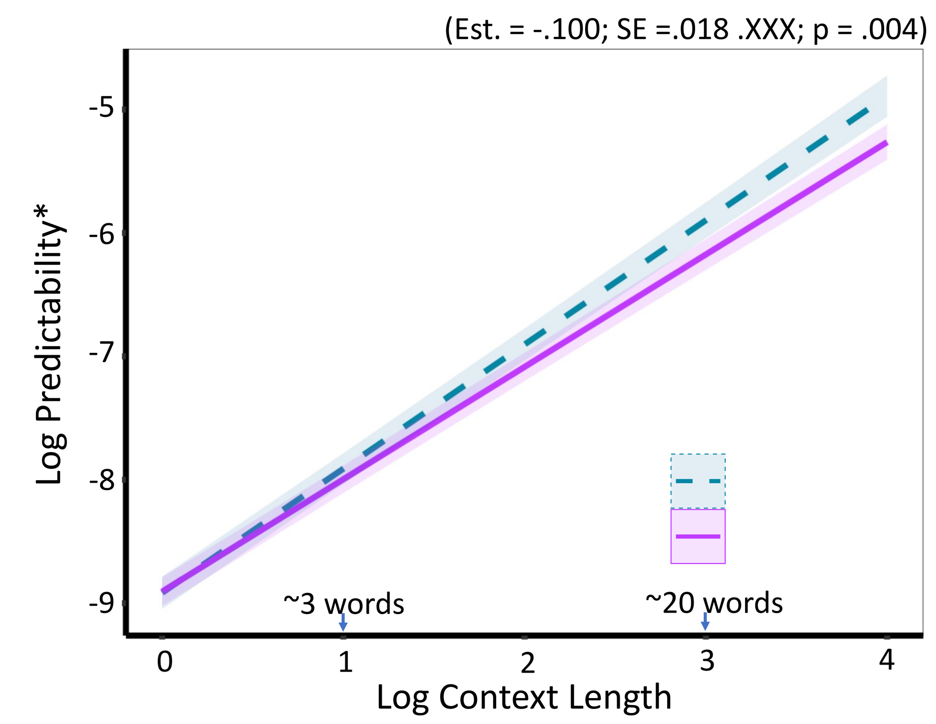
RESULTS

- Overall mean lexical predictability was indeed lower in patients than in controls.

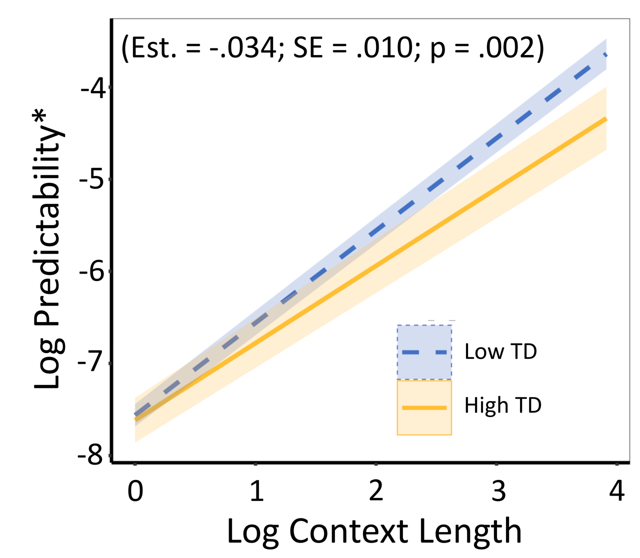


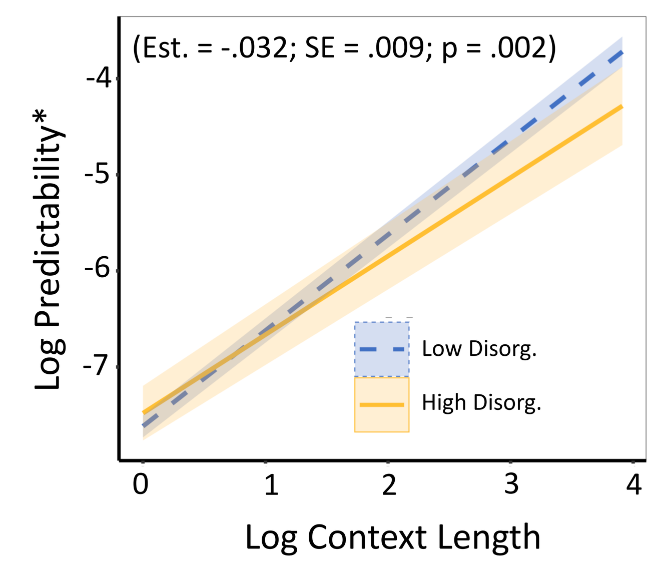
- However, use of very local context appeared to be intact.

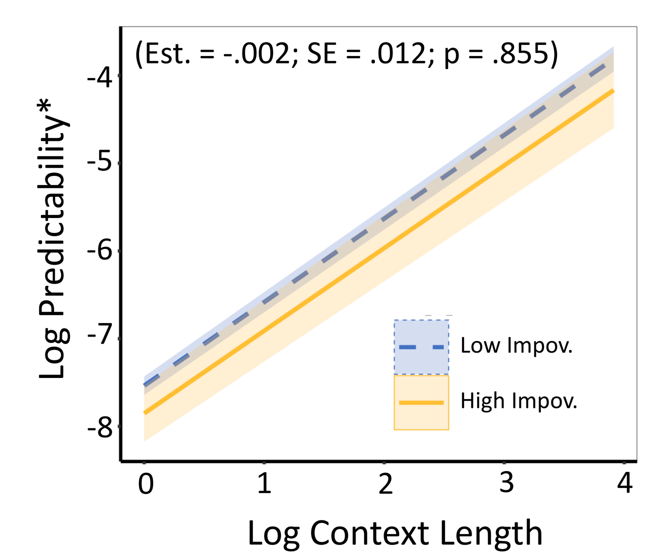




- The difference in overall predictability was driven by patients' failure to increase predictability with additional context to the same degree as in controls (an interaction between Context Length and Group).







- The degree to which use of global context was impaired was linked to overall scores from the Thought and Language Index[i], even after accounting for overall symptom severity
- It was also linked to Disorganization subscores, but not to Impoverishment subscores

* Log Predictability as predicted by the LMER models

CONCLUSIONS

- Our findings suggest that incoherent language output observed in schizophrenia may relate to impaired use of global (vs. local) context to produce upcoming words.
- In line with previous neural evidence showing patients have difficulties using global context to *predict* upcoming words during language comprehension[j,k]
- Connects to a large body of research documenting abnormalities in predictive processing in schizophrenia across multiple domains[l]
- We suggest lexical predictability may provide a useful metric that is easily quantified by computational models, has face validity with thought disorder, and may provide insights into neurocognitive mechanism.

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