Computational Speech and Language Biomarkers for Psychosis Symptoms during Acute Hospitalization

Sunny X. Tang, M.D., Michael J. Spilka, Ph.D., Sarah Berretta, B.A., Leily Behbehani, B.S., Michael L. Birnbaum, M.D., Ema Saito, M.D., Anna Costakis, M.D., M.B.A., Jessica Robin, Ph.D., Majnu John, Ph.D., Mark Liberman, Ph.D., Bill Simpson, Ph.D., John M. Kane, M.D.

Contact Me!
stang3@northwell.edu
@STANGlab

Figure 1. Study Design

	Session 1	Session 2	Session 3	Session 4
Timing:	Admission	Discharge	3 Months	6 months
N Participants:	68	54	22	18
Assessments:	• Language Tasks via WLL iOS App • Psychosis Symptoms (BPRS) • Negative Symptoms • Diagnostic interview	• Language Tasks via WLL iOS App • Psychosis Symptoms (BPRS) • Negative Symptoms • Social Cognitive Assessments • Global Functioning	• Language Tasks via WLL iOS App • Psychosis Symptoms (BPRS) • Negative Symptoms • Comprehensive neurocognitive evaluation • Global Functioning	• Language Tasks via WLL iOS App • Psychosis Symptoms (BPRS) • Negative Symptoms • Social Cognitive Assessments • Global Functioning

Study Design:
- Prospective longitudinal cohort study of people hospitalized for psychosis exacerbations.
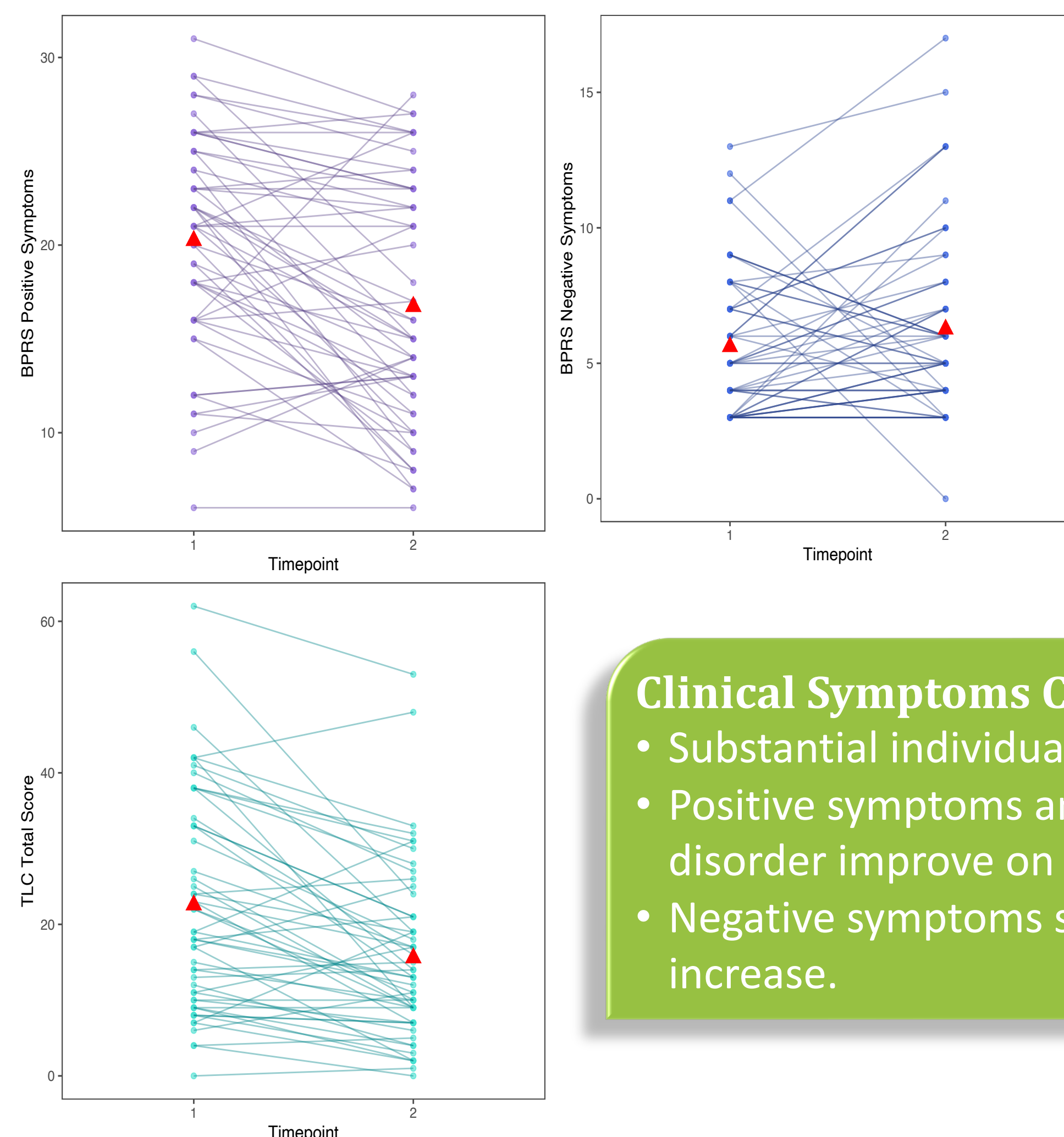- 54 participants assessed at admission and then after stabilization.

Table 1. Participant Characteristics

Characteristic	Values
N	54
Age	26.1 ± 4.7 years
Gender	
Man	38 (70%)
Woman	11 (20%)
Non-Binary	3 (6%)
Not Reported	2 (4%)
Race	
Black	24 (44%)
Asian	11 (20%)
White	10 (19%)
Multiple	3 (6%)
Other / Not Reported	5 (9%)
Hispanic Ethnicity	6 (11%)
Education	14.0 ± 1.8 years
Diagnosis	
Schizophrenia	29 (54%)
Schizoaffective Disorder	13 (24%)
Unspecified Psychotic Dis.	7 (13%)
Bipolar I w. Psychosis	3 (6%)
Schizophreniform Dis.	2 (4%)
Follow-up Interval	13.0 ± 5.5 days

Participants:
- Young people
- Mostly men
- Racially diverse
- Mostly SSD
- Follow-up 1-3 weeks, mean 13 days

Figure 2. Changes in Clinical Symptoms

Clinical Symptoms Changes:
- Substantial individual variability.
- Positive symptoms and thought disorder improve on average.
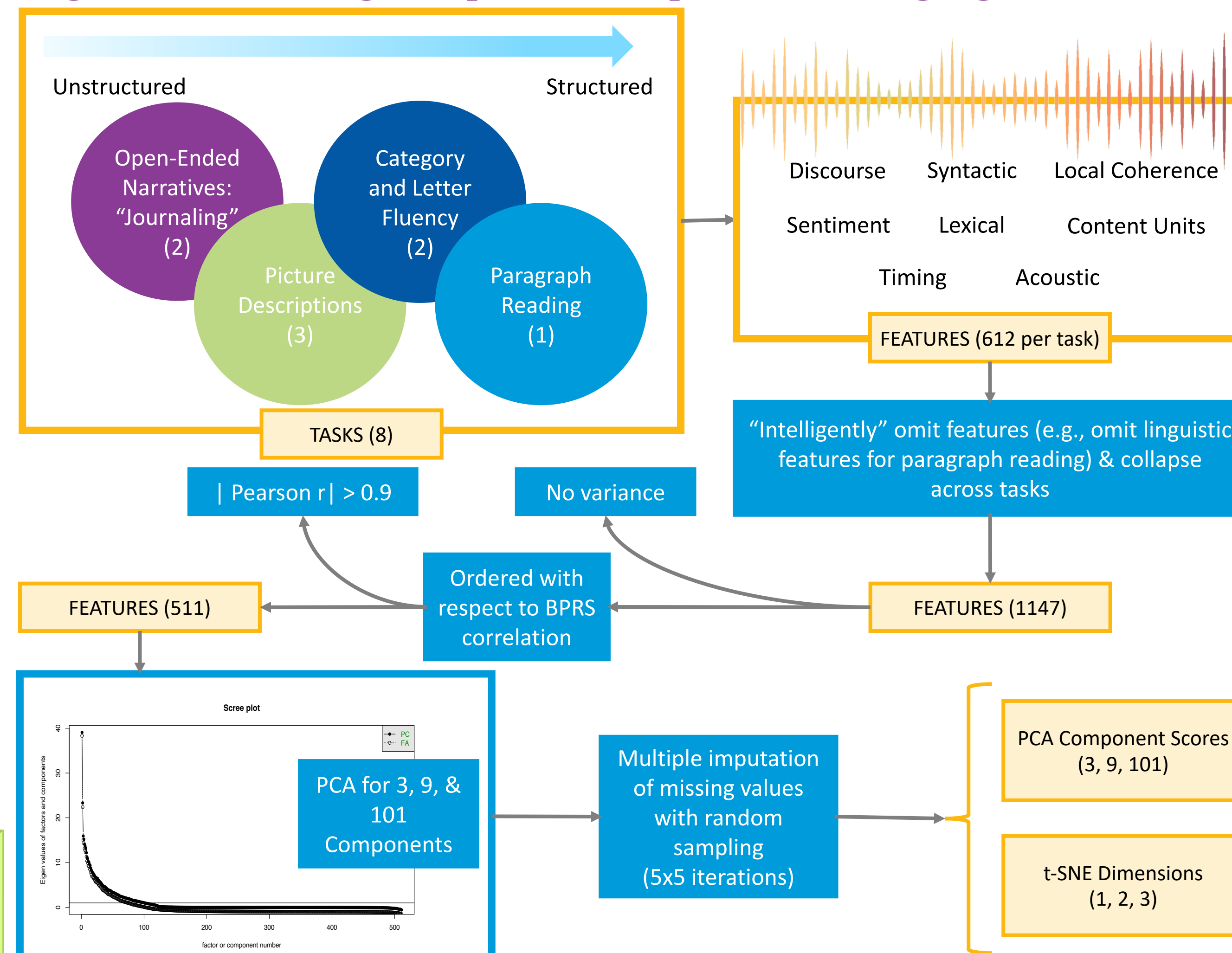- Negative symptoms slightly increase.

Objective:

- Can objective computational speech and language features can track changes in psychosis symptoms?
- Outcomes of Interest:
  - Positive Symptoms (BPRS)
  - Negative Symptoms (BPRS)
  - Thought Disorder / Disorganization (TLC)

Key Findings:

- Computational speech and language features are promising markers of treatment outcomes in psychosis.
- Improvements in positive symptoms were related to changes in vocabulary and syntax, especially in components of the noun phrase.
- Improvements in negative symptoms were related to greater ideational richness and fewer/shorter pauses.
- Improvements in thought disorder and disorganized speech were related to changes in language organization and semantic content across utterances.

Figure 3. Generating Computational Speech and Language Features
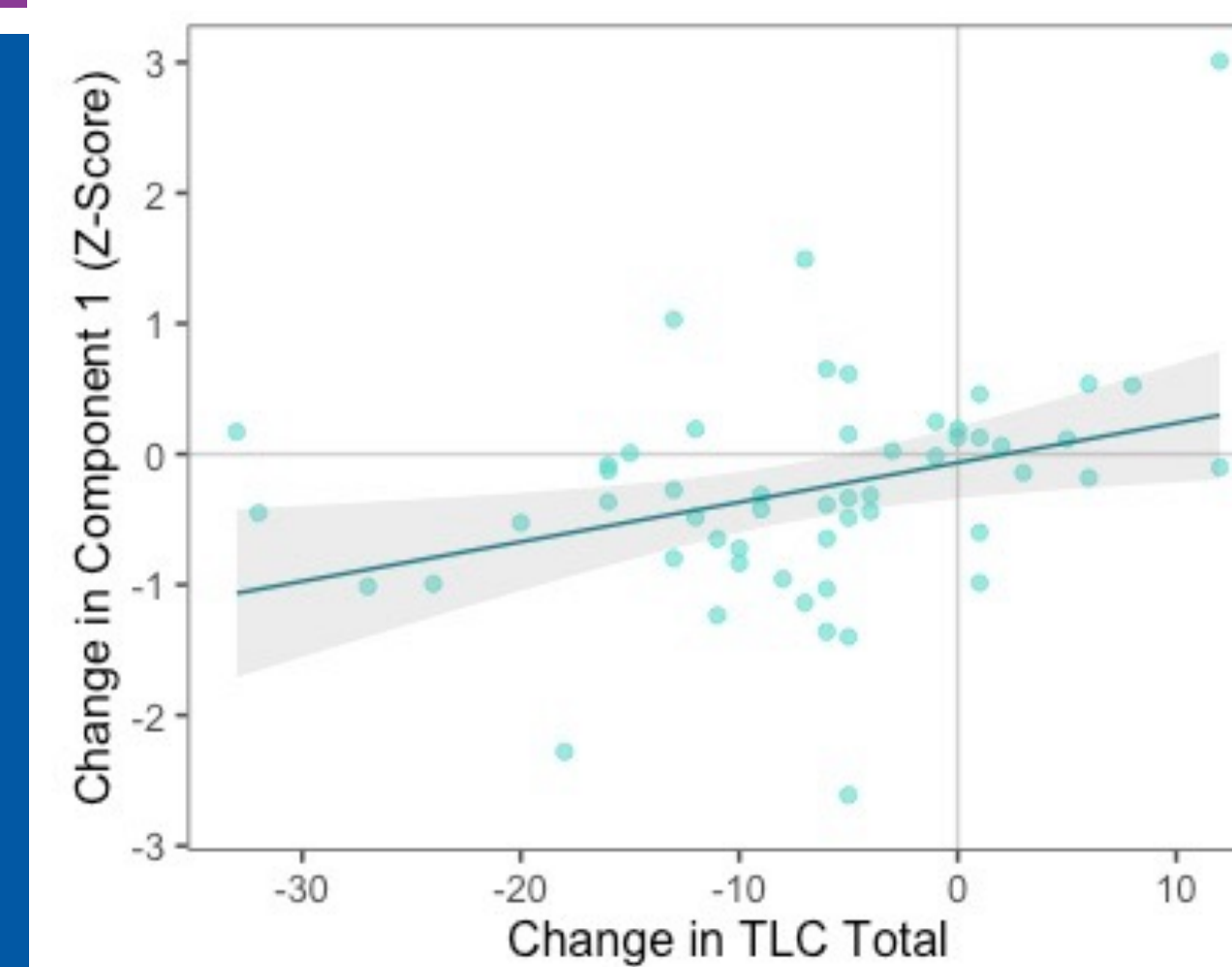

Computational Features:
- Raw features collapsed to 1147 features.
- Removed no variance or high collinearity, to generate 511 features.
- Component scores (3, 9, or 101 components) and t-SNE dimensions were calculated after imputation of missing values.

Figure 4. Predicting Changes in Clinical Symptoms with 3-Component PCA Scores

Linear Mixed Models:
- outcome ~ timepoint + predictors + ~1|subject
- FDR correction for multiple comparisons (x3 components)
- Results shown for 3-Component PCA. Other PCA solutions and the raw features also demonstrated positive results.
- t-SNE dimensions did not demonstrate significant relationships with symptom changes
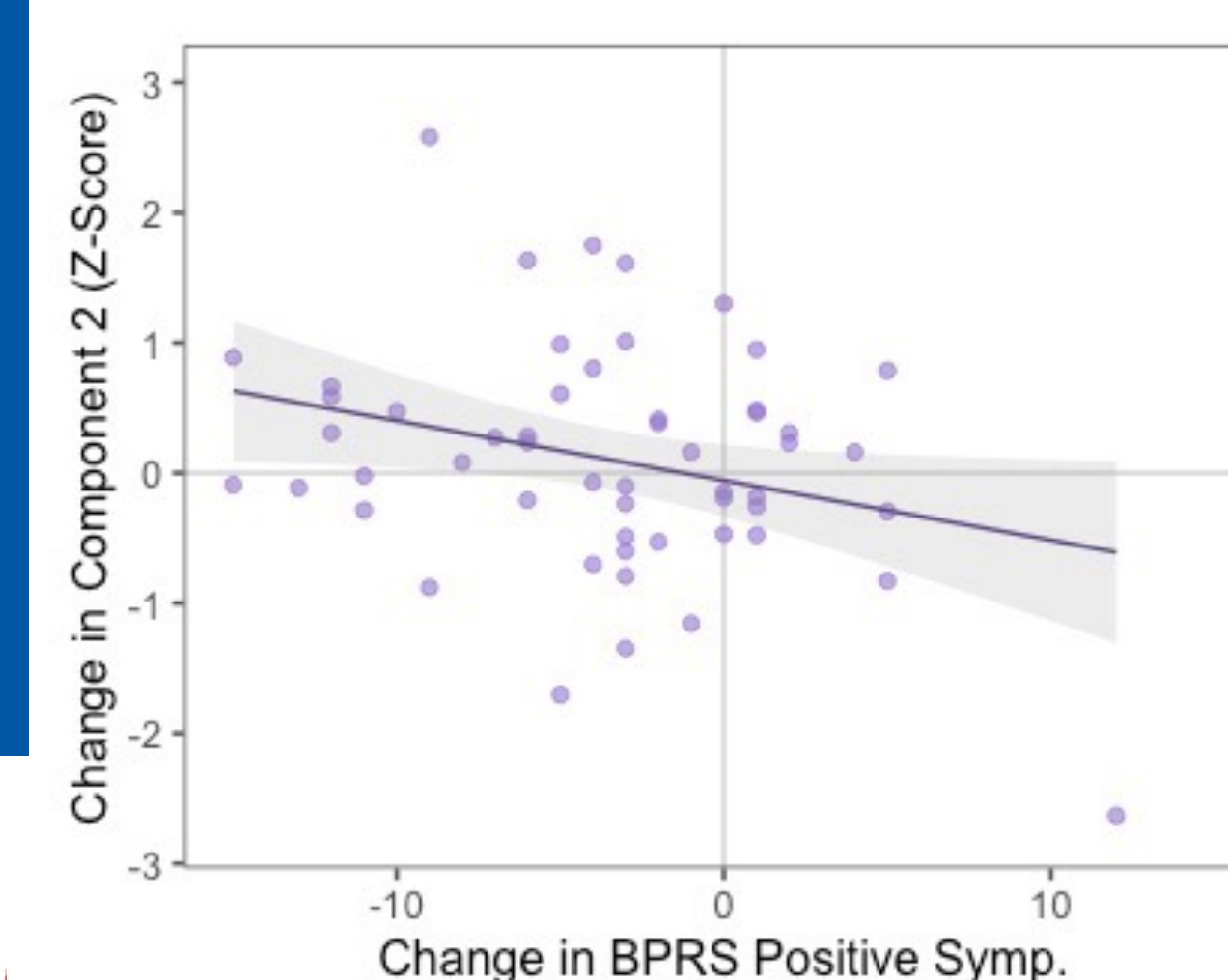
A) Component 1

- Significantly related to thought disorder
  - Std. Beta = 0.008
  - p = 0.008**

C1 - Top Loading Features

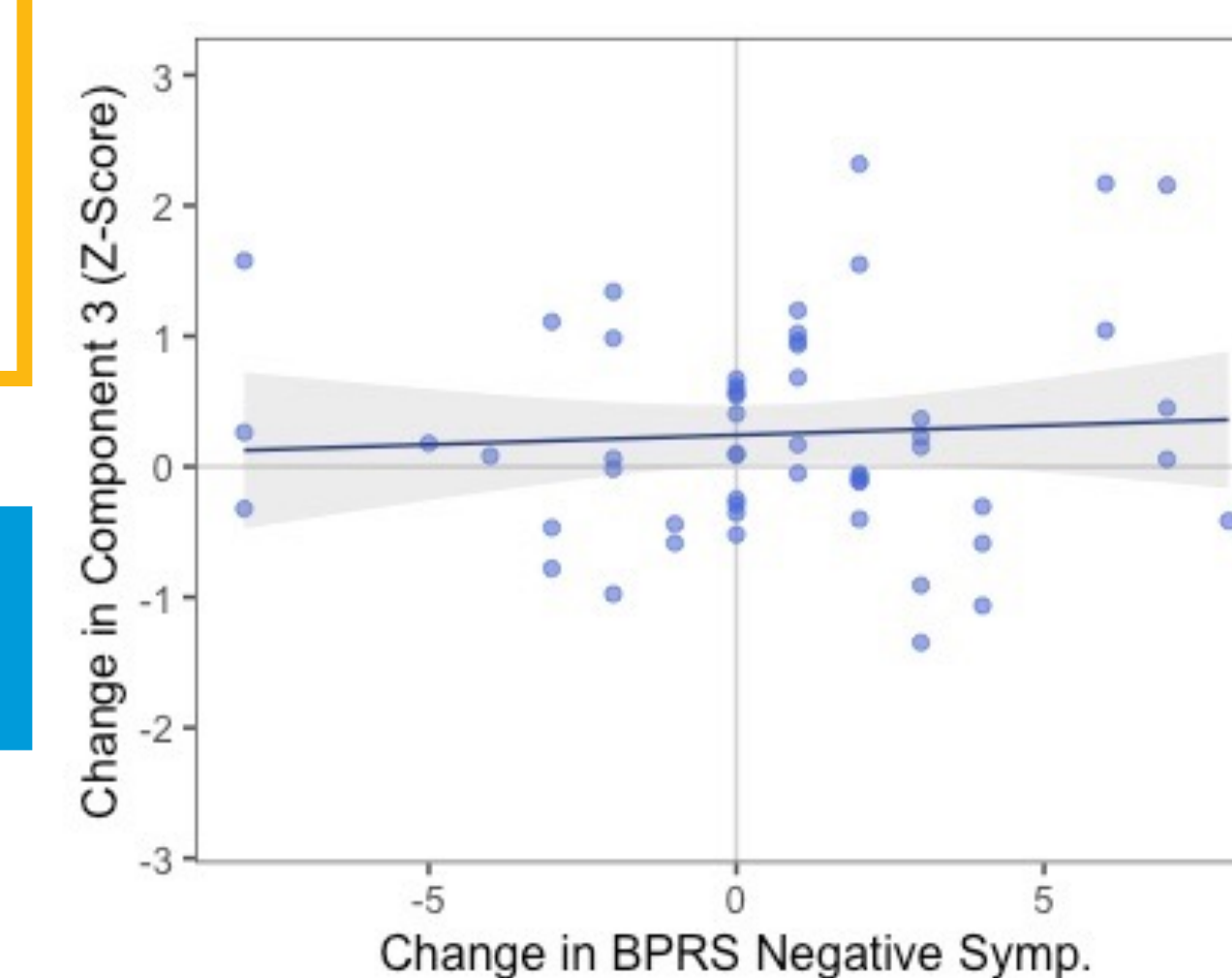| Loading	Description
-0.81	Average cosine distance between successive utterances using Google embeddings, across open-ended tasks
-0.79	Average cosine distance between successive utterances using fastText embeddings, across open-ended tasks
-0.70	Min cosine distance between successive utterances using fastText embeddings, across open-ended tasks
0.70	Length-insensitive measure of type-token ratio, across open-ended tasks
-0.70	Undirected graph, number of nodes in largest connected component, across open-ended tasks

B) Component 2

- Significantly related to positive symptoms
  - Std. Beta = -0.013
  - p = 0.005**

C2 - Top Loading Features

Loading	Description
-0.72	Ratio of pronouns to (pronouns + nouns), across open-ended tasks
0.71	Ratio of nouns to verbs, across open-ended tasks
-0.64	Raw pronoun count, across open-ended tasks
0.57	Count of complex nominals per clause, across open-ended tasks
0.55	Raw noun count, across open-ended tasks
0.55	Average length of clauses, across open-ended tasks
-0.54	Average frequency of words, across open-ended tasks

C) Component 3

- Significantly related to negative symptoms
  - Std. Beta = 0.011
  - p = 0.03*
- Significantly related to thought disorder
  - Std. Beta = -0.010
  - p = 0.01*

C3 - Top Loading Features

Loading	Description
0.63	Number of all content units mentioned, across picture descriptions
0.62	Raw determiners count, across picture descriptions
0.60	Number of subject content units mentioned, across picture descriptions
0.53	Proportion of unfilled pauses, across fluency tasks

Abbreviations & Citations:
- BPRS – Brief Psychiatric Rating Scale (Overall and Gorham, 1962). Positive and negative symptom factor scores derived from Overall (1973).
- PCA – Principal Component Analysis, performed with *psych* in R with promax rotation (Revelle 2021).
- SSD – Schizophrenia Spectrum Disorders.
- TLC – Scale for the Assessment of Thought Language and Communication (Andreasen 1986).
- t-SNE – A variant of Stochastic Neighbor Embedding to visualize high-dimensional data (van der Maaten and Hinton, 2008).