

Reading Fluency is in the Dynamics

A Self-Organization Perspective on Cognition

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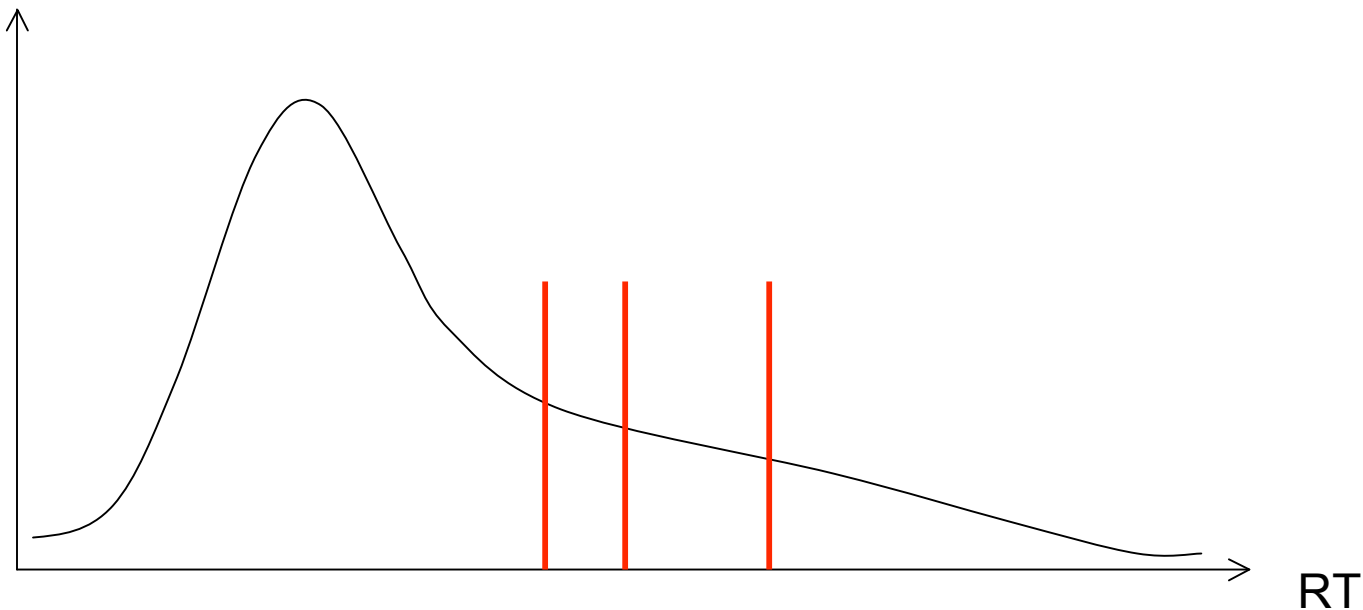
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Reading fluency: Static view

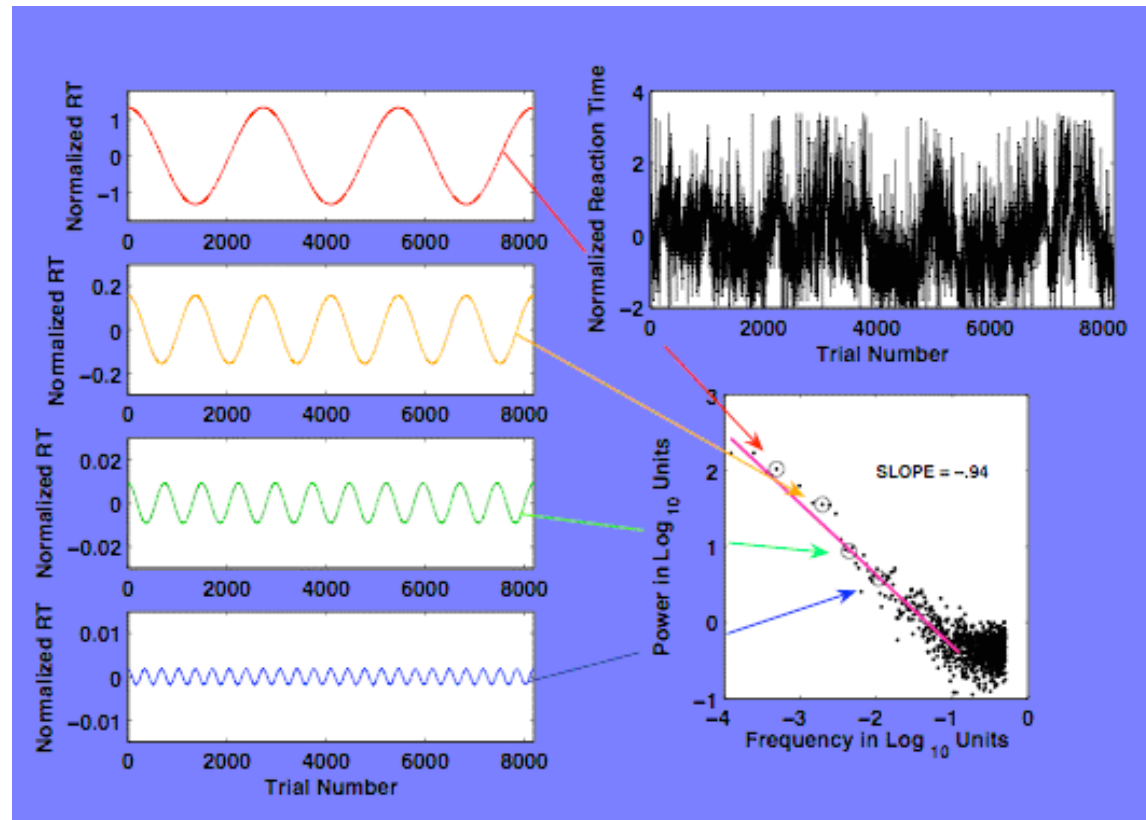
- Indication of reading problems / dyslexia?
- \approx Reading speed: a static, aggregate measure



PROBLEM: no agreement on appropriate reading speed

Reading fluency: Dynamic view

- Indication of reading problems/dyslexia?
- $\approx 1/f$ noise: a dynamical measure



Alternative: $1/f$ noise indicates healthy coordinated behavior

Mean scores versus $1/f$ dynamics

- Conventional analyses require that background variability is exclusively uncorrelated noise

$$X(t) = M(t) + N(t)$$

- $1/f$ noise:
 - Every data points exerts an influence of some magnitude on every other data point
 - Variation increases rather than stabilizes with larger sample sizes
 - Runs against standard statistical intuitions

1/f noise and reading fluency: Assumptions

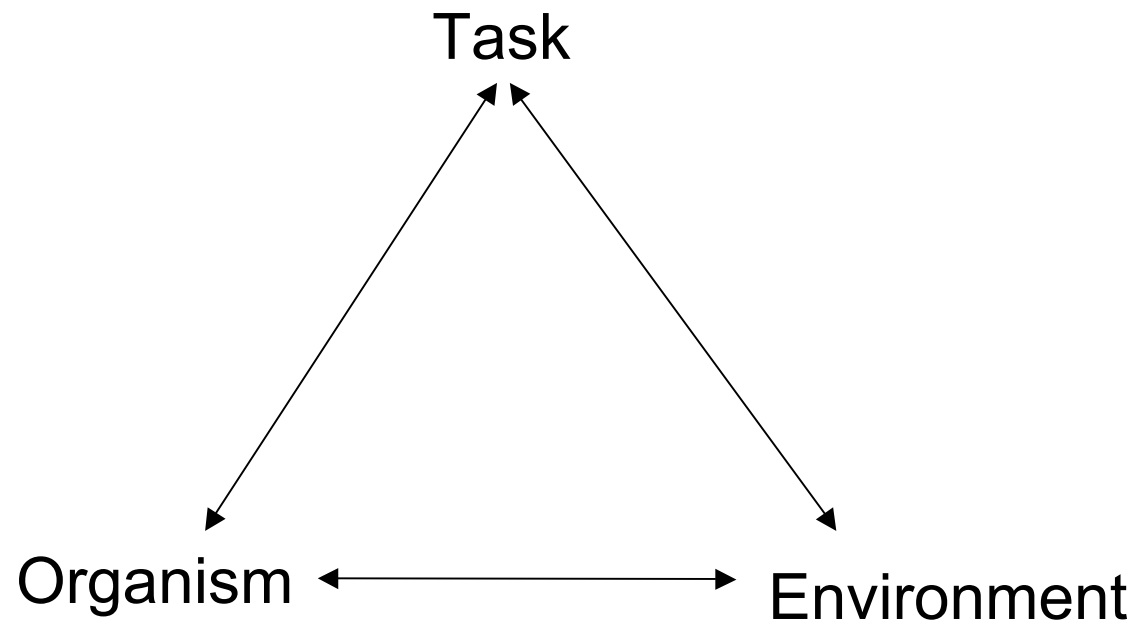
- Human performance self-organizes on longer timescales relative to processes on shorter timescales
- Self-organization limits the degrees of freedom for interactions among processes on shorter timescales
- E.g. reading speed of single words

$1/f$ noise: Some facts

- Ubiquitous in repeated cognitive performances
- External perturbation reduce $1/f$ signature
- Cognitive control and flexible coordination are reflected in the $1/f$ signature

Human behavior

Taxonomy of constraints (Newell, 1984)

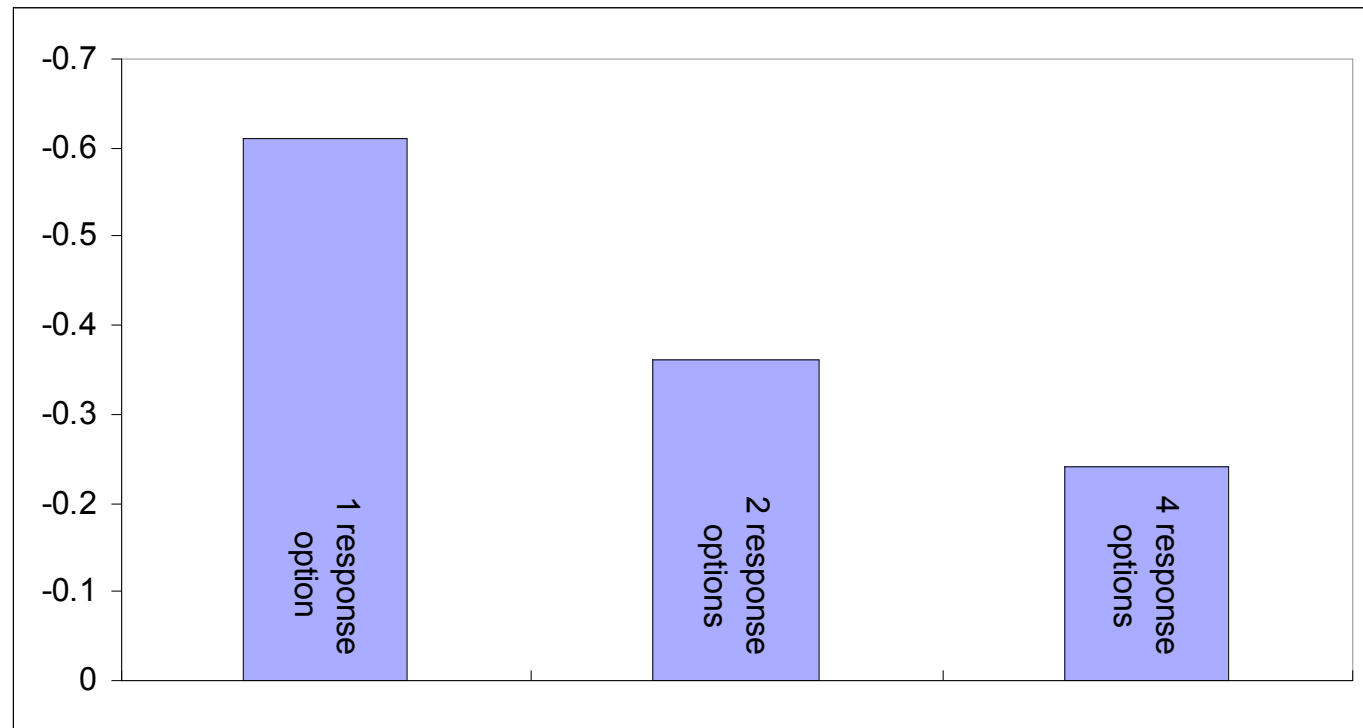


Task constraints

External perturbations add extraneous random variation to the measured performances

$1/f$ noise →

Random →

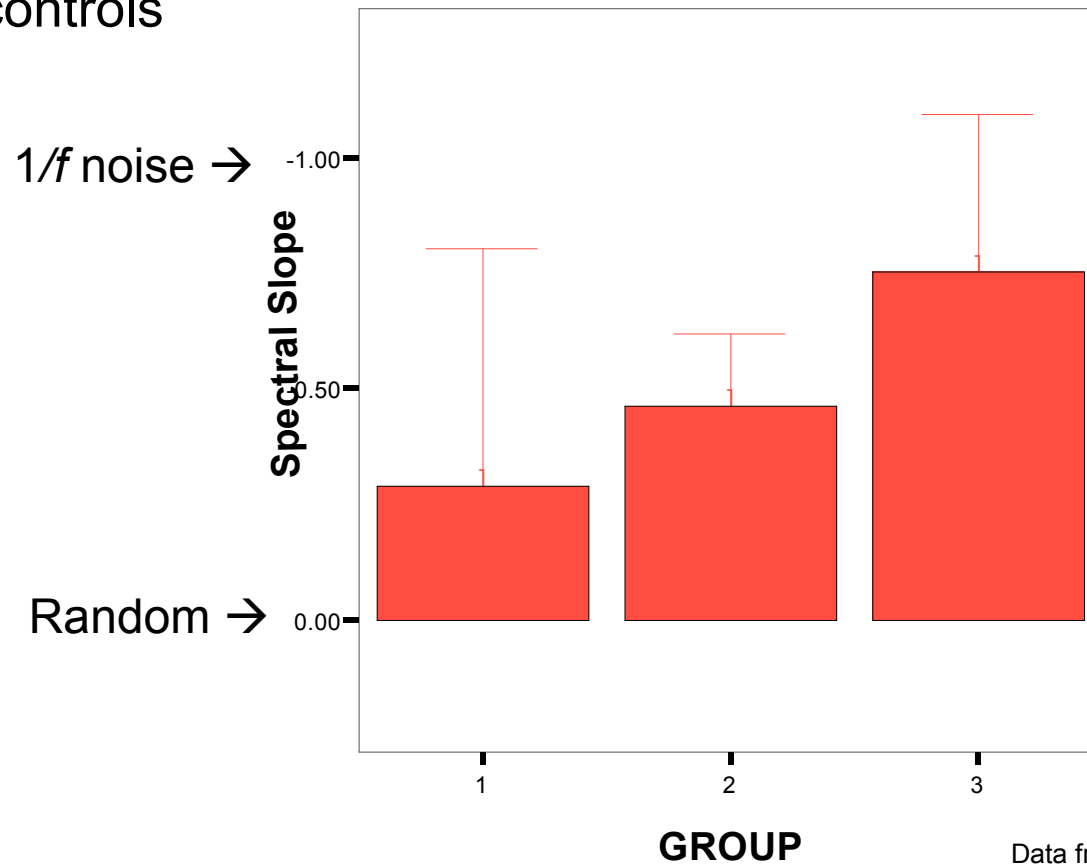


Choice Reaction Task

Organism constraints

Human gait

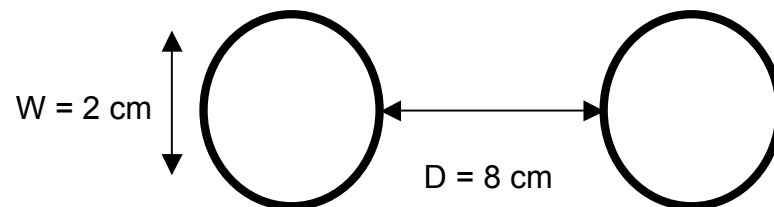
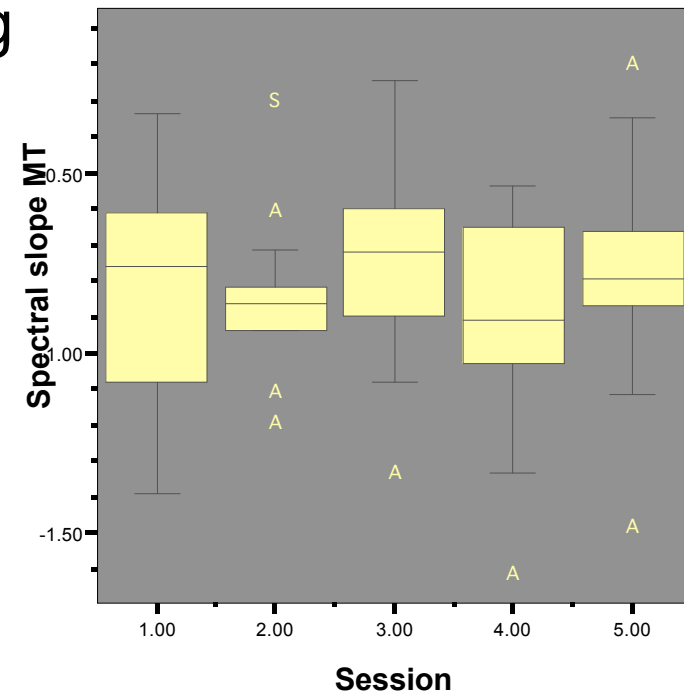
1. Old adults with Parkinson disease
2. Age-matched controls
3. Young adults



Data from: physionet.org

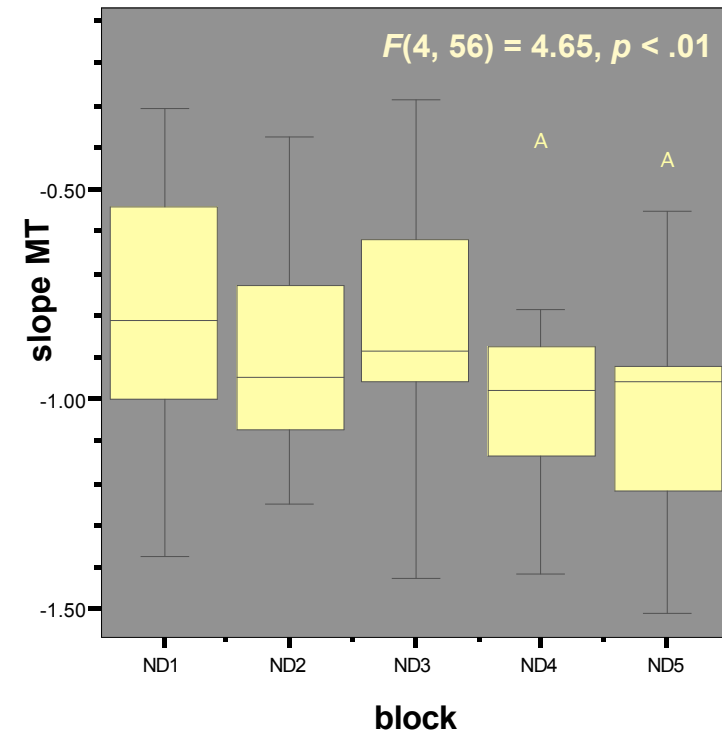
Task-organism constraints

- Precision aiming: no motor learning
- Intentionally easy
- Non-dominant hand
- 5 x 1100 lines
- No change in MT
- No change in accuracy
- No change in 1/f



Task-organism constraints

- Precision aiming: motor learning
- Intentionally difficult
- Non-dominant hand
- 5 x 1100 lines
- MT decreases
- Accuracy remains stable
- Increased 1/f signal



W = 0.8 cm



D = 24 cm



Reading fluency

- Could $1/f$ system dynamics serve as a criterion for reading performance?
- Word-naming task

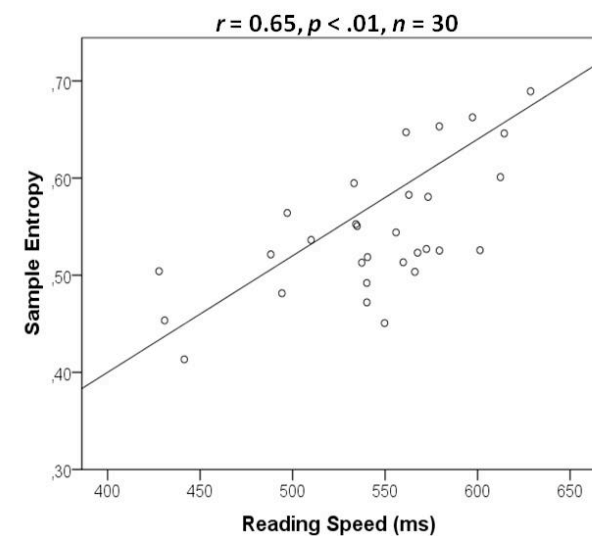
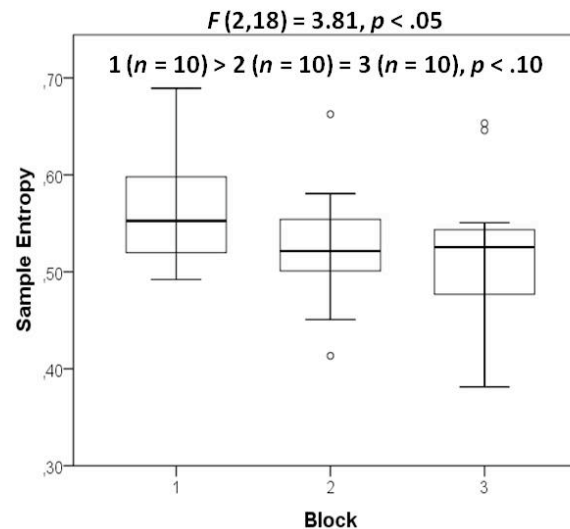
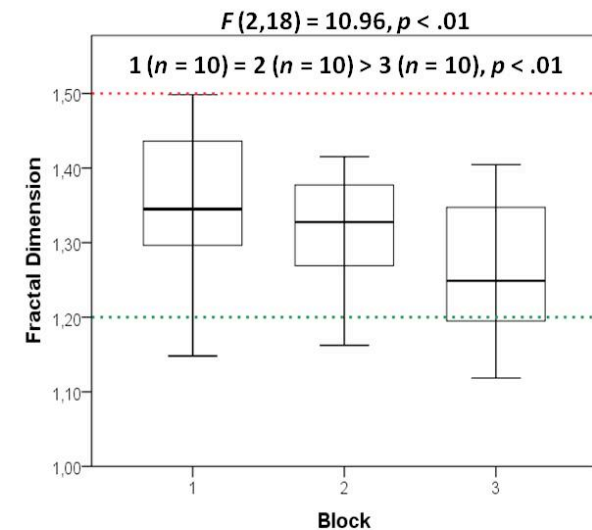
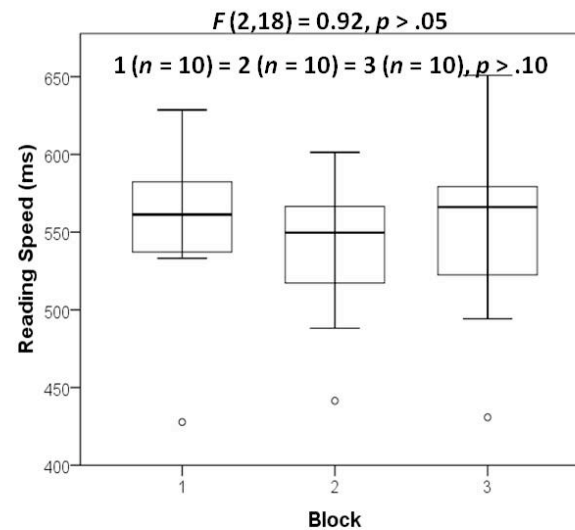
~~tablet~~

- Expectation:
 - $1/f$ more prominent with learning (i.e. word repetition)
 - $1/f$ less prominent in dyslectics than normal and expert readers

Reading fluency

Word repetition

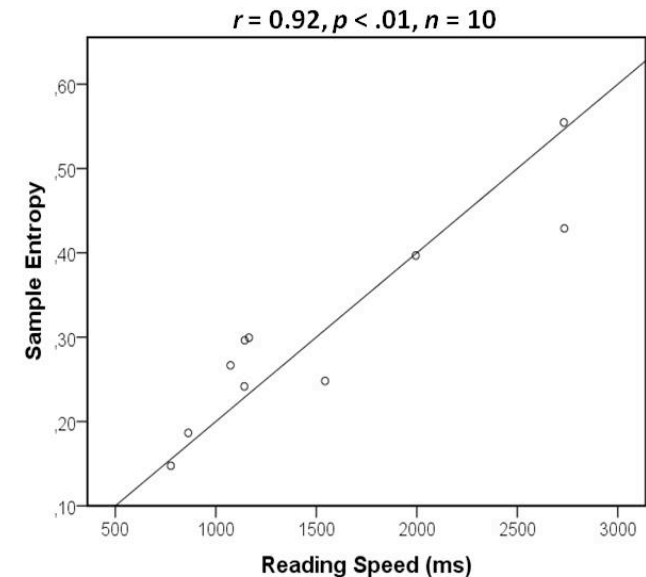
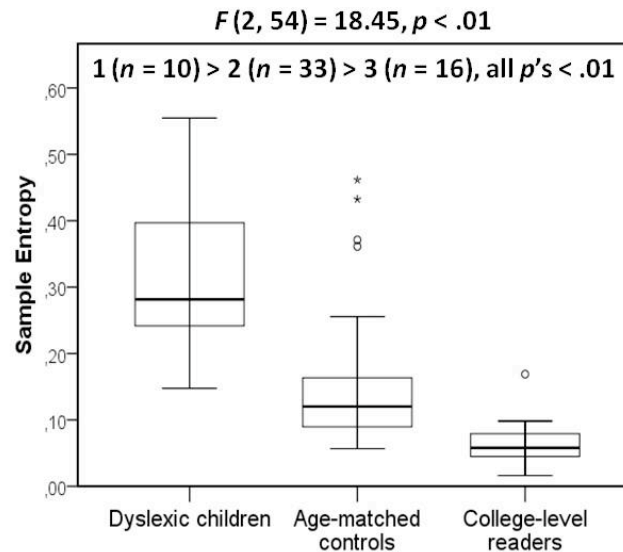
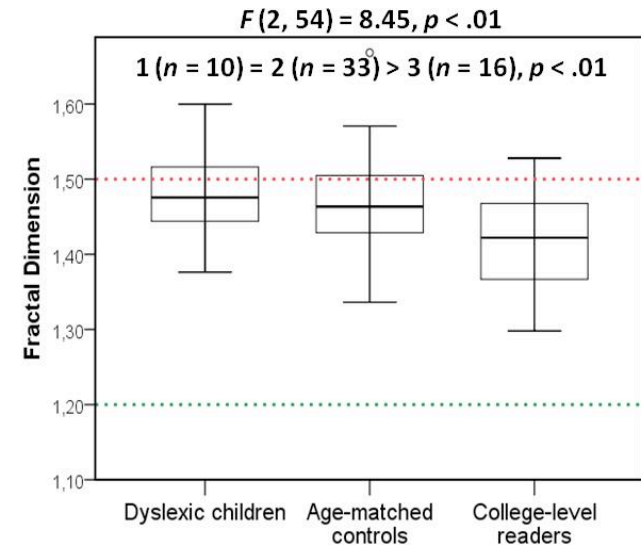
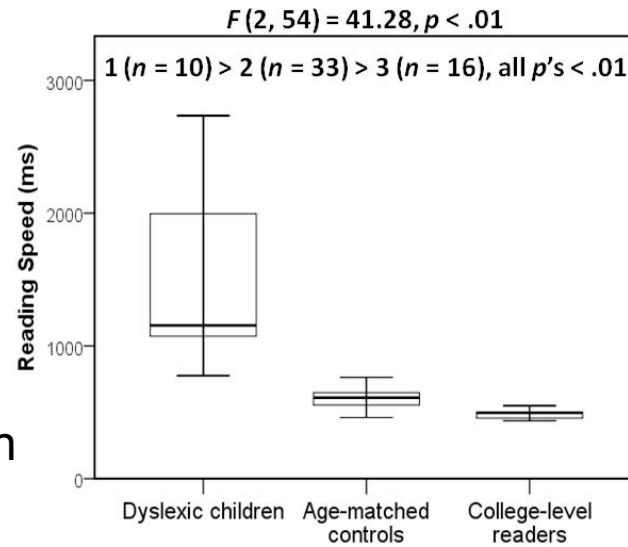
- Three same blocks of 1100 word stimuli
- Facilitates reading performance:
 - Reading speed
 - Fractal dimension
 - Sample Entropy



Reading fluency

Reading development and disability

- Dyslexic children
- Age-matched children
- Expert readers

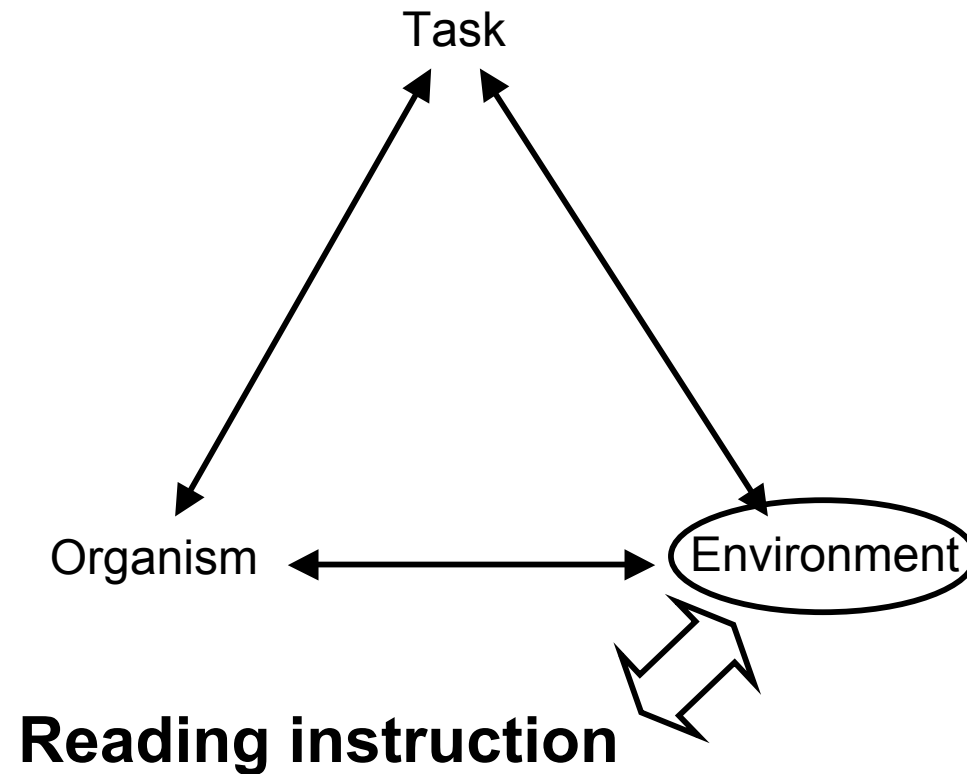


Conclusion

- 1/f dynamics are sensitive to reading fluency
- Does this give us a criterion for dyslexia?

Human behavior

- Taxonomy of constraints (Newell, 1984)



Future directions: Reading instruction

- School A: Low average performance
 - Good readers: approaching 1/f signal
 - Average readers: approaching 1/f signal
 - Poor readers: reduced to absent 1/f signal
- School B: High average performance
 - Good readers: approaching 1/f signal
 - Average readers:
 - Some reveal 1/f signal
 - Some reveal a reduced to absent 1/f signal **REAL DYSLEXICS?**
 - No poor readers

Kwestions?