

Overview

Fractal Scaling in Heart Rate Variability Dynamics in Relation to Cognitive Load

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Introduction

- Heart Rate Variability (HRV) is a measure that reflects the balance between parasympathetic and sympathetic regulation.
- Fractal Scaling is a mathematical term that describes patterns observable across varying scales along which it is viewed
- HRV typically decreases with increasing physical demands, which is thought to be indicative of diminishing adaptability
- **Detrended Fluctuation Analysis (DFA)** is a key statistical method used in analysis of scaling behavior in time series; it can be used to quantify fractal scaling in heart rate inter-beat intervals

Hypothesis: Reallocation of Attentional Resources Toward Cognitive Tasks/Demands Alters Heart Rate Fractal Scaling Dynamics

Methods

- 3 electrocardiogram (ECG) leads are placed across participant's torso to record heart rate activity before, during, and after cognitive tasks
- Participants undergo a **discounting task**, quantifying the subjective value (SV) of cognitive effort
- **R-R interbeat intervals are cleaned; DFA is applied** to quantify the fractal scaling before, during, and after all task levels

Analysis

- **Detrended Fluctuation Analysis (DFA)** is the primary statistical method used in quantifying fractal scaling in heart rate and RTs
- Exact procedural steps in performing DFA on a time series can be observed in the Introduction panel; we focus on the DFA exponent, alpha, which is the slope of the trend line in the range of time scales of interest (4-16 beats) on a log-log graph of variability as a function of window size
- In comparing DFA alpha values before, during, and after each stage of the cognitive task experiment, we can quantify HRV through fractal dynamics
- We compare accuracy rates and reaction times for each n-back task level to respective HRV DFA scores to examine correlations

Results

- Subjective effort increases and performance decreases with cognitive load
- DFA Measures of Heart Rate Variability (HRV):
 - Increase when comparing DFA values before and after cognitive tasks
 - Increase systematically towards alpha=1 with increasing cognitive load
 - Individual differences in subjective effort do not correlate with heart rate fractal scaling
- In DFA applied to performance (Reaction Times)
 - RT time series exhibit more fractal scaling as a function of cognitive load
 - There no clear linear relationship between fractal scaling in RT and HRV

Conclusions

- Fractal scaling in Heart Rate Variability (HRV) varies systematically with cognitive load as signified by N-back task level, but not as predicted. DFA measures indicate more fractal scaling as cognitive load increases
- HRV patterns do not predict task performance for individuals in regard to dynamics of reaction times as there is no strong linear correlation between DFA measures of either
- Effort discounting indicates higher subjective costs for more demanding tasks

Future directions

- Test for correlations between heart rate fractal scaling and cognitive flexibility
- Compare fractal scaling in HRV to fractal scaling in EEG dynamics
- Test for correlations between fractal scaling properties and high/low frequency HRV
- Investigate other nonlinear methods to apply more powerful methods
 - Poincare Method, Multifractal analyses
- Investigate heart rate variability and effort discounting in diversified groups

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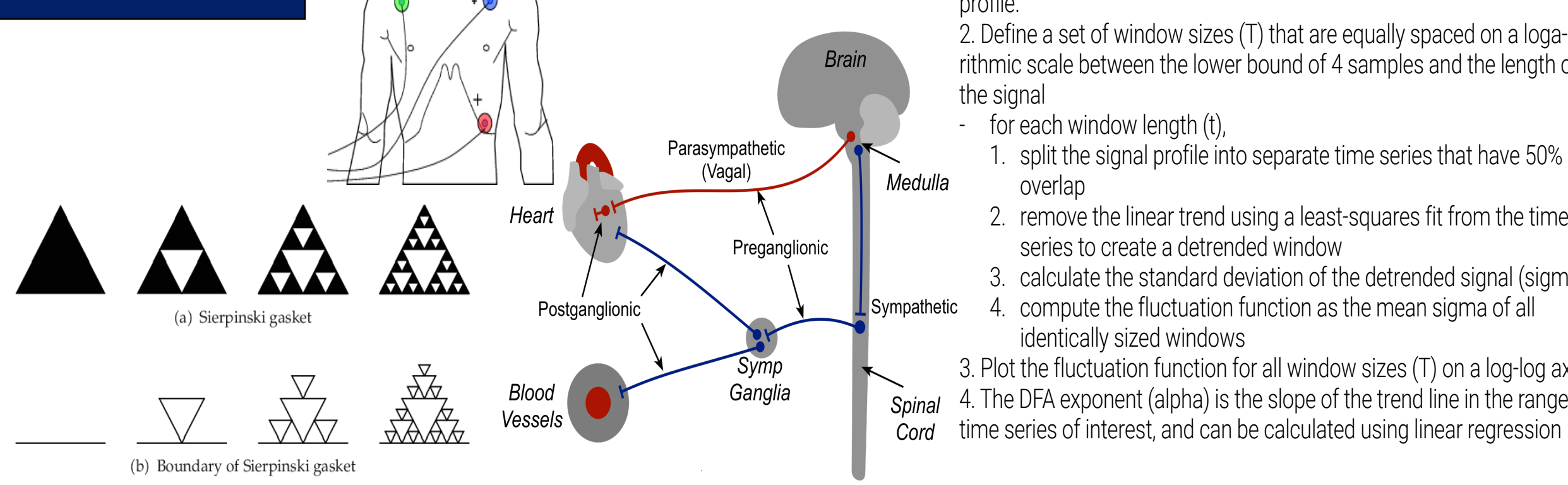
Heart rate fractal scaling and subjective effort *increase* with higher cognitive load.

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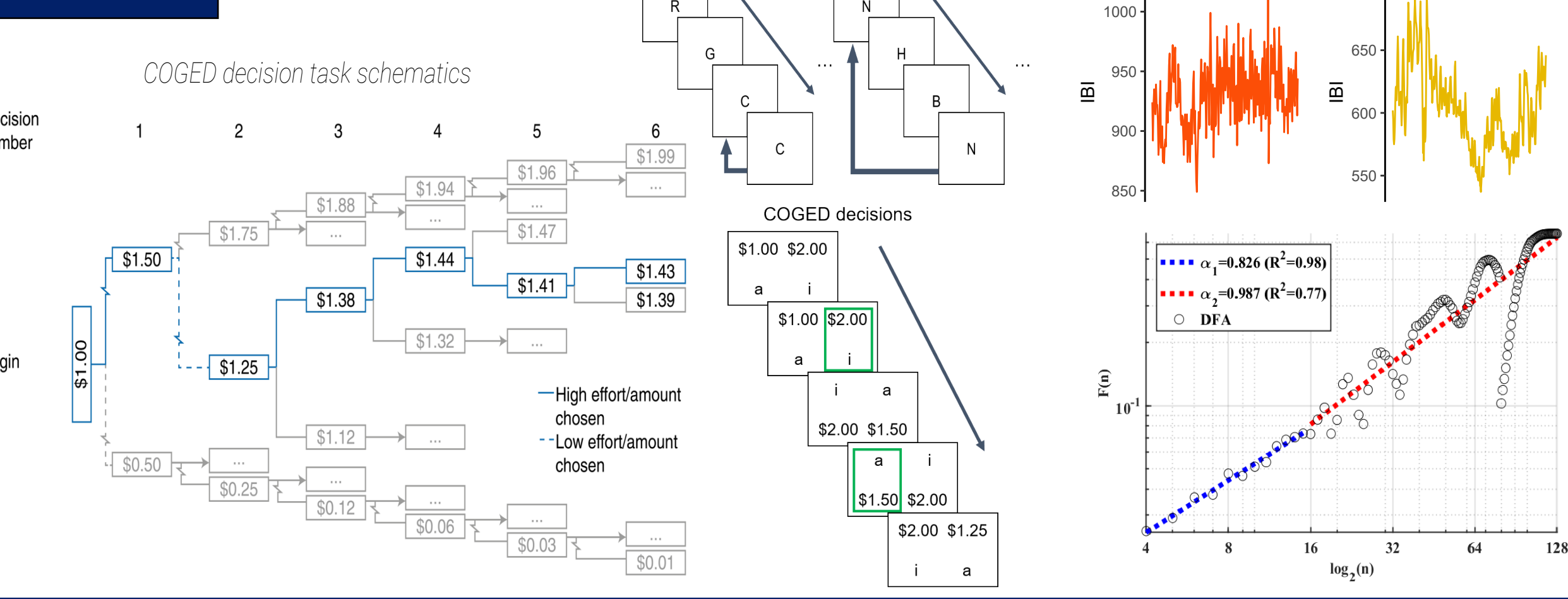
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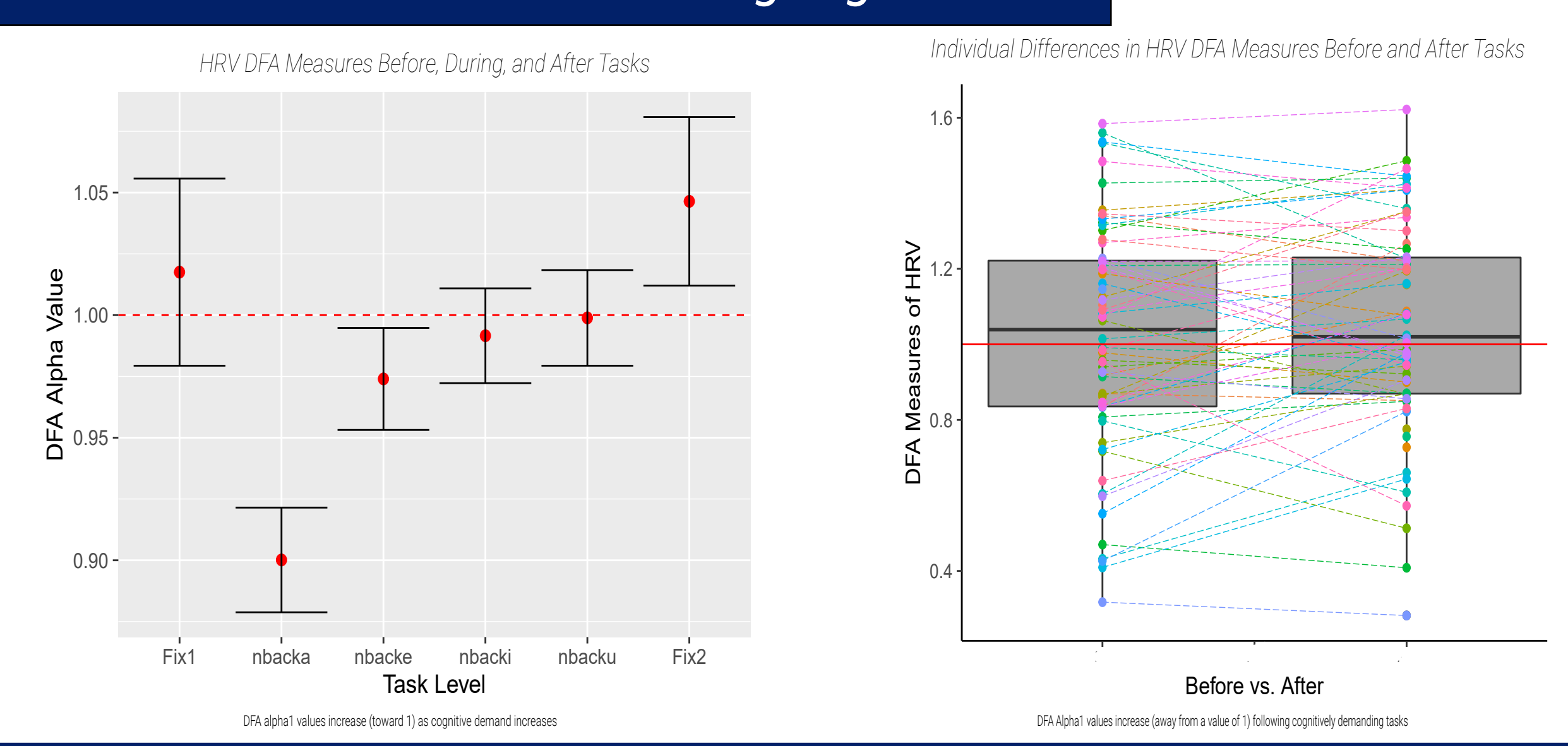
Introduction



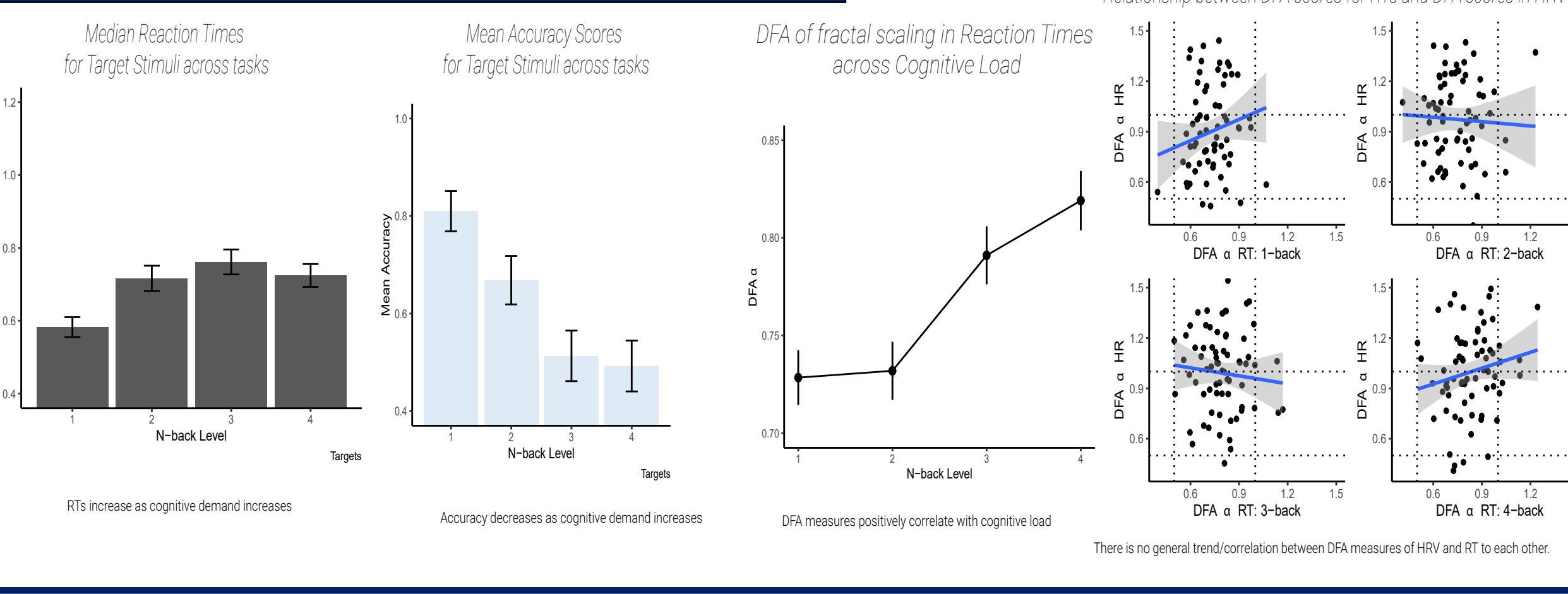
Methods



DFA tends to increase with increasing cognitive load



DFA of HRV and Performance Measures



Connecting DFA measures to Effort Discounting

