How conscious in-scanner thoughts modulate functional connectivity during resting-state fMRI

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INTRODUCTION

Previous research has suggested that ongoing in-scanner experience may modulate patterns of functional connectivity during resting-state fMRI (rsfMRI)[1,2,3,4]. However, the extent to which these experiences contribute to individual variability in rsfMRI functional connectivity (FC) remains unknown. Understanding these phenomena is key to explaining unknown variability in healthy subjects and clinical populations (i.e., biomarkers). To address this knowledge gap, we aim to analyze the relationship between FC and reported in-scanner experiences during resting-state fMRI scans. First, we look for significant differences in FC between scans grouped based on different reported patterns of thought. Then, we demonstrate it is possible to predict reported patterns of thought using FC data.

METHODS

Figure 1. Short New York Cognition Questionnaire[5]

FORM
- My thoughts were intrusive
- My thoughts were more specific than vague
- My thoughts were in the form of words
- My thoughts were in the form of images

CONTENT
- I thought about my present environment / surroundings
- I thought about other people
- I thought about myself
- I thought about past events
- I thought about future events
- I thought about something negative
- I thought about something positive

Figure 2. SNYCQ Response Matrix sorted by value of responses (463x12)

Non-negative matrix factorization and agglomerative clustering

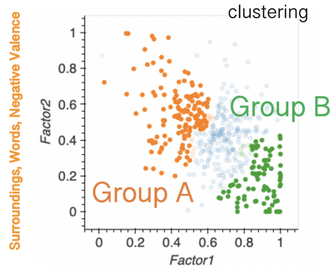
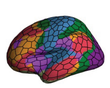


Figure 3. Dimensionality reduction and clustering results

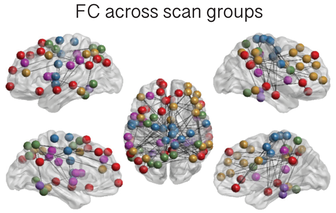
- **Group A** (high Factor 2 scores) consists of scans described as being accompanied by thoughts about **one's surroundings** in the form of **words** with a **negative valence**. (Figure 3)
- **Group B** (high Factor 1 scores) consists of scans described as being accompanied by thoughts about **other people** in the form of **images** with a **positive valence**. (Figure 3)

463 resting-state fMRI scans from 133 subjects from MPI-LEMON dataset[5] (duration: 15 min)



Functional Connectivity computed for the Schaefer 200 ROI/7 Network Yeo Atlas[6]

Applied Network Based Statistics[7] to look for significant differences in FC across scan groups



Connectome-Based Predictive Modeling[8] to predict answers to SNYCQ and Factor 1 and 2 loadings from scan-wise FC matrices

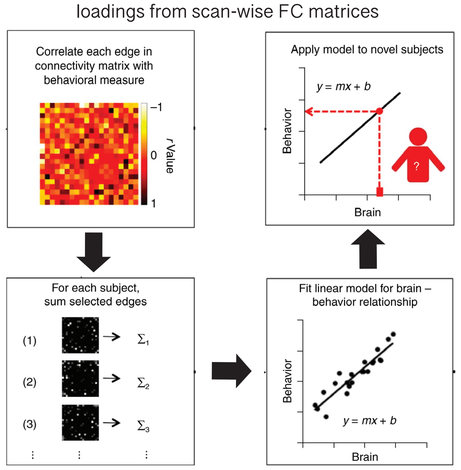


Figure 4. Description of Connectome-Based Predictive Modeling[8] (figure adapted from Shen et al. 2017)

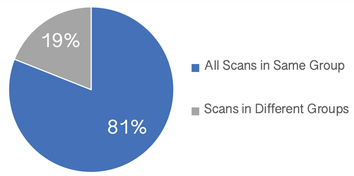


Figure 5. Proportion of subjects with scans in the same group

- A subset of subjects had more than one scan available. We found that 81% of these subjects had all their scans clustered in the same group, showing that subjects tend to think in a similar manner each time they rest in the scanner. (Figure 5)

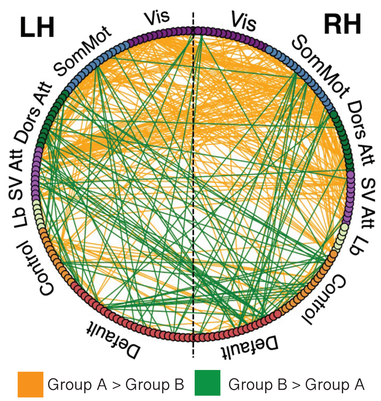


Figure 6. Significant differences in static FC across groups [Network-based Statistics; T > 3.1 at connection level and p<0.05 at the component level (5000 permutations)]

- Scans in **Group A**, which were more strongly associated with **externally focused thoughts**, showed stronger connectivity between sensory and attentional networks (Figure 6).
- Scans in **Group B**, which were more strongly associated with **internally focused thoughts**, showed stronger connectivity between the default mode network and most other networks (Figure 6).

- It is also possible to significantly predict the responses to the individual items on the SNYCQ. A few representative cases are shown to the right (Figures 9a-d)

Figure 9. Scatter plots showing observed versus predicted values in response to the respective questions.
(a) thinking in the form of images
(b) thinking in the form of words
(c) thinking about other people
(d) thinking about one's surroundings

RESULTS

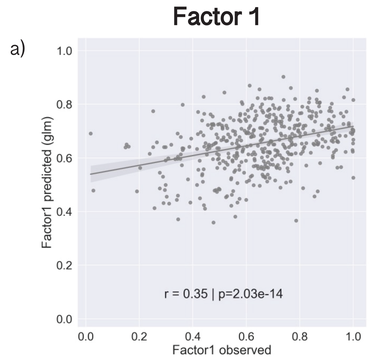


Figure 7. (a) Observed versus predicted values of Factor 1. Each dot represents a scan. (b) Edges contributing to the prediction of Factor 1.

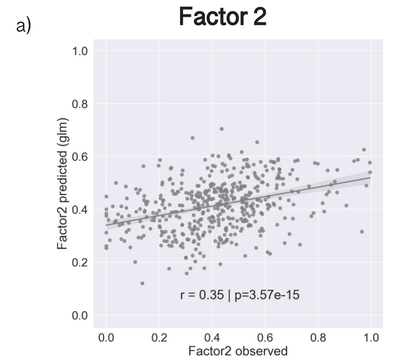
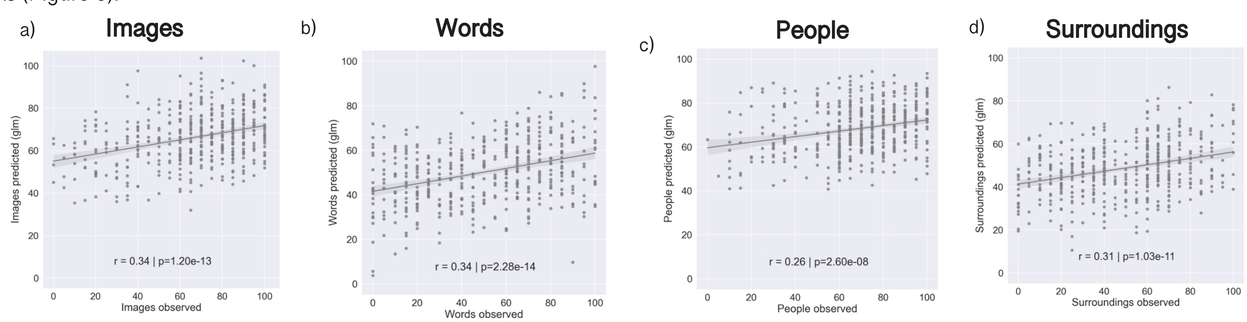


Figure 8. (a) Observed versus predicted values of Factor 2. Each dot represents a scan. (b) Edges contributing to the prediction of Factor 2.

Connectivity is positively correlated with behavior

Connectivity is negatively correlated with behavior

- Connections between the default mode network and sensory networks were positively correlated with Factor 1 scores, and connections within the visual network were negatively correlated with Factor 1 scores (among other connections) (Figure 7b).
- Connections between sensory and attentional networks were positively correlated with Factor 2 scores, and connections between sensory, attentional, and default mode networks were negatively correlated with Factor 2 scores (among other connections) (Figure 8b).



CONCLUSIONS

- Subjects systematically engage in similar thought patterns across several resting-state sessions.
- Significant differences in FC can be found by segregating scans in terms of thought patterns.
- Different aspects of thought patterns can be predicted using resting-state FC.
- Subjects' on-going in-scanner thoughts can strongly modulate FC during resting-state, and this should be considered when accounting for sources of inter-subject variability.
- The role of ongoing thought in fMRI must be better understood in order to properly interpret resting state connectivity.

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