A machine learning strategy for using rs-fMRI to predict study adherence in a mental training trial

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Introduction:

Mental training programs such as mindfulness meditation have become widely accessible for improving cognitive control and emotional regulation(1, 2). Some individuals adhere to the prescribed practice relatively more than others, yet the reasons for this remains unclear. Understanding neurobiological factors that predict adherence is necessary for understanding elements of learning and to inform better designs for new learning regimens. This study tested whether configurations of brain connections in resting state fMRI scans contain a priori information about a person's adherence to mental training programs.

Methods:

51 healthy participants underwent a structural and resting-state fMRI scan and then were randomized to a four-week mental training programs: meditation or creative writing program.
The optimized Harvard/Oxford parcellation scheme used to divide the brain's spatial domain into a set of non-overlapping regions (3, 4). Then the fMRI signals extracted to create correlation matrix at a range of network densities.
The graph theory concepts (clustering coefficients and degree centrality) were used to quantify functional networks of the brain(5-7). To identify the nodes that contributed to predicting adherence and if they were specific to the type of practice, we identified ones that showed a significant correlation (based on permutation test) between graph properties and adherence (based on total practice). The p-values were corrected for multiple comparisons by using FDR set at 0.05 for a range of network densities.
A ML based strategy was implemented to test the robustness of the brain metric for classifying individual capacity for adherence. The significant nodal measures were used as features. Four different classifiers applied in a binary setup (completed homework more than 10 times=High, otherwise=Low). A quarter of data were randomly separated as the hold out and the rest of the data were used to train classifier using leave one out cross validation (8-10). Finally, the trained classifiers were tested on the held-out set.

Results:

Node-wise metrics were correlated with the total number of home practice assignments to test whether graph measures observed in intrinsic networks can predict individual variability in adherence. We found that, these measures were significant predictors of adherence.
Nodes that predicted adherence to meditation group were affiliated with brain regions within the default mode network and sensory regions. The creative writing program was predicted by a few nodes in subcortical, attention and language/memory networks. For all participants combined, there was a clear affiliation of predictive nodes with regions in subcortical areas.
Decision tree was found to generalize better than the other models and is less likely to overfit for adherence classification (cross-validation score=0.82±0.076%, test score=0.76%).

Conclusions:

The findings indicate that the graph properties of rsfMRI predicts participants' adherence and engagement while learning new mental skills. Network properties are useful for summarizing and understanding the significance functional connectivity patterns of the brain.
The classifier's performance demonstrates feasibility and establishes some useful parameters for predicting adherence with rs-fMRI. The results were reproducible and consistent when tested across variables and the predictive measures showed robustness when tested with a machine learning approach. These classification approaches are applicable, but better approaches are needed that incorporate ML strategies that directly assess graph features for classification. Overall, these findings underscore the fact that adherence requires pre-existing capacity mediated by organizational patterns of functional connectivity.

Emotion and Motivation:

Emotion and Motivation Other

Higher Cognitive Functions:

Decision Making [1]
Executive Function [2]
Higher Cognitive Functions Other

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[1|2]Indicates the priority used for review