Modularity measures of functional brain networks predict individual differences in delayed recognition memory

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Long-term memory (LTM) is crucial to daily functioning, and individuals show a large variance in LTM capacity. In this study, we ask: to what extent does the functional organization of the brain explain individual differences in a widely studied form of LTM, delayed recognition memory (REC)? Recent work has adopted tools from graph theory to examine how modularity, the degree to which the brain can be divided into distinct modules, is related to cognition (Bertolero et al., 2018). Using fMRI data from n-back tasks and recognition memory data from the Human Connectome Project (n=708), we explored how different modularity properties of nodes in the brain may relate to individual differences in REC. More specifically, we focused on two properties that describe distinct aspects of network functioning: diversity (the extent to which a node has diverse connections with different modules; measured with participation coefficient [PC]) and locality (the extent to which a node has more connections within their own modules; measured with within-module degree [WMD]). To investigate if node diversity and locality are related to REC, we built a predictive model with these two measures and validated it in a leave-one-out cross-validation scheme. For PC, we first correlated the PCs of each node with REC across the subjects within the training sample and selected nodes whose PCs were correlated with REC. We then correlated each subject's PCs with the group-based PC-behavior correlation map of the selected nodes. This value represents how optimized this subject's PCs among the selected nodes are for REC performance. The same procedure was repeated for WMD. We then used linear regression to relate the PC and WMD optimality measures with REC performance in the training sample. This model was used to predict the REC score in the left-out test subject based on their modularity measures. This predictive model significantly predicted individual differences in REC (Pearson's $r = 0.26$, $p < .001$). In addition, we found that the node diversity of the Medial Frontal network contributed most to the prediction, while the node locality of the Frontoparietal, Visual I, and Visual Association networks contributed most to the prediction. Interestingly, for nodes in the Default Mode network, both diversity and locality played important roles in the prediction of REC. Using recognition memory as an example, our findings extend previous work on how the modularity of brain is related to cognition and demonstrate the utility of using graph-theory-based measures to reveal how the modularity of brain networks is related to individual differences in LTM performance.