Predicting Individual Differences in Cognitive Gains from Videogame Training Using Machine Learning Analyses of Plasticity in fMRI Functional Connectivity Patterns

Aki Nikolaidis[1], Nicco Reggente[2], Drew Goatz[3], Kathryn Hurley[3], Andrew Westphal[2], Jesse Rissman[2], Arthur Kramer[1]

[1]University of Illinois, Champaign Urbana; [2]University of California, Los Angeles, Psychology Department; [3]University of Illinois, Bioengineering Department

Take Home Message

Plasticity in networks most associated with a training strategy best predict learning in that same training strategy. Changes in graph theoretical topological features, such as betweenness centrality, offers perspective on training-induced plasticity necessary for learning.

Introduction

We need better metrics to assess how training-induced plasticity contributes to learning. Measuring changes in activation at single locations does not capture the dynamic nature of the distributed functional reorganization that occurs during learning[1-3].

Understanding how network-based functional plasticity predicts learning may help researchers develop training methods that speed learning processes or encourage transfer of training.

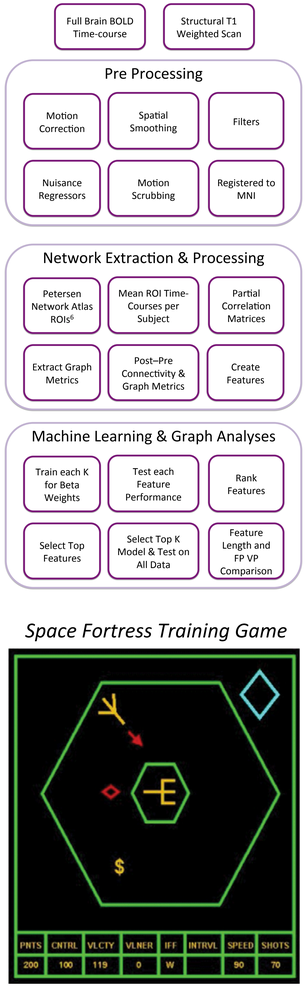
Objective: to explore how network plasticity predicts learning in different learning strategies.

Methods

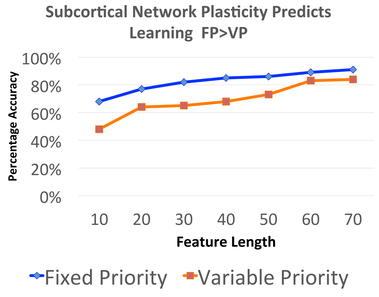
68 young adults trained for either 20 or 30 hours with Space Fortress(Figure 1). Before and after training, all trainees had an fMRI scan while playing Space Fortress. All participants followed one of two learning strategies: a Variable Priority (VP; n=35) or Fixed Priority (FP; n=33) strategy. During VP participants focus on maximizing their score on each subtask individually within the context of the whole task; in FP participants focus on maximizing total score overall[4]. We used a Reliable Change Index (RCI) to measure how much their performance improved in the Space Fortress task during the training[5].

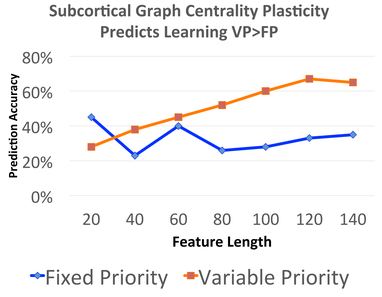
Our analysis stream followed this path: 1-We preprocessed each subject's pre and post fMRI data according to commonly used connectivity preprocessing methods; 2-extracted partial correlation networks and relevant graph theory parameters of these networks; 3-took the post-pre difference of the graph metrics and network values to make Ridge Regression Features; 4-trained the Ridge Regression on K-1 groups (K=N/5) and tested on K; 5- selected the best model beta weights to test on N.

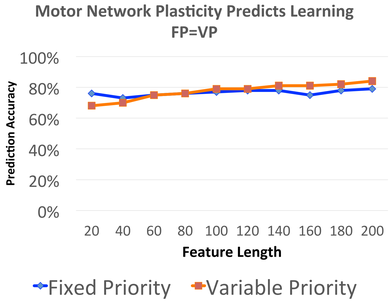
Full Experiment Overview

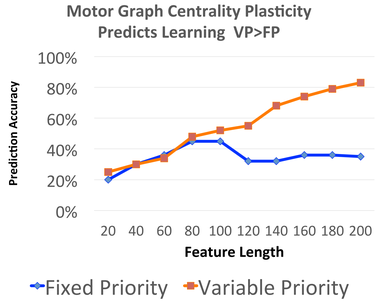


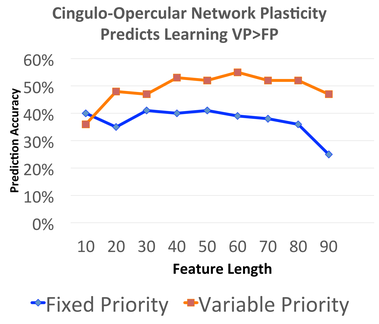
Space Fortress Training Game

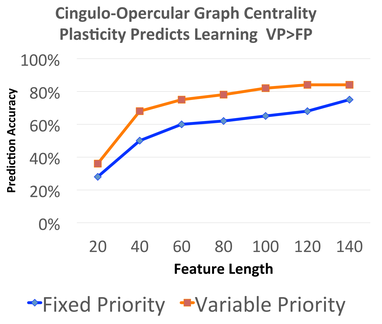












Results

- Plasticity in the Cingulo-Opercular network preferentially predicts learning in a training strategy that relies more heavily on executive control of attention and goal directed behavior (VP)[4].
- Plasticity in the subcortical network preferentially predicts learning in a training strategy that relies heavily on procedural learning (FP)[4].
- These findings extend previous work showing that distinct network plasticity contributes differentially to improvements depending on learning strategy[7].
- Plasticity in the motor network shows similar predictive power for both FP and VP groups, yet changes in centrality combined with connectivity are explanatory for the VP group alone.
- This indicates that the training strategies may induce similar changes in functional connectivity, but that the VP training strategy also alters global topology of the network.

Discussion

- We demonstrate the specificity of the relationship between network plasticity and training strategy.
- This suggests that cognitive training and therapeutic researchers should specify the training strategy employed by their subjects and patients, as differing strategies affect different networks, and the plasticity that occurs in these networks largely predicts their behavioral outcome.
- Unspecified training strategies, or 'practice' strategies, therefore may lead to undesired individual differences in network plasticity.
- Furthermore, plasticity in graph metrics in addition to functional network plasticity may aid in our ability to distinguish between how training strategies drive behavioral changes.

References

1-Dayan & Cohen 2011 Neuron; **2-**Kelly & Garavan 2005 *Cer. Cortex;* **3-***Buschkuehl, Jaeggi, Joindes 2011 Dev. Cog. Neuro;* **4-**Gopher 1989 *Acta Psych.*; **5-**Jacobson 1991 *J Consult. Clin. Psych.* **6-**Power *et* al. 2011 Neuron.