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Letter to the editor

Multivariate single-subject analysis of short-term reorganization in the language network

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Numerous functional neuroimaging studies in humans used univariate group analyses to identify brain areas that show increased activity across participants during specific tasks. However, there is increasing evidence that group-level analyses may obscure important parts of the signal response (Margulies, 2017; Poldrack, 2017). Here, we re-analyzed data from our recent study (Hartwigsen et al., 2017) that investigated functional reorganization in the language network. We show that across-voxel pattern-learning approaches are useful to isolate plastic changes in neural networks underlying cognitive functions at the individual subject level. Using predictive machine-learning tools to identify and exploit subject-specific neural activity patterns have been argued to become an important cornerstone of precision medicine in psychiatry and neurology (Arbabshirani, Plis, Margulies, 2017; Poldrack, 2017). Here, we re-analyzed data from our recent study (Hartwigsen et al., 2017) that investigated functional reorganization in the language network. We show that across-voxel pattern-learning approaches are useful to isolate plastic changes in neural networks underlying cognitive functions at the individual subject level. Using predictive machine-learning tools to identify and exploit subject-specific neural activity patterns have been argued to become an important cornerstone of precision medicine in psychiatry and neurology (Arbabshirani, Plis, Margulies, 2017; Poldrack, 2017).

Functional reorganization is a key process for language recovery after lesions. However, current knowledge of plasticity in language networks is insufficient (Turkeltaub, 2015). Combining focal perturbations induced by transcranial magnetic stimulation (TMS) and fMRI in the healthy brain, we recently provided insight into the reorganization potential of language networks (Hartwigsen et al., 2017). Causal impairment of a key node for the processing of the meaning of words (semantic processing) in left angular gyrus (AG) entailed decreased semantic activity in a large network, including the targeted area. Despite this inhibition, there was no significant performance deterioration. Strikingly, this inhibition resulted in an upregulation of a neighboring network for phonological processing (processing of the sound of words), including left supramarginal gyrus (SMG) and adjacent superior parietal lobe (SPL). These regions were not engaged during semantic processing before TMS. This upregulation might have partially compensated for the disruption of the semantic network. In contrast, TMS over the phonological node in SMG resulted in strong inhibition of phonological regions and performance deterioration, without any compensatory upregulation of other areas. The difference in the activity patterns for both tasks might reflect the differential potential of brain networks for compensation of focal disruption that may be non-identical in different individuals. Despite its role in phonological processes, SMG/SPL appears to be capable of supporting semantic processing when task demands increase (after a virtual lesion of AG). In contrast, there was no evidence for a supportive function of the AG after perturbation of SMG.

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A) After sham TMS, discriminatory neural activity underlying semantic processing (natural vs man-made word stimuli) was found in left AG. After effective TMS perturbation of AG during the same experimental task, we observed a shift of discriminatory neural activity patterns from the AG to predictive voxels in left SMG and adjacent superior parietal lobe. B) In the second MVPA, we tested for discriminability of effective TMS over AG against sham TMS across all semantic stimuli. This analysis revealed areas that carried information about the presence versus absence of our TMS intervention. To provide principled guidance to our data-driven analyses, we based our searchlight approach on a topographical map of the left inferior/superior parietal lobe that was derived from neural activity information of two experimental task contrasts devoted to contrast semantic activity versus rest (showing increased activity in left AG) or phonological activity versus rest (showing increased activity in left SMG/SPL) in our original study (Hartwigsen et al., 2017). Both contrasts were derived by thresholding at a lenient threshold of \( p < .01 \) uncorrected, and the respective clusters were merged into a map that informed our searchlight approach. For visualization purposes, the depicted classification accuracy maps were thresholded at a voxel accuracy of 57% correct task/intervention in unseen brain scans (i.e., out-of-sample performance), showing only voxels with statistically relevant effects (cf. Bludau et al., 2016). The depicted results were based on a searchlight radius set to 5 mm, but were virtually identical to analysis with a smaller (2.5 mm) or bigger (10 mm) radius.

Fig. 1 – Multi-voxel single-subject analysis (MVPA) results from 5 representative individuals. The full data set is shown in Supplementary Fig. 1.
for a flexible redistribution of function. Our results help to identify adaptive patterns of reorganization after a lesion to a cognitive core region. Particularly, multivariate approaches might inform future studies to select areas for the application of TMS to facilitate language recovery after brain lesions. Based on our findings, we speculate that facilitation of neighboring regions might help supporting language recovery.

Despite only 60 stimuli per semantic condition and the fact that neural patterns underlying cognitive processes tend to be subject-specific (Saygin et al., 2011), we successfully isolated predictive patterns in all subjects. Future studies may provide insight from larger data sets and optimized experimental designs. Such studies would advance the current knowledge of plasticity in cognitive networks and ultimately help to understand how the brain reorganizes after lesions to process-specific nodes. The combination of TMS and machine-learning statistics has the potential for new insight into plastic changes on the individual subject level that might be used for outcome prediction and therapeutic intervention in future personalized medicine.

Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.cortex.2018.06.013.

References


