

Regulatory functions of prefrontal cortex during single word production [☆]

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Over the past decade, many neuropsychological and neuroimaging studies have investigated the putative linguistic and nonlinguistic functions of prefrontal cortex, specifically the posterior portion of the left, inferior frontal gyrus (LIFG) also known as “Broca’s area”. A number of these studies have converged on the hypothesis that LIFG functions to regulate activation among competing representations across a wide variety of linguistic (and nonlinguistic) situations (e.g., Robinson, Blair, & Cipolotti, 1998; Thompson-Schill, D’Esposito, & Kan, 1999). This hypothesis draws on a large body of research into the function of prefrontal cortex (e.g., Miller & Cohen, 2001), and contrasts with other more domain-specific accounts of the function of Broca’s area. Here, we present both functional neuroimaging data from young, healthy volunteers and lesion-deficit analyses of patients with focal brain damage that jointly provide support for the regulatory hypothesis of LIFG involvement in language processing, and that more broadly inform the study of both linguistic and nonlinguistic cognitive processes.

In several prior studies (e.g., Kan & Thompson-Schill, 2004), we manipulated competition during single word production across items, by systematically varying intersubject name agreement (e.g., a picture of a banana, which is consistently named as such, versus a picture of a shirt, which is alternatively named as a blouse, a top, a jacket). Activation in LIFG—and errors made by a patient with focal damage to this region—increased during naming of pictures with many, compared to few, competing names. Although these findings are consistent with the hypothesized regulatory role of LIFG in word production, differences across items are subject to a number of alternative interpretations. In the present series of experiments, we manipulated competition during single word production *within* items, taking advantage of a robust interference effect on picture naming that results from semantic blocking: Repeated naming of a group of pictures drawn from a common semantic category is slower (and in patients with aphasia, more error-prone) than is repeated naming of *the same pictures* arranged in unrelated blocks (e.g., Damian, Vigliocco, & Levelt, 2001; Schnur, Schwartz, Brecher, & Hodgson, 2006). We (and others) have argued that this semantic blocking

manipulation increases competition among semantically related items, and thereby increases demands for a regulatory (control) process that is hypothesized to require the LIFG.

In the first experiment, fMRI data were collected while sixteen subjects named line drawings of common objects. Half of the picture naming blocks comprised repeated sets of unrelated pictures. The other half of the picture naming blocks comprised repeated sets of either semantically-related pictures (i.e., same category) or phonologically-related pictures (i.e., names with same onset). Comparisons of semantically-related blocks to unrelated blocks revealed increased activation in LIFG, $t(15) = 2.37$, $p < .05$ and left temporal cortex, $t(15) = 2.14$, $p < .05$; however, only the former was correlated with behavioral performance, $r = .76$. Furthermore, the effect of semantic blocking was greater than the (null) effect of phonological blocking – which is typically associated with facilitation, not interference—only in the LIFG, $t(15) = 2.21$, $p < .05$.

In the second experiment, we analyzed error rates of twelve chronically aphasic patients attempting to repeatedly name pictures appearing in semantically related or unrelated blocks. We obtained high-resolution MRI or CT scans in order to perform a number of analyses relating structural abnormalities to functional impairments. First, in a region of interest analysis, we found that patients who exhibited a large blocking effect had more substantial LIFG damage than did patients who exhibited a small (or absent) blocking effect, $t(10) = 3.59$, $p < .01$. (In this and subsequent analysis, the magnitude of the blocking effect was described by a measure of the interaction between semantic blocking and repetition on error rates.) Second, we conducted a whole-brain analysis, comparing the magnitude of the blocking effect as a function of tissue status (damaged versus intact) at every voxel in the brain. In aggregate, lesions from the twelve patients covered 62,990 left hemisphere voxels. After applying a critical threshold determined from repeated permutations of the data ($t > 5.40$), we observed a significant effect of brain damage on performance in only one region, the left inferior frontal gyrus (BA 44).

In both of these studies, data revealed a network of brain regions involved in single word production; however, the posterior LIFG appears to be uniquely responsive to the increased demands to regulate activation of competing representations during word production created, in this case, by repetition of semantic associates. Several studies, including other papers presented in this symposium, shed light on the nature of the competitive interactions that are created by this semantic blocking manipula-

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tion. Here, we argue that a cognitive control mechanism that can help regulate competition in this instance is in fact shared across a number of tasks and domains.

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