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**SYMPOSIUM—INTRODUCTION**

# Frontal injury: Impairments of fundamental processes lead to functional consequences

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Frontal functions, or impairments, have achieved the status of pornography: everyone knows them when they see them, but there is little agreement on their exact defining properties. Patients with frontal lobe lesions have impairments in planning, monitoring, sequencing, and inhibiting responses. They cannot organize complex behaviors. They are somehow simultaneously unaware and distractible, irritable and apathetic, violent and passive, impulsive and perseverative. They lack empathy, self-awareness, and emotional regulation. Patients often are incapacitated by frontal impairments that paradoxically are not at all obvious to most observers. To understand the effects of frontal lesions, science has sacrificed countless rats and nonhuman primates. Neuropsychology and Neurology have sanctified a few tests as *the* tests of frontal function, and then spent money, time, and the mental health of countless graduate students and research assistants trying to tease out of those tests some basic knowledge of frontal functions. Experimental Psychology has brought novel constructs to the problem of defining frontal functions, and modern neuroimaging has merged the traditional clinical and the novel experimental with imaging technology. (A quick PubMed search of “fMRI and frontal lobes” on October 12, 2005 retrieved 4,646 articles, the most recent, “An fMRI study of the Trail Making Test”.) Yet, confronted with a patient with a large right prefrontal lesion who cannot hold a job or even be relied upon to buy the groceries he set out to buy, we have precious few tools to define his problem and almost nothing to offer to fix it.

This symposium was developed to identify some of the clinical and research obstacles that we face and to describe some approaches to future study that might bring us clearer understanding and even some therapeutic interventions. What do we hope that the reader will glean from these 6 reports?

There are several key conclusions. First, the several theories and models of frontal function (e.g., the supervisory attentional system or the goal management model) can all be deconstructed into component parts. Second, these component parts are excellent constructs for motivating experiments, but they are very hard to operationalize as neural functions. What does “updating” or “strategy implementation” actually mean in neural terms? Third, and nevertheless, there are, or must be, processes or operations that can be mapped to neural bases that underlie these constructs and models. Fourth, these operations are not uniformly and diffusely spread through the frontal lobes. They are distributed in discrete regions, such that lesions in different regions produce different patterns of deficits in the neural operations that, in turn, cause different clinical and functional problems. Fifth, it is the action of these operations in particular environmental contexts, under particular emotional and drive states, which concatenate under specific time and response constraints to produce the large-scale behaviors that are thought of as “frontal”. Sixth, these larger-scale behaviors are achieved through networks, with additional processes being recruited depending on the environmental context. Seventh, because of the potential for recruitment of different regions, despite the regional divergence of fundamental neural operations, there may be considerable capacity for reorganization, for utilizing compensatory behaviors, and for relearning, but the surface has just been scratched in understanding how these occur or may be fostered.

Burgess et al. lay out the arguments for reversing the typical approach to research into the effects of frontal lesions. They suggest that we have been looking through the experimental telescope from the wrong end. We have been asking how multidimensional tasks that are virtual historical accidents can be parsed to explain basic processes or to predict clinical behaviors. We should set ourselves a different course. What are the critical clinical problems and can we create tasks that exist in the same contextual frame as “real life”?

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Davidson et al. grapple with a very similar concern regarding the effects of frontal lesions on memory. For each construct of memory—encoding, retrieval search, and retrieval monitoring—they attempt to identify the underlying neural operations. Then they ask how well do these constructs and operations speak to the actual function of memory in “real life.” They point out how the considerable and creative literature on various operations that underlie learning and recall can each be matched to functional deficits.

Anderson et al. approach an even more difficult problem from a similar perspective. What is the nature of impaired emotional regulation after frontal injury and how does it relate to functional failures? Loss of regulation of emotional responses to specific environmental cues can affect “real life” function even in the absence of standard cognitive failure. Poor calibration of the emotional significance of an act may bias decision-making or cause distraction due to over-reaction. They demonstrate that the most accurate measure of frontal deficits may come from asking those who live with the patients about their function.

Alexander examines why patients with left frontal lesions cannot manage the procedures for complex narrative (i.e., in “real life” tell about their vacation, relate the plot of a movie, etc.). There are identifiable operations that underlie this capacity, but they are not linguistic ones. This complex acquired ability to tell a narrative requires a series of attentional operations whose relative weighting may constantly shift as a consequence of a varying moment-to-moment context.

D’Esposito et al. provide an example of the uncertainties involved in mapping functional imaging studies into the clinic. Despite the extraordinary interest in studying working memory (926 articles and 74 reviews retrieved from PubMed searching for “fMRI and working memory,” the

most recent review by D’Esposito) and despite the robust demonstration of activation in dorsolateral frontal regions of normals with every paradigm, including the one in the current article, seven patients with lesions in exactly that area had no deficit in span or sensitivity to interference. The authors identify several possible reasons for this, but acknowledge that these dissociations between imaging and lesions studies leave the meaningfulness of the working memory construct in some doubt.

Stuss returns us to the basic operations. He reviews a number of studies that demonstrate that attention is constructed of several distinct operations, that they are regionally distributed in frontal structures, that their recruitment depends on the task and the context, that these operations are largely domain-general and that only one appears critical for all tasks in all contexts. This activation or energization—to avoid confusion with all of the other levels of explanation that are labeled activation—is a discrete function, although not the only attentional function of superior medial structures.

So, no card sorting, no trail making, no Stroop. No planning and no sequencing. Much different terminologies from paper to paper, but a similar emphasis throughout. Traditional tests fail on almost every count. They do not provide direct evidence for the existence or nature of basic operations of frontal systems. They are remote from and not informative about clinical functional failures. Functional imaging in normals can test and improve experimental constructs but cannot, ironically, inform very deeply about function. If interested in patients’ function, the tests should be meaningfully functional. If interested in basic neural processes, the tests should be unambiguously operational. It remains to be seen if these two goals can be meaningfully merged—a test of our collective “executive functions” perhaps.