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Looking both ways through time: The Janus model of lateralized cognition

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Abstract

Existing models of laterality, while often successful at describing circumscribed domains, have not been successful as explanations of the overall patterns of hemispheric asymmetries. It is therefore suggested that a new approach is needed based on shared contributions to adaptive hemispheric roles rather than functional and structural intrahemispheric similarities. This paper proposes a model of laterality, the Janus model, based on evolutionary considerations of complementary hemispheric roles. It is proposed that the left hemisphere has the role of anticipating future scenarios and choosing between them while the right hemisphere has the role of integrating ongoing information into a unitary view of the past in order to immediately detect and respond to novel and unexpected events. Evidence for these complementary roles is provided in research on motor control and semantic priming. Finally, the Janus model is contrasted with efforts to cast the frequency model as a general model of laterality.

Keywords: Attention; Event-related potentials; Laterality; Motor; Semantic priming; Animal cognition

1. Introduction

One of the fundamental mysteries of the human brain is the functional nature of the division of the human brain into the left hemisphere (LH) and the right hemisphere (RH). Very few cognitive functions are not touched by lateralized differences at least in some respect. Despite the ubiquity of lateralized activity, the underlying organizational principle for these findings remains obscure. It will be argued that efforts to formulate generalized dichotomies have proven inconclusive, resulting in a diverse but disorganized body of observations. A past effort to develop an integrative model of brain lateralization (Bradshaw & Nettleton, 1981) served as an opportunity for laterality researchers of the time to have a conversation about the state of the field. It is suggested that it would be useful to mark the 25th anniversary of this landmark discussion by reviewing the current state of the laterality field and making an updated effort to form an integrative framework. Furthermore, recent developments documenting pervasive patterns of lateralization in animals (Rogers & Andrew, 2002) have profound implications for laterality theory that also need to be addressed.

This paper will be divided into three major sections: (1) A broad overview of five major lines of laterality theory (Table 1), with a special focus on frequency theory and its Coarse Coding extension to the semantic domain. (2) a proposal for the Janus model of laterality, and (3) a comparison of contrasting predictions by the Janus model and the Coarse Coding model. Given the impossibility of addressing the full scope of laterality findings in a single journal article, the goals of this manuscript are limited to making the case that the Janus model is a viable alternative to current cross-domain laterality frameworks and that it

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Table 1
Laterality models

	Left hemisphere	Right hemisphere
Content	Verbal	Visuospatial
Relations	Categorical	Coordinate
Organization	Analytical	Configural
Learning	Routinization	Novelty
Frequency	High	Low

may apply to at least two domains, that of motor control and that of semantic priming. No claim will be made that it applies to all aspects of laterality.

1.1. Review of five laterality models

It is a reflection of the fragmented state of the laterality field that there is no review available at present that summarizes and contrasts the main laterality theories (for some earlier reviews, see Allen, 1983; Bradshaw & Nettleton, 1981; Moscovitch, 1979; Segalowitz, 1983). Because of this fragmentation, laterality papers usually cite only one theoretical view, leading to further balkanization. This fragmentation is largely a reflection of dissatisfaction with efforts to forge broad dichotomies to account for hemispheric asymmetries (clearly evident in the commentaries on perhaps the last major such effort: Bradshaw & Nettleton, 1981). Efforts have therefore largely turned to single-process models. A thoughtful argument for such an approach (Allen, 1983) held that it might be more fruitful to approach laterality findings from the standpoint of subprocessors scattered throughout the two hemispheres and to decompose tasks accordingly rather than to posit hemispheric level generalities (see also Moscovitch, 1979). The potential problem with pursuing this approach is that it can result in the present state of affairs, which is largely that of a laundry list of hemispheric differences without broad principles with which to organize them. While it may indeed be the true state of affairs, it seems worthwhile to try to reverse the theoretical pendulum somewhat and seek a more moderate position between the extremes of simplistic dichtomania and fatalistic anarchy. The present treatise will seek to propose a model posed in terms of subprocessors rather than broad hemispheric asymmetries, consistent with current approaches, but to also argue that the distribution of the subprocessors into the two hemispheres can nonetheless be understood as following meaningful principles of adaptiveness.

In order to further the goal of providing an integrative perspective, this paper will first review the five primary lines of laterality theory. In doing so, it is important to note that the boundaries for each of these theories are largely unspecified. That is, each has been proposed as an explanation for observations in a limited range of laterality studies, followed by ongoing efforts to apply them more widely. Thus, no claims will be made that a laterality model must account for all laterality findings to be valid. Likewise, it should be understood that the researchers who have developed these theories have not made broad claims about their domain, leaving it to individual researchers to investigate broader applications. Rather, this review should be understood as being a survey of how these models have fared in these ongoing incremental efforts to extend them and to what extent they can currently be used as broader explanatory frameworks for laterality findings. The critical test, then, will be whether a model can be applied outside of its core domain of cognitive processes.

In making this point, it may be helpful to utilize a distinction between proximal and distal (or ultimate) causes made by comparative psychologists (Alcock, 1993). A proximal cause is the immediate mechanism for an event, such as wings and a loud noise for the event of a bird flying. A distal cause is the circumstances that led the mechanism to be developed in the first place, as in the need to avoid predation. The following models concern the proximal causes of laterality observations within a domain of research and, as such, take a structural approach to explaining the differences between hemispheres. As has been argued at various times (Bogen & Bogen, 1969; Federmeier, 2007; Hutsler & Galuske, 2003; Ivry & Robertson, 1998; Kosslyn, Chabris, Marsolek, & Koenig, 1992; Levy, 1977; Sergent, 1982; Vallortigara, Rogers, & Bisazza, 1999), they have the potential to be extended to the distal level by making the argument that when there are two approaches to a computation, one can optimize them by differentially instantiating them in the two hemispheres, in what might be termed the architectural efficiency framework. Such a distal cause suggests the potential for these structural differences to extend to other domains than the one directly addressed by a laterality model.

1.1.1. The LH-verbal/RH-visuospatial model

The LH-verbal/RH-visuospatial model characterizes lateralized functions according to discrete domains of information. Neuropsychologists noted early on (e.g., Broca, 1865) that language disorders such as aphasias generally arise from left hemisphere lesions. In contrast, it was observed that neglect cases typically arise from right hemisphere lesions (Brain, 1941; Vallar, 2001). Neglect patients tend to ignore the left side of space in spite of demonstrating intact vision. The spatial nature of this and other disorders linked to the right hemisphere led to the formulation that the right hemisphere mediates "visuospatial" processing, in contrast to the verbal functions of the left hemisphere (Kimura, 1973; Milner, 1958, 1971). Visuospatial has generally been understood as including pictorial representations, not just spatial judgments. Of course, this dichotomy is meant to describe the general case as it pertains to right-handers, where estimates suggest (Knecht et al., 2000) suggest that roughly 8% of the right-handed population has RH dominance for language.

Much of this research has been conducted using the visual half-field technique (Banich, 2003; Bourne, 2006)