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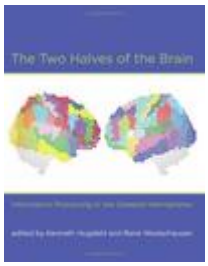

Neuropsychology and Cerebral Lateralization: A Long History and a Renewed Vigor

A Review of

The Two Halves of the Brain: Information Processing in the Cerebral Hemispheres
by Kenneth Hugdahl and René Westerhausen (Eds.)
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Reviewed by

Simon M. McCrea

In 1998 Ivry and Robertson published *The Two Sides of Perception*, which brought the study of the cognitive neuroscience of laterality to a wider scientific audience. Between 1998 and 2010, many new technical developments have enhanced cognitive neuroscientists' understanding of hemispheric differences such that old theories have been tested and verified and in some cases significantly modified.

These lengthy developments include genetic methods, evolutionary studies and theory, new functional neuroimaging techniques such as event-related functional magnetic resonance imaging (fMRI), diffusion tensor imaging, white-matter fiber tractography, combination electroencephalography with fMRI and/or positron emission tomography studies, monkey fMRI studies and optical imaging, application of clinical cognitive neuroscience to psychopathological populations, developmental cognitive neuroscience and theory, magnetoencephalography, wider dissemination and use of transcranial magnetic stimulation, and establishment of large-scale brain–behavior databases involved in lesion mapping.

Many of these new methods have allowed for the direct testing of some of the hypotheses advanced in *The Two Sides of Perception*. A new book edited by Hugdahl and Westerhausen, *The Two Halves of the Brain: Information Processing in the Cerebral Hemispheres*, heralds cognitive neuroscience's return to its structural and functional neuroanatomical roots that has been accelerated with the proliferation of these new technologies.

It is not often that one finds an academic textbook that is timely, cutting edge, and well integrated. This new text on hemispheric lateralization ranges from genetic studies of differential hemispheric expression of proteins in the brain to evolutionary theories of

speciation. It could easily be used as a graduate textbook for an advanced-level cognitive neuroscience course of hemispheric lateralization.

This treatise contains beautifully illustrated diagrams and figures and color illustrations of brain structural and functional images as well as fiber tract visualization, which is possible with techniques such as diffusion tensor imaging tractography. There are eight sections to the book, which cover genetic perspectives, nonhuman species, neuroimaging, hormonal influences, perceptual asymmetry, cognition, neurological disorders, and schizophrenia. It is definitively organized around theoretical concerns within each of these sections.

The coverage is thorough, and yet careful editing has ensured that the writing is accessible to specialists and nonspecialists alike. The acknowledged expert authors have been careful not to lose sight of the essential wider theoretical implications of their individual contributions. However, the nonexpert may not grasp from the book why cerebral lateralization is even important to study at all or if it is just simply a thing of the past.

In 1978 MacLeod, Hunt, and Mathews used a visual displaylike apparatus to examine individual differences in the verification of sentence–picture relationships. Subjects were required to determine whether a sentence provided a true description of a subsequent visual display (e.g., circle above a rectangle). The majority of subjects used a linguistic strategy to solve the question, whereas a small proportion of subjects used an exclusively visuospatial strategy, and subsequent testing found that these subjects had high spatial ability.

These high-spatial-ability individuals converted the sentence propositional code into a pictorial representation in their mind’s eye and then matched this representation with the subsequently presented picture. The spatial or topological strategy was twice as efficient compared with the verbal strategy—a finding with important implications for search strategies within informationally rich domains.

In 1987 Vicente, Hayes, and Williges asked subjects to locate information within a complex hierarchical computer filing system. These investigators found that the spatial ability along with receptive vocabulary were the best predictors of performance on this task. Experience with these systems had no effect, and high-spatial-ability subjects were twice as efficient as low-spatial-ability subjects. This type of research was instrumental in the development of second-generation visual graphical interfaces and displays used in many software operating systems and Internet search engines of today.

What Vincente and his collaborators were studying was essentially general spatial visualization, which is a form of raw intellectual capacity closely akin to Cattell’s fluid intelligence. General spatial visualization is a highly inheritable trait, with some estimates as high as 65 percent, which is equivalent to a second-tier verbal cognitive ability score (Ando, Ono, & Wright, 2001).

A Swedish study of 15,000 recruits found that as the level of general intelligence increased, so did the amount of variance accounted for by spatial visualization. The conclusion was that the genetic substrates of general intelligence are differentiated through development in stable, higher order specific abilities such as general spatial visualization, which is sometimes abbreviated as Gv (Ullstadius, Carlstedt, & Gustafsson, 2004).

This developmental hypothesis of Gv is intriguing because it may shed some interesting light on developmental cognitive neuroscience studies of the maturation of white-matter fiber

tracts. Traditional psychometric theory has always held that the distribution and reentrant white matter connectivity between different areas and regions of the brain was the neural substrate of fluid intelligence. However, there were never any particular specifications by these theoreticians as to what form this white matter connectivity took, only that it was continuous and was able to form an abundance of associative bonds.

These studies highlight the importance of highly lateralizable cognitive functions such as general spatial visualization, used, for example, in information searching and spatial planning, and high-level social communication skills, used for example, in interpreting the facial expressions and hence intentions of others (e.g., see Hellige, Laeng, and Michimata's discussion of a newly discovered right lateralized mirror neuron system in their chapter "Processing Asymmetries in the Visual System").

Spatial visualization has traditionally been the poor stepsister of the *g* factor and discounted by psychometricians and applied psychologists alike. There are signs of change in the air with the recent publication of well-standardized instruments and recognition that it constitutes much more than ostensibly spatial abilities.

Hemispheric laterality has a long history, beginning with Kimura's studies of dichotic listening in the early 1960s. She adapted Broadbent's original task for studying flight controllers' vigilance and attention capacities during World War II. These early researchers attempted to examine in young recruits spatial visualization capacities such as triangulation to determine location with such newly developed technologies as radar and sonar.

Similar cognitive functions were purported to involve systematic sorting through and classification of many scrambled frequency channels containing either valid or invalid enemy messages, presumably through the use of binary decision criteria. So, it seems that when one looks beyond the surface literature and catchy new titles to popular new cognitive neuroscience articles, there are some real reasons why cerebral lateralization mattered in the past and likely still matters today.

Recent studies have shown that language dominance can be now be detected by automated segmentation analysis of gray matter volumes in the left and right hemispheres (Keller et al., 2010). Finger tapping or silent ruminative thinking in the fMRI scanner will also reveal an individual's atypical language dominance pattern in the brain (although this may be just as easily discovered serendipitously as when a left-ear-dominant subject uses a phone).

Keller and colleagues (2010) mapped the gray matter asymmetry in the right and left planum temporale, Broca's area, and insula and found that only the right insula demonstrated asymmetry in 10 right-hemispheric language-dominant subjects. Keller's finding of an asymmetry in the insula fits well with findings from a group of French cognitive neuroscientists studying right hemisphere language in neurosurgical patients. Vassal, Le Bars, Moritz-Gasser, Menjot, and Duffau (2010) demonstrated the first case in which stimulation of the right occipitofrontal fasciculus generated semantic paraphasias, where confusion exists between and within categories of word relationships. This new ventral semantic stream has recently been the subject of much hyperbole as to just what functions it carries out; however, it is clear these functions are complex.

New techniques such as correlating behavioral performance on neuropsychological tests with tractography data will likely be a boon to cognitive neuropsychology over the next decade as cognitive neuroscience provides empirical and theoretical inroads in neuropsychiatric and

Axis II disorders. As an example, Catani, Forkel, and Thiebaut de Schotten in Chapter 7 of *The Two Halves of the Brain* show how scores on the California Verbal Learning Test—II correlate with fiber density and orientation of tracts within subtracts of Geschwind's territory.

These studies are fascinating because they teach us from a purely structural standpoint what theorists in the fields of intelligence theory and psychometrics have always known—that there is a huge range of differences between and within the sexes. *The Two Halves of the Brain* shows how powerful the neuroanatomical approach can be in skilled hands and outlines a program of research to which other clinical neuroscience experimenters can aspire.

For example, diffusion tensor imaging and high-resolution structural imaging can often now be run through automated routines, obviating the need for local expertise in pulse-sequence programming or extensive expertise in physics and mathematics. A good armamentarium of neuropsychological tests, knowledgeable cognitive neuroscientists, and access to standard conventional neuroimaging are all that is needed.

Other highlights from this book include Casagrande's chapter "Laterality and Sleep," which is rich in content and ripe for speculation. Motor priming of the left hand during different stages of sleep and a unique role for the right hemisphere in many aspects of sleep suggest a multitude of means of studying dreaming in the laboratory. Dreams constitute a significant body of research in clinical and personality psychology and could provide an area for some integration of ideas of the past with contemporary neuroscientific ones.

Studies of songbirds' auditory system (Chapter 4 by George) and pigeons' visual system (Chapter 5 by Güntürkün and Manns) have enabled the development of sophisticated new models of how callosal and subcortical structures are involved in hemispheric lateralization in humans as well as the canalization toward ever more complexity in cognitive apparatus. The studies of multisensory integration between the auditory and visual channels that Hämälläinen and Takio discuss in Chapter 14 provide unique insights into the functioning of multimodal hemispheric cortex involved in spatial and selective attention that originates within the right inferior parietal cortex.

Finally, the unique functions of laterality for individuals are explained from an evolutionary perspective by Corballis (Chapter 3) and from the vantage point of when things go terribly wrong, as in the psychopathology of schizophrenia, by Crow (Chapter 21). In their chapter "Visuospatial Function and the Neglect Syndrome," Singh-Curry and Husain describe the anatomy of neglect and the relationship of the right temporoparietal junction more generally in switching between local and global attentional signals. Spatial and nonspatial deficits result from lesions in this area, which plays a particular role in novelty and behaviorally salient events when attention must be directed beyond current goals as an alerting mechanism.

In his introductory chapter "Differential Gene Transcription in the Left and Right Cerebral Cortex," Sun shows that no fewer than two dozen genes have been discovered in the last five years that have unilateral hemispheric localization. Functional neuroimaging in conjunction with such advanced genetic methods will likely constitute one of the fastest growing areas of cognitive neurosciences and with the widest of implications for the first half of this century.

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