Issues and Opinions

Hemispheric Specialization, Cognitive Differences, and Their Implications for the Design of Decision Support Systems

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Introduction

Robey and Taggart, in an article in the June 1982 issue of *MIS Quarterly,* set forth an interesting proposal regarding the roles of man and machine. They called for an appropriate division of labor between the electronic computer and the human "bio-computer" for information processing and decision support systems. Robey and Taggart (1982) based their proposal on the assumption of hemispheric asymmetry and hemispheric specialization of the human brain, and the "fact" that human information processing and cognitive style differences in individuals are related to biological specializations of the human brain. In this comment, we first give evidence for the incorrectness of the use of hemispheric specialization and asymmetry as a theoretical explanation for the observed phenomena of differences in cognitive style among individuals. Second, we show that in spite of the incorrectness of the theoretical explanation, the observed phenomena of differences in cognitive behavior that lead to the division of labor concept can have important implications for DSS and human-machine interface design.

Hemispheric Asymmetry and Specialization

The brain consists of two cerebral hemispheres, the left and the right. Robey and Taggart's thesis is that (1) the left cerebral hemisphere performs rational, sequential, and analytic functions and can thus be modeled by the electronic computer; and (2) the human "bio-computer," on the other hand, is considered to have an intuitive style of problem solving and is therefore related to the right cerebral hemisphere, which operates intuitively and holistically. They further classified a variety of information processing functions as falling into left and right-brained categories.

The basis for the concept of hemispheric asymmetry was medical and clinical research in the 1970s with split-brain patients (surgically split or brain-injured patients). These were abnormal subjects on whom experiments were conducted in highly unnatural and constrained conditions (Bagnara, et al., 1982). Based on such experiments, researchers predicted corresponding functional hemispheric differences in normal people in everyday life. Subsequent research (Bagnara, et al., 1983; Boles, 1984) shows this is not necessarily true because:

1. The laboratory-produced asymmetry is reliably strong only in right-handed males.
2. Each hemisphere performs functions that are performed by the other, and neither hemisphere is as specialized as originally thought.

3. Normal people's hemispheres communicate with each other extensively. This is why asymmetry even in the laboratory is strongest when responses are gathered from subjects so quickly that the hemispheres have had little time to share. Thus, split-brain patients are necessary for clear examination of asymmetry.
4. Even among split-brained patients, there are several problems of interpretation of experiments. First, the nature of the patient sample is suspect. Most of the patients have severe and longstanding epilepsy and are unlikely to have had normal brains prior to surgery. Further, surgical incision of the brain itself may lead to certain cognitive disturbances, thus implying that the functioning of cerebral hemispheres may be different from that in normal subjects. Most importantly, recent studies of split-brain patients suggest that cerebral hemispheres may have more channels of cross communication than formerly supposed (Bouma, 1990).
5. Outside the laboratory, people manipulate their perceptual and motor apparatus so that both hemispheres participate in all activities. For example, each eye feeds both hemispheres. The participatory mechanism of the hemispheres is so powerful that split-brain patients appear normal outside the laboratory constraints. In fact, Bagnara, et al. (1983) have conclusively shown that though visual fields interact, they fail to do so in a manner consistent with the assumption of hemispheric dichotomy. Therefore, it is quite fallacious to describe the right hemisphere as a holistic processor and the left hemisphere as an analytic processor.
6. Posner, et al. (1984) studied the effect of spatial cues on performance of patients with unilateral parietal lesions and found that patients with left and right-sided lesions were equally impaired when an invalid cue was presented on the side ipsilateral to the lesions. Based on these findings they suggested that both hemispheres contribute equally to selective aspects of attention.
7. Even if perceptual or motor asymmetry shows up in the subject in the laboratory experiment, one should be cautious in interpreting it as being necessarily related to cerebral asymmetry. A whole host of variables may influence any difference that emerges. For instance, laterality effects have been reported to vary with age, sex, handedness of subjects, individual differences in cognitive ability, and/or mode of processing (Bouma, 1990).

A more recent article by Taggart, et al. (1985) in the *Journal of Management Studies* reports empirical research findings that support the concept of hemispheric asymmetry. This was based on the amount of electrical activity in the brain as measured by EEG techniques. Alpha and beta brain waves were recorded and compared. The basic assumption of this experiment was that alpha waves were considered to depict a passive idling state, and if the amplitude of alpha waves were larger in the right hemisphere than in the left, it implied that the right hemisphere was less active than the left. However, as Hines (1987) shows, this basic assumption has itself been questioned (Gevins, 1983; Rothschild and Thorson, 1983). Rothschild and Thorson point out that neither the physiological origin of alpha activity nor its cognitive significance are clear. In addition, a problem that occurs is that it is difficult to see the changes in the EEG that relate to the occurrence of specific stimulus events. Changes that could occur in response to the presentation of specific stimuli are hidden by the overall activity of the brain (Springer and Deutsch, 1989). In addition, as Hines (1987) notes, several factors about the arithmetic task being performed while the EEG's were being recorded, such as information about stimuli presentation, length of response time, difficulty of problems, etc., were not detailed in the Taggart, et al. (1985) article. The failure to control the response variables could possibly result in spurious findings of hemispheric differences in EEG measures. When such variables are taken into account, no evidence for a relationship between EEG patterns and cognitive task or style has been found (Gevins, 1983; Hines, 1987).

A possible approach that has been proposed (and carried out in recent experiments) in order to come up with a definitive answer to the debate on hemispheric asymmetry is to conduct research with better tools (Springer and Deutsch, 1989). A more refined tool for measuring brain activity is the magnetic counterpart of EEG, known as magnetoencephalogram (MEG). This is considered to be a major improvement over the EEG in its ability to better localize within the brain the source of activity being recorded (Beatty, 1990). Other more refined methods than EEG for measuring cerebral activity are positron emission tomography techniques and regional cerebral blood flow techniques. Positron emission tomography is the only technique developed so far that can produce regional three-dimensional quantification of glucose or oxygen metabolism in the living human brain (Pahl, 1990). Studies using the better tools consistently show that cognitive tasks increase activity levels in both hemispheres. This essentially implies that no part of the brain is passive and idle while performing a cognitive task. Hence, there is little evidence to support the notion that either one or the other hemisphere turns on to perform a specific task all by itself. Each of the more refined methods point to the involvement of many areas of the brain in even the simplest of tasks (Bouma, 1990; Hines, 1987; Rothschild and Thorson, 1983; Springer and Deutsch, 1989).

Because recent neuropsychological literature has abandoned the notion of general hemispheric functions, hemispheric specialization cannot be used as a supportive argument for Robey and Taggart's proposal. While there are asymmetries in activity between the spheres, they can be very subtle, a fact that should lead us away from thinking about hemispheric specialization in overly simple terms (Springer and Deutsch, 1989). In summary, considering the recent evidence, we can eliminate the concept of hemispheric specialization as a possible theoretical explanation for cognitive style and perhaps also question the relevance of findings of hemispheric asymmetry for management theory and practice.

Differences in Cognitive Behavior for DSS Design

It is important to realize, however, that the above discussion has in no way eliminated the concept of differences in cognitive style, nor even decreased its importance. Information systems researchers, management researchers, as well as computer science (AI and cognitive psychology) researchers, are primarily concerned with cognitive style (as an observed phenomenon) and secondarily with hemispheric asymmetry (as a theoretical explanation for the observed phenomenon). In this context, it is relevant to quote De Waele (1978): "there is no reason why the social sciences in general should omit the preliminary phenomenological schemes based mainly on pure observation, which seem to have been so useful for the arrangement of facts in disciplines like chemistry or particle physics" (p. 5).

For purposes of the design of human-machine and decision support systems, which is where the division of labor can play an important role, it is the differences in behavior, and not the differences in hemispheres, that are important (Barnard, 1938; Simon, 1987). Regardless of the theoretical basis, cognitive style and cognitive process, as well as decision-maker characteristics with respect to problem solving, have implications for DSS design (Chi, et al., 1988) and for human-machine interactive systems (Norman, 1991a; Rasmussen, 1986; Ulich, 1987).

In his widely cited article in *Management Science,* Huber (1983) argues effectively that cognitive style research does not provide a legitimate basis for MIS and DSS designs. His article leaves the reader with the impression that such research is "much ado about nothing." However, in his article, Huber himself constructively identifies some major areas where cognitive style research may still make a contribution. First, he suggests that research in the assessment of cognitive styles is likely to help decision makers in the accurate assessments of natural propensities. In a closely related second suggestion, he identifies contingency-focused research as useful for decision makers in matching styles to situations. Third, he points out that cognitive style research could help in training decision makers to employ cognitive styles other those to which they are naturally predisposed.

In his rejoinder to Huber's article, Robey (1983) concedes that cognitive style research has not served as a satisfactory basis for operational DSS design and suggests a potentially valuable role for cognitive style awareness in the DSS development process. He envisions, as a corollary, that future DSSs will be sufficiently flexible to complement users' predispositions or aid their preferred decision-making style.

For the purposes of this comment, we will focus on the areas that are directly related to the implications of design for decision support systems. We specify how cognitive research falls into (1) the first two areas above, suggested by Huber, and (2) the corollary that Robey identifies in his rejoinder.

Clearly Huber's first two suggestions have major implications both for enhancing the productivity of the decision maker as well as the design of DSS. If one can match decision-making styles to tasks and can accurately determine the natural propensities of the decision makers, then one can assign tasks to decision makers with appropriate skills. At the same time, knowledge of the skills and task requirements allows the design of DSSs that can complement as well as supplement the decision makers' skills.

Empirical evidence indicates that a decision maker's perception of a decision problem and search for information and evaluation of alternatives is based on cognitive style, cognitive process, knowledge, and experience (Blaylock and Kees, 1984). The approaches taken by decision makers are also impacted by decision-maker characteristics; examples include expert vs. novice characteristics and problem-solving approaches that range from intuitive to analytic. Simon (1987) suggests these differences in cognitive style have implications for designing systems to support management functions.

There is a wide variation in the capabilities of a novice and an expert (Simon, 1987). A novice may have knowledge about the problem domain but may have difficulty in applying it and, thus, tends to mechanically utilize concepts learned in the past; an expert, on the other hand, would be more creative in his or her approach to problem solution (Chi, et al., 1988). The expert's creativity is an offshoot of experience and having learned how to effectively apply knowledge. A novice usually has limited experience in a particular problem domain. Recognition of the association or relationship between events assists a novice in building up knowledge. Also, memorization allows concepts and knowledge necessary for solving decision problems to be reinforced.

Within the two groups, experts and novices, two problem solving approaches—intuitive and analytic—can be considered (Keen, 1973). In general, one may not find extremes but rather a preference for one approach or the other. Analytic thinkers tend to be attentive to detail and to the exact implications of a piece of data. They may insist on a complete examination of a set of data before deriving conclusions. A method and a plan for solving a problem are usually adhered to. Specific constraints of the problem are defined early in the problem-solving process, and an orderly search is conducted for additional information. Analytic thinkers move through a process of increasing refinement of analysis (Keen, 1973).

On the other hand, intuitive thinkers tend to look for cues in a set of data, focus on patterns, and jump from one section of a data set to another while building a set of explanatory percepts. In addition, they redefine the problem frequently as they proceed, rely on unverbalized clues, and can consider a number of alternatives and options simultaneously. They can jump from one step in the analysis or search to another and back again, as well as explore and abandon alternatives very quickly (Keen, 1973). In general, analytic decision makers have been seen to consistently prefer more quantitative information and require more decision time than intuitive decision makers (Keen, 1973; Robey and Taggart, 1981; Zmud, 1979). The requisite measures for the assessment of intuitive and analytic decision styles have been developed in recent research by Taggart and Valenzi (1990).

Discovering natural propensities and matching decision-making styles to problems lead to the ability to operationalize Robey's suggestion of a DSS complementing the user's style. Differences in cognitive style impact two major issues. First, a support system can help solve problems that decision makers cannot solve (Jacob and Pirkul, 1990), perhaps because of human limitations (for example, computation-intensive and memory-intensive problems); second, the support system acts as a guide, a facilitator/aid, and a consultant to the decision maker in solving a problem. Many early DSSs focused on the first issue, while current systems tend to focus on the second.

Recent developments in DSS (such as symbiotic decision support systems and intelligent and active decision support systems) require that individual differences, in terms of expertise, cognitive processes, and approaches to solving problems, be actively moderated by the computer working independently of explicit user direction (Manheim, et al., 1990; Mili, 1989). Further, considerable work in human-computer interaction has been devoted to methods for displaying information that rely on cognitive models of the decision maker (Murphy and Mitchell, 1986). Particularly interesting is the effort in the development of the Programmable User Model (Young, et al., 1989). This is a step in bridging cognitive models, system models, and interface design issues. It is possible that the use of such a system to guide the decision-making process could actively help a notice to learn and move toward the expert end of the problem-solving spectrum. Indeed, future research could focus on studying the use of such systems by novices and whether there is any impact on the acquisition of skills.

In designing a DSS, one needs to supplement the capabilities of the decision makers. Individuals whose problem-solving styles are inconsistent with the capabilities possessed by the DSS are unlikely to use it. Alternatively, a DSS that conforms to a decision maker's cognitive style could result in strengthening biases and inconsistencies in thinking, both of which are potentially dangerous problems (DeWaele, 1978; Huber, 1983). A possible solution is to integrate the concept of symbiotic systems and active DSS (Manheim, 1990; Mili, 1989), where the computer works independently of explicit user direction. This follows the concept of the menu selection model of human-machine interaction (Card, et al., 1983; Norman, 1991b), where a set of cognitive processes is engaged to handle the interaction from the standpoint of the decision maker. This integration would allow the foreground of the system to consist of menus that conform to the user's cognitive style, whereas in the background the computer would work independently of the user and supplement the user's cognitive style. This suggests a variant of Huber's third suggestion for research, namely whether a DSS that supplements the decision maker's capabilities enhances the quality of the decisions, in spite of the decision maker not having been trained in cognitive styles to which he or she is not naturally predisposed.

In conclusion, this comment has provided evidence against the use of the microscopic approach of neuroscience for providing theoretical foundations for DSS and human-machine interface design guidelines. The focus should instead be on psychological issues where cognitive functions are studied independently of their physical implementation. Research on cognitive functions should be carried out in terms of their high-level characteristics rather than their micro-organization (Serra and Zanarini, 1990). This is consistent with the movement of research in artificial intelligence to closer linkages to cognitive psychology.

Finally, based on the assessment of cognitive style for accurate assessment of propensities of the decision maker, it is possible to design a DSS to better complement and supplement decision-making skills. By relating cognitive styles to decision-making situations, a DSS would have the appropriate capabilities and tools to allow an analytic/intuitive decision maker or an expert/novice to perform effectively (Simon, 1987). For example, it could actively help a novice learn and move toward the expert end of the problem-solving spectrum by being a critic, advisor, or consulting partner in the decision-making process. Although Huber (1983) points out that cognitive style is only one of several factors impacting individual differences, research in cognitive styles is an important component in providing a basis for designing systems to supplement the user's knowledge and cognitive capabilites.

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Response to Rao, et al.: More Ado About Cognitive Style and DSS Design

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I respect Professors Rao, Jacob, and Lins' perseverance in searching for connections between DSS design and cognitive style, despite Huber's (1983) concerns about the payoffs from such research. Their criticism of the link between hemispheric lateralization (not specialization) and cognitive style is also welcome, and I am pleased that the speculative article written by myself and Taggart (Robey and Taggart, 1982) helped to provoke their criticism, even 10 years later. I will use this opportunity to clarify some of the reasons for using the preliminary evidence on hemispheric lateralization to suggest directions for DSS design. However, I do not wish to extend the debate on the value of lateralization to management and information systems research. Such exchanges have occurred elsewhere (Hines, 1987; Robey and Taggart, 1983; Schweiger, 1983) and are not necessary to revisit here. I will, however, address the more important question of whether Rao and his colleagues have advanced our thinking on these topics as much as they claim.

The initial clinical evidence on hemispheric lateralization suggested a physiological basis for the numerous dichotomies produced by personality theorists and cognitive psychologists. Bearing an essential mistrust of unobservable psychological constructs, I became interested in linking the concept of intuition to the visual, nonverbal operations of the right cerebral hemisphere (as it was described in the late-1970s literature). Most discussions of business decision making and management science seemed to emphasize analytical procedures, loosely associated with the left cerebral hemisphere. Taggart and I adopted the right and left hemisphere capabilities as a metaphor for discussing decision making, creativity, and human potential in the contexts of management and information systems.

The most important feature of that metaphor was the notion of *integration* of the intuitive and analytic styles, not their separation. Rather than thinking of individuals as either intuitive or analytic, we saw human decision makers as integrated processors capable of defining and solving problems using both intuitive and analytic processes. Nonetheless, we were criticized by skeptics who misinterpreted our purpose and claimed that decision making was too complex to be divided into simple categories derived from medical research with split-brain patients. They are, of course, correct. But, used properly, the physiological metaphor conveys the importance of using all of one's potential (the whole brain) in solving business problems. Since most normal people have two hemispheres and draw upon both to accomplish an astonishing variety of complex tasks, why not extend those capabilities to managerial problem solving? Years later, this still seems like a reasonable, if not fashionable, idea.

We detected an emotional, almost irrational undertone in the published and unpublished critiques of our work. Some critics seemed threatened and outraged by the implication that the practice of management could be informed by something so remote as neurological research. As Hines (1987) stated, "The domains of the neurosciences and management are so far removed in terms of the nature of the problems studied and the research methods used that findings in one field essentially will have no implications for the other" (p. 605). (Researchers interested in neural networks, beware!) One of our colleagues, after presenting a talk on the importance of taking a whole-brained approach to making decisions, was confronted by a member of the audience. "This is foolish," he said. "What could the brain possibly have to do with management?" More illuminating contributions to the issue have come from Huber (1983) and from Simon (1987).

Rao and his colleagues conclude that the theoretical explanation that Taggart and I used to reach our conclusions about the division of labor between humans and computers has since been proved incorrect. Despite this new evidence, however, they suggest that our conclusions remain valid. Intuitive and analytic individuals differ in their information preferences and needs, they argue, and a DSS can and should be designed to accommodate those cognitive differences. Thus, while the new evidence cited by them dispels simplistic associations between the two cerebral hemispheres and decision behavior, Rao and his colleagues invoke the same logic, involving even older dichotomies of cognitive style, to support the same conclusion. This amounts to moving the field forward by relying on arguments of the past, or accomplishing addition by subtraction.

The dichotomy of analytic and intuitive styles is rooted in Jungian psychology and captured by such venerable instruments as the Myers-Briggs Type Indicator (MBTI) (Briggs and Myers, 1973), which was developed 30 years before the whole-brained movement of the 1970s. Cognitive style dichotomies also predate the research critical of the right-brain/left-brain dichotomy that Rao and his colleagues so painstakingly document in their comment. The new neurological research, therefore, does not serve as the logical basis for their endorsement of cognitive differences. In stating that DSS technologies can be designed to both supplement and complement a user's decision-making propensities, Rao and his colleagues have contributed little beyond earlier conclusions drawn by myself (Robey, 1983; Robey and Taggart, 1982), Huber (1983), or DeWaele (1978). Incidentally, their endorsement of Taggart and Valenzi's (1990) measure overlooks the conceptual connections among it, the MBTI, and the concept of hemispheric lateralizaton from which it is drawn.

A more logical conclusion that might be drawn from the information that Rao and his colleagues present is that DSS researchers should stop using simple dichotomies of congitive style and behavior. If neuropsychological research's more complex picture of human cognition is correct, our approaches to DSS research should try to capture that complexity. We should reduce our obsession for sorting individuals into categories and acknowledge their broader range of capabilities and preferences. Conventional experimental studies designed to tease out the main and interaction effects of individual characteristics and DSS features are probably destined to become more "ado about nothing," or at least not accumulate into a coherent understanding of decision behavior. More inductive research showing how real users interact with DSS tools may provide a better basis for subsequent theoretical development with practical design implications.

We should also acknowledge the limits of psychologically based research in DSS. A focus on cognition potentially excludes social factors that also affect the definition and use of a DSS. Research on the social construction of technology (Pinch and Bijker, 1987) suggests that technology's material features and objective routines are subjectively reinterpreted and reinvented by its users. Studies of word processing (Johnson and Rice, 1987) and CASE tools (Orlikowski, 1991) have shown that information technologies are susceptible to social interpretation and that social meanings affect the development and use of information technologies. The social meanings ascribed to a DSS by its developers and users may influence patterns of use to a greater degree than either the DSS's objective properties or the cognitive styles of its users. DSS research programs that never leave the university laboratory are in a weak position to discover the social interpretations of technology and their implications for DSS use.

In conclusion, the quest by Rao and his colleagues for a rationale to support research that links cognitive style with DSS design is not served by the recent neurological findings they cite. Rather, these findings more closely support the notion of integrated, whole-brained cognitive processes. Researchers adopting an integrated, organic view of human information processing, in place of the analytic-intuitive dichotomy, should discover more challenges and more rewards in their efforts.

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Response to Rao, et al: How to Deal With Cognitive Style

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In his wonderful article "That's Interesting!" Murray Davis (1971) reminds us that what is "interesting" is that which is believable but which also refutes our current assumptions. I find two such interesting ideas in the comment by Rao and his colleagues.

The first is that "we can eliminate the concept of hemispheric specialization as a possible theoretical explanation for cognitive style. . ." This contention is contrary to a commonly held belief, so it is interesting. But for our professional purposes, it is also unimportant. As Rao, et al. acknowledge, "we can. . . perhaps also question the relevance of findings of hemispheric asymmetry for management theory and practice."

Their second idea deals with the issue of prescriptive versus permissive technology (Galegher and Kraut, 1990) and how the issue might be addressed in a DSS that incorporates knowledge of the user's cognitive style. This idea is not only interesting but may be important. On an earlier occasion I set forth four reasons why cognitive style research will not lead to operational DSS design guidelines (Huber, 1983). One of these was that "we do not know if DSS designs should (1) conform to the user's cognitive style or (2) complement the user's cognitive style" (in order to overcome the dysfunctional effects of his or her cognitive predispositions) (p. 570). We are no more enlightened now about whether, when, or how we should facilitate, complement, or curtail users' biases than we were then, and it seems both risky and unethical to implement a DSS that could lead the user astray by either reinforcing a task-inappropriate style or by interfering in an unexplained and unsanctioned way with the user's intentions.

Rao, et al., drawing on Mili (1989) and Manheim (1990), may have found a way around this obstacle when they suggest that a DSS might be developed that "would allow the foreground of the system to consist of menus that conform to the user's cognitive style, whereas in the background the computer would work independently of the user and supplement the user's cognitive style." Of course, the ethical issue would still have to be addressed: Are there forms of "user support" that are unethical? A solution may be an intelligent DSS that learns about its human partner's propensities or ignorances by interacting with him or her and then, with the human partner's permission, calls into use programs that complement the user's cognitive shortcomings, whatever their nature. The specificity and manner with which these complementary programs should be made apparent to the user is a subject for study.

It is, of course, a long way from a vaguely stated idea to an operatonal and saleable DSS, but this second idea from Rao, et al. is indeed "interesting." My own guess is that future applications of the idea will be few relative to applications employing the more general idea that:

> . . . in the race between (1) management scientists aspiring to develop a cognitive style literature that is a satisfactory basis for deriving operational DSS design guidelines, and (2) management scientists and computer scientists working together to develop DSS generators and data accessing technology . . . (that users could manipulate and alter) according to their weekly whims and needs . . . a person would be well advised to bet on the latter. (Huber, 1983, p. 571).

Still, Rao, et al.'s suggested approach in some contexts may have important advantages. Especially for those researchers driven primarily by intellectual curiosity, it represents an attractive challenge.

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