14

Right Hemisphere Contributions to Creative Problem Solving: Converging Evidence for Divergent Thinking

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Ever since Broca documented the relation between damage to the left hemisphere and aphasia, claims have been made regarding the intellectual inferiority of the right hemisphere. Although recognized to possess strong perceptual–spatial abilities, the right hemisphere is usually considered to possess minimal linguistic abilities and to be virtually devoid of the inferencing skills necessary for complex problem solving. As Gazzaniga (1983) observed, "Indeed, it could well be argued that the cognitive skills of a normal disconnected right hemisphere without language are vastly inferior to the cognitive skills of a chimpanzee" (p. 536).

The standard low assessment of the cognitive capabilities of the right hemisphere (RH) has led "serious" researchers to view with some disdain claims in the popular press that the RH is the seat of creativity. The claim that creativity may be associated with the RH is typically considered purely pop psychology, which, like other taboo psychological subjects (e.g., at least until recently, consciousness; cf. Cohen & Schooler, 1997), is outside the fray of appropriate topics for rigorous research. In our view, however, the excesses of popular discussions should neither lead us to accept unfounded claims regarding the RH's creative capacities, nor discourage us from exploring the possibility that such capacities might in fact exist. Only with clear definitions of constructs coupled with strong empirical findings will we be able to begin to understand the relation between the RH and higher cognitive processes.

In this chapter we review evidence suggesting that at least one component of creative human behavior may have some association with RH functions. Specifically, we argue that insight—the sudden recognition of an alternative approach that leads to the solution of a problem that previously seemed insoluble—may rely on cognitive processes associated with the RH. In supporting this claim we first examine a number of striking parallels between the properties of insight problem solving and the cognitive characteristics of the RH. These include: (a) a reliance on nonverbal processes, (b) avoiding perseveration, (c) access to nondominant interpretations, and (d) perceptual restructuring. Consideration of cognitive and neurocognitive findings suggests that all four of these cognitive attributes are associated both with insight problem solving and with the RH. Although the evidence discussed is circumstantial, our goal is to persuade the reader that our presentation of this evidence provides a unifying account of disparate processes with an intuitively appealing explanation. Thus, such parallels suggest the real possibility that the RH might be involved in the culmination of these processes, namely, the formulation of insightful solutions. In further support of this claim, we report recent empirical evidence, using a split visual field priming paradigm, suggesting that the RH may be uniquely receptive to information that can lead to insightful solutions.

INSIGHT PROCESSES AND THE RIGHT HEMISPHERE: NEUROPSYCHOLOGICAL AND PSYCHOLOGICAL PARALLELS IN THE PROBLEM-SOLVING PROCESS

Nonverbal Nature of Insight: Right Hemisphere as Silent

In this section we briefly consider a portion of the research that led to the belief that language is a purely left hemisphere (LH) function. As is currently believed, language is not a purely LH function; rather, qualitative differences between LH and RH language function exist, and it is these differences that may result in the RH having a great deal of influence on the insight process.

As early as 1836 it was speculated that human language abilities primarily reside in the left hemisphere (Dax, 1836, as cited in Springer & Deutsch, 1993). Such claims were further substantiated by Broca's (1863, as cited in Springer & Deutsch, 1993) demonstrations of the existence of specific language related centers in the LH. Perhaps the most dramatic evidence for linguistic differences between the RH and LH comes from studies of commissurotomy patients. Such studies reveal that the RH is typically capable of only modest language comprehension and virtually no language production. On the basis of a review of the performance of commissurotomy patients, Gazzaniga (1983) concluded that the normal RH is "nonlinguistic." Although there remains some dispute regarding the precise magnitude and generality of the linguistic deficiencies of the RH (e.g., Zaidel, 1990) and, as discussed later, there may even be certain linguistic associative skills for which the RH actually excels, overall, there is little question but that the RH's language capacities are rather limited.

The RH's reported dearth of language skills has been further associated with broader claims regarding the RH's deficient, perhaps even "subhuman" intellectual capacities (Eccles, 1965, as cited in Bradshaw & Nettleton, 1981). For example, Gazzaniga (1988) discussed research where commissurotomy patients "have an exaggerated incapacity to carry out the simplest activities in their disconnected right brain" (p. 433). In addition, Gazzaniga and colleagues claimed that the RH is nearly incapable of making the most rudimentary of inferences (Gazzaniga & Smylie, 1984). Commissurotomy patients shown simple pictorial sequences such as a person and a fish were to combine these and match the new concept with another picture (e.g., someone fishing). The RH performed significantly worse on this task even though it was able to define the new concept. Given this and similar findings, Gazzaniga (1983) asserted that "the price of lateral specialization for language on the left is a state of rudimentary cognition for the right hemisphere" (p. 536).

The inferior intellectual performance of the detached RH puts fundamental constraints on the view that the RH is critically involved in creative processes. Indeed, such findings provide a strong argument for the possibility that the alleged creative abilities of the RH are merely a popularized fiction. Nevertheless, we must be cautious in overextending the implications of the performance of the RH when it is separated from the left. Specifically, although the RH may be incapable on its own of generating creative solutions, it may still be critically involved in cognitive operations that, in combination with the LH, can lead to such solutions. In the remainder of this chapter, we review the converging evidence suggesting that, although the RH alone does not dominate the insight process, it may possess certain cognitive capabilities that, in its normal state of interaction with the LH, enable it to uniquely influence creative thought.

Insight and Nonverbal Cognition

Although the modest verbal skills of the RH may preclude many higher order cognitive abilities (e.g., complex propositional reasoning), certain advanced cognitive processes, such as the ability to recognize nonobvious insightful solutions to problems, may not rely on language and indeed may even be hampered by it. As Koestler (1964) observed, language is "necessary to maintain the discipline of routine thoughts but may become an impediment to the creative leap" (p. 169). Galton made a similar observation about the disruption that language can have on creative thinking, noting:

> It is a serious drawback to me in writing, and still more in explaining myself, that I do not think as easily in words as otherwise. It often happens that after being hard at work, and having arrived at results that are perfectly clear and satisfactory to myself, when I try to express them in language I feel that I must

> begin by putting myself upon quite another intellectual plane. I have to translate my thoughts into a language that does not run very evenly with them. (Galton, 1887, as cited in Springer & Deutsch, 1993, p. 310)

A recent series of studies by Schooler, Ohlsson, and Brooks (1993) provides empirical support for anecdotal claims that creative insights may involve nonverbal processes that can be hampered by language. Previous research showed detrimental effects of verbalization on visual memory (Schooler & Engstler-Schooler, 1990), on visual image processing (Brandimonte, Hitch & Bishop, 1992a, 1992b), and on decision making (Wilson & Schooler, 1991). Collectively, this research demonstrated that participants who are forced to verbalize various processes perform more poorly on certain tasks or make less satisfactory decisions than those who do not perform any type of verbalization—a phenomenon termed *verbal overshadowing* (e.g., Schooler & Engstler-Schooler, 1990). Schooler et al. (1993) broadened this search to examine the effects of verbalization on individuals' ability to successfully solve two types of problems. One problem set consisted of logical problems comparable to Graduate Record Examination (GRE) analytic problems in which participants need to work through a series of propositions in order to reach a logical conclusion. These problems have been characterized as being "solved by an incremental series of steps, each producing a reportable product" (Schooler et al., 1993, p. 173). Another set consisted of insight problems: puzzle or "aha" type problems that cannot be solved in a systematic logical manner, but rather require the identification of a nonobvious alternative approach to the problems solution. Specifically, Schooler et al. (1993) described an insight problem as one that is within the ability of the average person to solve, is likely to lead to a state of impasse when the problem solver is unaware of what to do next, and is likely to produce an affective response when the solution suddenly is realized (i.e., the classic Aha! experience). Unlike logic problems then, for which there is an extended period of time between the identification of the appropriate approach for a problem and its solution, for insight problems, once the correct approach is recognized, the solution is produced almost immediately (Duncker, 1945; Kohler, 1921; Metcalfe & Wiebe, 1987; Wertheimer, 1959). Schooler et al. found that verbalization (thinking out loud while solving the problem) markedly impaired individuals' ability to find solutions to insight problems whereas it had no effect on logic problems. In light of the observation that verbalization disrupts a variety of other tasks that rely on nonreportable cognitive processes (e.g., face, color, taste, and music memory) whereas it did not affect tasks that involve more readily reported processes (e.g., verbal memory; for a review see Schooler, Fiore, & Brandimonte, 1997), the differential effects of verbalization on insight and logical problem solving suggest that insight problems may rely more on nonreportable processes that are vulnerable to verbalization.

Additional evidence for the differential role of nonreportable processes in insight versus noninsight problem solving is suggested by a protocol analysis of the verbalizations associated with the two types of problems. Schooler and Melcher (1995) found marked differences between the reported processes associated with insight and noninsight problem solving. For noninsight problems, logical argumentation played an important role in successful problem solving, as reflected by the frequent mention of logical steps, and the strong relationship ($r = .57$) between participants' usage of such arguments and their eventual solution to the problem. In contrast, logical arguments were significantly less frequent in the insight problem-solving protocols and their usage was unpredictive of success ($r = .08$). In fact, consistent with the role of nonreportable processes, there was little in the contents of participants' insight protocols that was predictive of success. Insight protocols were instead characterized by frequent pauses (suggesting nonreportable processes) and explicit mentioning of the difficulty of articulating the processes that were being used (e.g., "there is nothing that's going through my mind that's in a verbal fashion").

In short, it appears that language may relate very differently to logical versus insightful problem solving. The processes associated with solving logical problems are readily verbalized and unhampered by articulation (cf. Ericsson & Simon, 1984). In contrast, insight problem-solving processes are not well suited to verbal analysis and can even be disrupted by verbalization. Given prior discussions regarding the two hemisphere's relative language capacities, this analysis suggests that the two hemispheres may also differ with respect to their problem-solving capacities. The LH, with its reliance on language processes, should be superior to the RH with respect to logical language-based problem solving, thus accounting for the previously mentioned general problem-solving deficiencies of the RH. In contrast, the RH might actually have some advantages over the LH with respect to insight problem solving, a process less dependent on, and sometimes even disrupted by, language processes. Note that our argument here is not that the RH may be independently capable of insight problem solving, but rather that it may be involved in critical processes that contribute to insightful solutions. Of course, the claim that the RH might excel in the nonverbal processes associated with insight begs the question of what such processes might be. We now turn to a discussion of candidate processes. A number of the processes involved in insight problem solving are also associated with suggestive evidence implicating their correspondence to RH functions.

Overcoming Fixation

A central challenge in most insight problems is to overcome preconceptions about how a problem is to be solved. For example, consider the problem of tying together two dangling strings that are out of reach of one another, when people have at their disposal only a seemingly random assortment of tools (e.g., a hammer and a screwdriver). Most individuals initially assume that the solution to the problem involves using one of the tools in a standard fashion. This mental set or "functional fixedness" (Duncker, 1945) can thereby interfere with realizing that the solution to the problem involves using a tool in a nonstandard way, for example, as the ballast at the end of one rope so that it can be set in motion like a pendulum and then caught when one is standing in reach of the other rope. In order to solve such problems one must overcome his or her initial fixation with using a tool according to its standard function, and continually try new approaches until the correct approach is identified.

Early research on fixedness focused on rigidity in problem solving, that is, on an inability to overcome a nonoptimal problem representation. Fixedness occurs when participants are unable to release their preconceived notions regarding a particular object or strategy, thereby preventing them from considering alternative solutions. Evidence for this came from classic Gestalt psychologist research using this "two-string" problem (Adamson & Taylor, 1954; Maier, 1931) and a variety of other problems demonstrating that participants can ignore a given object as relevant to the solution because it requires them to use that object in a novel manner, that is, a manner inconsistent with its more typical use. Other illustrations of fixation came from demonstrations that once participants have been working on problems that require complicated solutions, they continue to apply such solutions even to problems that could be solved in a much simpler fashion (Luchins & Luchins, 1950).

More recently, the negative effects of set or fixation have been demonstrated in other areas of problem solving as well as in creative design tasks. When participants are given suggestions or some form of direction on solving a particular problem, their performance is often worse than participants without such information. For example, in a scientific discovery paradigm, participants who are given a priori hypotheses tend to seek out evidence consistent with their initial hypothesis, thereby inhibiting their ability to establish new goals that can lead to successful solution (Dunbar, 1995). In creative design tasks, participants' designs have been hindered either by their own constraints on a problem or by their own expectations. When participants are allowed to choose their own categories in creative design tasks, the likelihood of discovering a creative invention is often decreased (Finke, 1990). Similarly, when given a design task with or without examples of faulty designs, participants who have seen the faulty designs are more likely to conform to the examples they are shown, even when told to ignore such features (Jansson & Smith, 1991).

In sum, these studies show that successful solutions to problems that require the identification of nonobvious approaches are often hindered by previous experience. Participants will either fixate on a particular solution path they deem as appropriate or will fixate on nonoptimal solution paths the researcher has introduced. Essentially, both situations result in blocking the participants' search for alternative solutions, and this blocking produces the impasse in the problem-solving process.

Perseveration: Evidence for Right Hemisphere Involvement in Overcoming Fixation

An analogue of fixation in the neurocognitive literature is perseveration—the persistent repetition of an action or maintenance of a hypothesis despite its previous ineffectiveness. Perseveration resembles fixation in that it reflects a failure to consider alternative approaches. Accordingly, an inclination toward perseveration would be expected to be particularly disruptive for insight problem solving, which requires the continued consideration of alternative approaches. Perseveratory tendencies, however, might be less problematic for logical problem solving, which requires individuals to persevere in completing the initially specified goal. In this context, it is notable that the frequency of perseveratory errors resulting from brain damage critically depends on the hemisphere that is injured. For example, Rauch (1977) investigated patients' concept-learning strategies in left and right anterior temporal lobectomized patients. Rauch observed that right anterior temporal lobectomized patients (i.e., patients relying on their LH) perseverated on the same hypotheses. In contrast, left anterior temporal lobectomized patients (i.e., those relying on the RH) continually re-represented the problem, considering new hypotheses even though their previous attempts could have been appropriate.

Similarly, Drewe (1974) and Sandson and Albert (1987) found that patients with LH lesions made more nonperseveratory errors whereas patients with RH lesions made more perseveratory errors. Such findings led Goldberg and Costa (1981) to conclude: "It thus appears that the left hemisphere has greater facility for the utilization of previously learned information, while the right hemisphere tends to approach every task as a novel experience" (p. 153).

In the context of logical problem solving, in which one needs to keep track of prior arguments, the utilization of previously relevant information is critical. Therefore, according to the preceding characterization, the LH should have an "upper hand" for logical problem solving. However, in the case of insight problem solving for which previous experience can actually impair performance, continually approaching the problem with a novel perspective could be most helpful. Thus, the ability to maintain a fresh perspective may represent a characteristic for which the RH may show unique advantages in the context of solving insight problems.

Access to Alternative Interpretations: Retrieving Nonobvious Problem Elements

Although insight problems require individuals to avoid fixating on prior approaches, they still typically involve access to prior knowledge. In particular, individuals often need to retrieve multiple interpretations of particular problem elements. For example, in the two string problem, individuals need to think about a hammer not only as a tool, but also as a heavy object that could be used as the weight for a pendulum. In short, solutions to insight problems often require individuals to ignore the initially accessed interpretation of a problem element in order to access alternative interpretations. Access to nondominant interpretations is readily illustrated by many insight word problems for which the critical word in the problem has more than one meaning but the solution rests with the meaning that is less frequent or not currently active. Consider, for example, the following insight problem:

> A man who lived in a small town in the U.S. married 20 different women of the same town. All are still living and he has never divorced one of them. Although it is illegal to be married to more than one spouse at a time, he has broken no law. Can you explain?

In this instance, the critical word is *married* and the typical action is that of "getting married to someone." Access to this more dominant meaning thus precludes a participant from considering the less frequent action, "to be responsible for marrying people" (Gick & Lockhart, 1995). The ambiguous phrasing results in the participant fixating on the conventional phrasing and thus attempting to solve the problem by considering how someone can be married to more than one person at the same time. Fixation is overcome when the participant retrieves the nondominant meaning of *married* and realizes that the man is a minister or justice of the peace.

Because of the centrality of memory retrieval to insight processes, many theoretical models of insight focus on the possible retrieval mechanisms that might enable individuals to access alternative interpretations. For example, Ohlsson (1992) and Langley and Jones (1988) posited theories of insight that assume insights result from spreading activation processes where sufficient activation of related concepts ultimately pushes the critical problem element above the threshold of awareness. Evidence for such memory activation processes in insight is provided by Bowers, Regehr, Balthazard, and Parker (1990). Bowers, et al. looked at the attempted responses provided by participants who were unable to generate correct solutions to "insight-like" problems such as recognizing distant semantic associates (e.g., "What word relates to playing, credit, and report?"—the solution is *card*). Bowers, et al. found that incorrect guesses often have some semantic relationship to the correct solution, indicating that solution relevant information was being activated and implying that subawareness activation may ultimately contribute to solving the problem.

Priming of Distant Associates: The Right Hemisphere and Access to Nondominant Meanings

Evidence from neurological studies of patients with right hemisphere damage (RHD) suggests that damage to the RH can impair memory retrieval processes that may be involved in insight-like processes. For example, consider comprehension of a metaphor. In order to comprehend a metaphor one must make a nonliteral translation of meaning. To accomplish this the reader must consider alternative meanings and recognize the fit between the literal and nonliteral meaning with the present context. Specifically, when the reader realizes the connection between the literal text and its nonliteral application in the present context, a type of insight occurs, an insight that involves access to alternative approaches to the wording. Winner and Gardner (1977) found that patients with RHD still possess the ability to comprehend the literal meaning of language but are less able to determine the context in which language might be used. Furthermore, patients with RHD show difficulty in matching the language to its appropriate context, suggesting that they have lost the use of surrounding, pragmatic features. When asked to match a metaphorical phrase with an appropriate picture, patients with RHD were as likely to pick the literal depiction as they were to pick a picture correctly representing the metaphor (Foldi, Cicone, & Gardner, 1983).

Humor represents another insight-like process that shows RH involvement. Like insight, understanding a joke often involves going from some expected resolution (with the application of the dominant meaning of a given word/concept) to an unexpected one (with the application of a nondominant meaning). Studies with brain-damaged patients show that patients with RHD are sometimes unable to appreciate the humor in jokes. For example, Gardner, Ling, Flamm, and Silverman (1975) found that patients with RHD could not appreciate the point of a cartoon when no caption was provided. In addition, patients with RHD exhibited peculiar humorous responses, and responded differently to items than did patients with LHD and normal controls. In addition, patients with RHD "seem to be characterized by an inappropriate sense of humor … they have a well-documented penchant for making inappropriate jokes, and for doing so in inappropriate contexts" (Foldi et al., 1983, p. 77; see also Wapner, Hamby, & Gardner, 1981).

Perhaps the most direct evidence for the RH's ability to access nondominant interpretations of concepts comes from split visual field priming studies in which individuals are asked to identify unilaterally presented target words after being centrally presented with related word primes. The measure of interest in these studies is the degree of facilitation in recognizing the target as a function of prior exposure to primes. In a series of experiments, Beeman et al. (1994) found that the left visual field-right hemisphere (lvf-RH) was shown to benefit more from a series of distantly related primes followed by a remote target (e.g., *foot, cry, glass* followed by *cut*) than did the right visual field-left hemisphere (rvf-LH). Conversely, participants benefited from direct primes (e.g., *scissors* followed by *cut*), more for targets presented to the rvf-LH, whereas the lvf-RH showed no difference between direct and summation primes. To account for these processing distinctions Beeman (1993) suggested that the RH codes information coarsely while the LH codes information finely. Specifically:

> The RH may coarsely code semantic input, so that one comprehended word activates many semantic features, but each only weakly.... In contrast, the LH may finely code semantic input, so that one comprehended word activates few semantic features, but all so strongly that they are accessible to consciousness and selected for further processing. (p. 90)

Additional evidence that the RH differs from the left with respect to its access to nondominant associates comes from studies examining the relationship between visual field presentation and priming for intraconceptual versus interconceptual prime relations. Intraconceptual relations are connections between concepts that are based on relationships between their properties (e.g., *bus–train*), whereas interconceptual relations are based on knowledge of the world (e.g., *coffin–earth*). Drews (1987) showed greater priming for the rvf-LH from within-class, intraconceptual relations (e.g., *saw–axe*), whereas the lvf-RH showed greater priming from between class, interconceptual relations (e.g., *shepherd–pasture*). Drews interpreted her findings according to the Collins and Loftus (1975) spreading-activation model. Accordingly, the greatest facilitation will occur with the concept nodes most highly cross-linked in a given semantic network. Drews suggested that "these cross-links seem to be more determined by logical classificatory properties in the left hemisphere, and by situational referential aspects in the right hemisphere" (p. 424). In another study showing a different pattern of asymmetric priming, Chiarello, Burgess, Richards, and Pollock (1990) found that the rvf-LH was only primed by associated words from the same category (e.g., *arm–leg* for the category "body parts") whereas the lvf-RH was also primed by unassociated words from the same category (e.g., *arm–nose*).

The RH's often observed advantage for accessing distant associates may occur because it does not have as strong an inhibitory mechanism as does the LH. Although access to nondominant interpretations can be useful in the context of insight problem solving, in many situations such access can readily lead to confusion. Consequently, there can be great adaptive value to inhibiting nondominant meanings in many situations. The growing appreciation of the value of inhibition to cognitive processes has led to an increasing role of inhibitory processes in models of cognition (Anderson & Bjork, 1994; Neumann, Cherau, Hood, & Steinnagel, 1993). For example, Neumann et al. (1993) suggested a memory retrieval model involving a spreading inhibition equivalent to spreading activation, and others have shown inhibitory processes through research on negative priming (Tipper, 1985).

There is growing evidence that inhibition may play a critical role in differential semantic priming between the two hemispheres. Specifically, several studies suggest that the RH tendency to be more primed by distant associates relative to the LH can be attributed to greater inhibition of nondominant interpretations in the LH. For example, Burgess and Simpson (1988) investigated the relationship between laterally presented primes and retrieval of dominant and subordinate meanings of ambiguous words. Based on prior work (Simpson & Burgess, 1985), they expected that with brief intervals between prime and target (termed *stimulus onset asynchrony* or SOAs), priming would be automatic and therefore purely facilitative in nature. In contrast, with longer SOAs priming would involve strategic processing and consequently might also involve inhibition. On the assumption that inhibitory processes are more likely to be observed in the LH versus the RH, they predicted an interaction between SOA, visual field, and priming for dominant versus subordinate word meanings. In this study participants were shown ambiguous primes and then after SOAs of either 35 msec or 750 msec were shown either dominant or subordinate targets to the lvf-RH or rvf-LH. For example, participants were shown *bank* and then *river* in the subordinate condition and *bank* and then *money* in the dominant condition. Results showed that for lvf-RH presentation only the dominant meaning is activated at the short SOA (perhaps reflecting slower lexical access for the RH), whereas both meanings are activated at the long SOA. For rvf-LH presentation, priming occurs for all meanings at the short SOA (suggesting exclusively automatic priming processes). However, at the longer SOA only the dominant meaning is still activated whereas the subordinate meaning is inhibited (suggesting inhibitory strategic processes in the LH). Similar patterns of results were reported by Nakagawa (1991), who further observed that the addition of a concurrent activity, thought to reduce strategic processing by taxing the resources of the anterior attention system, resulted in the disappearance of inhibition in the LH. Nakagawa suggested that these findings "support the inhibitory role of the anterior attention system for semantic priming in the left hemisphere" (p. 318).

In sum, there now exists considerable evidence suggesting that the RH may be more likely than the LH to maintain access to nondominant interpretations of words and concepts. Because the ability to recognize alternative interpretations of problem elements represents a critical component of insight problem solving, this ability represents yet another illustration of insight related processes associated with the RH. In addition, explanations of this hemispheric difference in terms of inhibitory processes may also help to account for the previously discussed advantage of the RH with respect to insight—namely, its ability to avoid fixedness or perseveration. Accordingly, a tendency to fixate on a particular problem approach might be the consequence of active inhibition of all but the currently activated problem elements. If the RH has less of an inhibitory mechanism than the LH, more concepts are likely to be accessed and more divergence from the current approach is likely to occur, thus increasing the likelihood that problem fixation may be overcome.

Restructuring

Once the problem solver has overcome a set and successfully engaged in beneficial memory retrieval, the problem elements are ready to be restructured into a new solution and to thus produce the insight experience. Gestalt psychologists considered this process of restructuring to parallel the perceptual recognition processes by which an object's identity is suddenly apprehended. The parallels between problem restructuring in insight and perceptual recognition are seen in many contexts. For example, Ellen (1982) suggested that insight is similar to figure–ground reversals (e.g., the necker cube) in which an individual suddenly recognizes an alternative interpretation of an object. Ohlsson (1984) considered the discovery of insight solutions as occurring when the solution comes into "the horizon of mental look-ahead," and Ippolito and Tweney (1995) characterized insight as "a special form of perception."

Recently Schooler and Melcher (1995) provided further evidence of an association between insight problem solving and perceptual pattern recognition. In a study examining 11 potential correlates of insight problem-solving success (e.g., Verbal SAT [Scholastic Aptitude Test], Math SAT, embedded figures test) the single best predictor of insight problem-solving performance was the ability to recognize out-of-focus pictures ($r = .45$). Although this finding may seem counterintuitive at first, the experience of recognizing an out-of-focus picture is in fact quite similar to that of solving an insight problem. When one initially views an out-of-focus picture, its identity may be entirely unclear (comparable to the initial impasse associated with insight problems). One can consequently form an inappropriate interpretation (Bruner & Potter, 1964) that can interfere with reaching the correct interpretation (comparable to fixedness). If and when the identity of an out-of-focus picture is finally determined, the experience is typically quite sudden and associated with a completely changed perception of the object, for example, "oh, of course, it's a dalmatian" (comparable to the Aha! experience of insight restructuring). Given these parallels, one might expect that out-of-focus picture recognition, like insight, would also be vulnerable to verbalization. And indeed, in a recent unpublished study, Schooler, Gabbino, and Brandimonte (1997) found that thinking out loud while trying to recognize out-of-focus pictures can impair people's ability to make accurate identifications. Thus, it seems there is good reason to suspect that the conceptual restructuring associated with insight problem solving may draw on processes comparable to the perceptual restructuring associated with the interpretation of ambiguous perceptual patterns.

Evidence for Right Hemisphere Processes in Global Pattern Recognition/Restructuring

There are several strands of evidence suggesting that the RH might be involved in processes associated with restructuring. First, for many years it has been suggested that the RH is superior at tasks that involve global integration whereas the LH has an advantage at more fine-grained analyses (Semmes, 1968). More recent incarnations of this viewpoint can be found in Beeman's (1993) coarse versus fine coding theory, which is applicable to verbal information, and Kosslyn's categorical versus coordinate relations theory, which is applicable to nonverbal information (Kosslyn, 1987; Kosslyn, Chabris, Marsolek, & Koenig, 1992; but see Metcalfe, Funnell, & Gazzaniga, 1995). Because problem restructuring requires the general reorganization of the entire problem, this RH advantage for global processing would be expected to contribute to successful insight solutions.

There is also considerable evidence that the RH may have an advantage in global pattern recognition, a process that, as discussed, appears to have close parallels to insight restructuring. For example, an RH advantage for recognizing faces, a task that typically requires the appreciation of configural relations between features, is one of the most ubiquitous and reliable results that has been reported in the literature (Ellis, 1981; Leehey, Carey, Diamond, & Cahn, 1978). In contrast, face recognition tasks that have been specifically designed to favor featural processing strategies have shown an LH advantage (Hillger & Koenig, 1991). Similarly, Moscovitch (1979) found an RH superiority in pattern display recognition. An RH advantage has also been found in dot localization tasks (Bryden, 1976; Kimura, 1969), and in the perception of line orientation (Atkinson & Egeth, 1973), and Nebes (1978) discussed research showing that the RH is better at perceiving relationships between component parts of a display. Indeed, there is even evidence to suggest that the RH may be specifically superior in the processes necessary for identifying out-of-focus pictures, a task that we have argued typifies the global restructuring associated with insight. For example, Goldberg and Costa (1981) found that picture recognition was superior in the RH as compared to the LH, and Sergent and Hellige (1986) observed that the RH is superior at the recognition of faces that have been distorted by a low-pass filter (which makes them appear out of focus). In short, it seems that the RH consistently excels on those types of global pattern recognition tasks that would be expected to draw on the processes associated with insightful restructuring.

Summary

Although there is little direct evidence supporting popular claims that the RH may be involved in creative insight, consideration of the various cognitive attributes of the insight process consistently reveals striking parallels with the specific proficiencies of the RH. Insight problem solving appears to involve nonverbal processes that can, in fact, be disrupted by language, thus providing an advantage for the RH that is generally characterized by a reliance on nonverbal processes. Insight problem solving can be hampered by cognitive fixations resulting from prior experience; however, the RH appears to be less influenced by prior experience, continually treating old problems as if they were novel. Insight problem solving often requires individuals to consider nondominant interpretations of problem elements, again a process at which the RH appears to excel. Finally, insight problem solving relies on global restructuring of problem elements in a manner comparable to perceptual pattern recognition and, once again, both global integration and global pattern recognition are particularly well accomplished by the RH. In short, the RH appears to have many of the ingredients needed to excel at insight problem solving. We now consider direct empirical evidence that the RH contributes to solving insight problems.

EMPIRICAL SUPPORT FOR RIGHT HEMISPHERE INVOLVEMENT IN THE INSIGHT PROCESS

In order to directly examine the RH's role in the creative problem-solving process, we conducted an experiment using insight problems akin to "verbal riddles." We speculated that if the RH is uniquely involved in the insight process, then unilaterally presented one-word "hints" should show differential effects on participants' ability to solve a given problem. Indeed, in the following experiment we present evidence that demonstrates superior problem solving following hint presentation to the lvf-RH.

The experiment examined potential involvement of the RH in insight problem solving by examining whether there are any differences in individuals' ability to benefit from insight hints presented to the right and left visual fields. This experiment also examined the possible role of impasses in mediating such differences. If an impasse resulting from fixation on an inappropriate problem representation is a critical component to true insightful solutions, and if RH processes are indeed critical for a participant to overcome such an impasse, then differences between individuals' receptivity to hints presented to the right and left visual fields may be magnified after participants have spent time struggling unsuccessfully with a problem. To test this prediction we presented participants with laterally presented hints at two different delays: Immediately after participants read the problem, and after participants had unsuccessfully worked on the problem for 2 minutes. If overcoming an impasse requires RH involvement, then the longer delay should be associated with a greater RH advantage than the short delay.

Methods

Participants. Participants were 72 students from an introductory psychology participant pool at the University of Pittsburgh. Because evidence suggests that females and left-handed individuals can show less consistent lateralization characteristics (Springer & Deutsch, 1993), participants were limited to right-handed males.

Materials. Nine insight problems were taken from previous work on insight problem solving (Metcalfe & Wiebe, 1987; Schooler et al., 1993). As an example, consider the following problem:

> A man was found dead in the middle of a freshly plowed field somewhere in the midwest. The man was found lying face-down in the dirt; he was fully clothed and wearing a large backpack. There were no gunshot or stab wounds on the man's body, and there were no footprints leading to or from the spot where his body was lying. In spite of the lack of clues surrounding the mystery, the police were sure he wasn't murdered. How could they know this?

The hint for this problem was *sky*, and the solution is that he was a parachutist and the "large backpack" is his parachute that failed to open.

Procedure. In order to equate word-identification performance between the left and right hemisphere, participants initially participated in a word presentation calibration task (see Beeman et al., 1994). We chose to calibrate identification accuracy because we were more interested in qualitative than quantitative differences between the hemispheres. Participants were shown words in the right and left visual field (rvf-LH and lvf-RH) and told to read them aloud (approximate subtended visual angle was 5–7 degrees). Thus, to avoid any LH ceiling effects the presentation speed for words to the rvf-LH was calibrated such that participants' identification accuracy on words presented to the rvf-LH and lvf-RH was within 5% of each other. This procedure resulted in an average presentation rate of 115 msec to the rvf-LH and 165 msec to the lvf-RH, with a mean word identification accuracy rate of approximately 50% for both visual fields. After appropriate presentation rates were determined, participants were randomly assigned to one of two experimental groups (delay versus no-delay). For the no-delay condition, participants merely read the problem presented on the computer and moved directly to the hint section. In the delay condition participants were presented an insight problem on the computer and given 2 min in which to solve it. The 2-min delay was thought to be sufficient for participants to reach an impasse. Previous studies have shown that when participants successfully solve similar insight problems they usually do so within the first minute (Schooler et al., 1993). If, at the end of the 2 min, participants had not solved the problem, they were given a hint identification task.

In the hint identification task participants judged whether or not they thought words presented to the lvf-RH or rvf-LH were hints to the particular problem on which they were working (e.g., the word *sky* for the problem given in the materials section). For any given problem, participants were twice presented with six words. On each trial, a problem hint was presented to either the rvf-LH, the lvf-RH, or not at all, with the visual field of presentation remaining consistent across the two presentations. This procedure was repeated with eight additional problems resulting in each participant receiving three rvf-LH targets, three lvf-RH targets, and three neutral (no target) presentations. Counterbalancing across participants assured that each target occurred equally often in all three conditions.

Participants were instructed to indicate, by button press, whether they thought the word presented was possibly a hint or clue to the problem and were told to make their judgment regardless of whether they were sure they had seen the word. Following the hint identification stage participants had an additional minute to work on the problem. After participants had attempted all nine problems they were given a word identification task similar to the one given in Task 1. This final calibration check was conducted to insure that the identification accuracy was still comparable across hemifields.

Results

Because the hint manipulation could only be introduced in cases in which participants were unable to solve the problems on their own, initial success at solving a problem resulted in a missing observation for that trial. Because participants were often successful in solving problems prior to the hints, this inherent constraint of the present design resulted in a considerable number of missing observations for each participant. Consequently, in order to generate a more stable measure of performance in each condition, "macrosubjects" were composed from the pooled performance of sets of three participants (see Loftus, Donders, Hoffman, & Schooler, 1989, for a discussion of the value and validity of the macrosubject approach). Each macrosubject set corresponded to a fully counterbalanced participant block in which, across participants, each problem had been assigned to all three hint conditions. A given macrosubject could be composed of three participants who varied in success on problem solving from solving none to solving all nine; the concern was only that within a given macrosubject, each participant had at least one problem corresponding to each condition (rvf-LH, lvf-RH, neutral). A total of 12 macrosubjects per condition was thus used in the analysis.

Not surprisingly, participants in the delay condition (i.e., participants who had already struggled unsuccessfully with the problems for 2 min) solved fewer problems following hint presentation than participants in the no-delay condition (.48 vs. .61, respectively), $F(1,21) = 7.23$, $p < .05$. Of particular concern for the present discussion, though, was the relationship between hint presentation and problem solving accuracy. As predicted, there was a significant main effect for hint presentation: When hints were presented to the lvf-RH, participants solved 74% of the problems, compared to 57% for the rvf-LH and 33% for the neutral condition (no hint presented), $F(2,42) = 46.13$, $p < .001$. Figure 14.1 illustrates this effect. In addition, post hoc means comparisons showed that participants solved reliably more problems following lvf-RH hint presentation than following rvf-LH hint presentation, $F(1,42) = 15.42$, $p < .001$.

There was also a significant interaction between hint presentation and delay type, $F(2,42) = 4.93$, $p < .05$. As can be seen in Fig. 14.2, this interaction reflects the observation that the magnitude of the RH hint advantage was greater in the delay relative to the no delay condition. In the delay condition participants solved 75% of the problems with lvf-RH hint presentation,

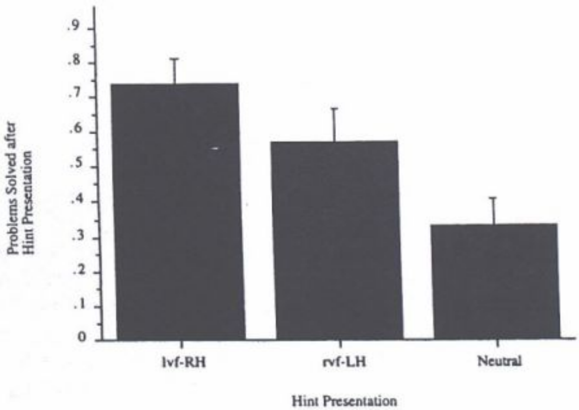

FIG. 14.1. Main effect of hint presentation on problems solved.

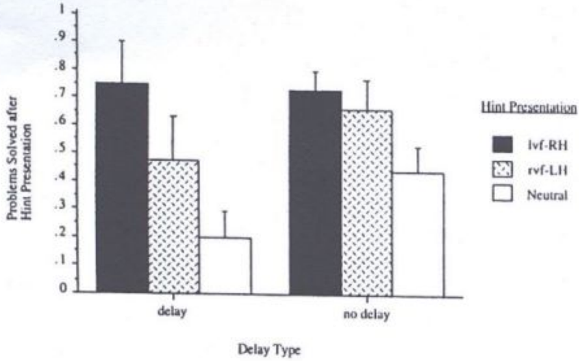

FIG. 14.2. Interaction between delay type and hint presentation on problems solved.

compared to 47% for the rvf-LH. Post hoc means comparisons showed that this difference was significant, $F(1,20) = 13.51$, $p < .01$. In the no-delay condition, when hints were presented to the lvf-RH participants solved 73%, compared to 66% for the rvf-LH and the 44% for the neutral condition. Post hoc means comparisons showed that this difference between lvf-RH and rvf-LH presentation was not significant, $F(1,22) = 2.01$, $p > .05$. Although the lvf-RH appears to have benefited more from the hint presentation in the solving of insight problems, there were no significant differences in actual hint identification accuracy (i.e., in identifying a hint as a hint) for either condition or visual field presentation. Hint recognition accuracy for participants in the no-delay condition was approximately 54% for the lvf-RH and 60% for the rvf-LH. Hint recognition accuracy for participants in the delay condition was approximately 60% for the lvf-RH and 57% for the rvf-LH. As stated, these differences were not significant.

Finally, the identification test used at the end of the experiment revealed that these findings can not be interpreted in terms of differential word identification performance for items presented to the right versus left visual field. At the end of the experiment, participants' word identification rates for the two visual fields were still quite comparable, with 49% accuracy for the lvf-RH and 52% accuracy for the rvf-LH.

Discussion

Although only a preliminary study, this experiment provides more direct empirical support for the hypothesis that the RH may be critically involved in processes leading to insight problem solutions. Insight hints briefly presented to the lvf-RH were more likely to subsequently lead to insight solutions than were hints presented to the rvf-LH. Of particular interest was the additional finding that the RH advantage interacted with delay such that it was substantially larger when participants had been working on the problem unsuccessfully for 2 min. This latter finding suggests that RH processes are particularly involved in insight problem solving mainly when individuals have become entrenched in an impasse.

One possible concern with the present study is that in order to equate word identification performance for items presented to the two visual fields, the hint and distractor items were presented on average for longer durations to the lvf-RH than to the rvf-LH. Thus, one might try to dismiss the RH advantage as simply resulting from the longer exposure durations. There are, however, a number of arguments against such an interpretation. First, and perhaps most obviously, although the presentation rates were different, the identification rates were virtually the same and, as revealed by the final calibration check, this equivalency was maintained throughout the entire experiment. If the benefit of the insight hint presentation was simply a consequence of the longer exposure duration, then one would expect to have seen comparable advantage in final word identifications. Second, exposure duration differences cannot explain why there was a greater RH advantage in the delay as compared to the no-delay condition. This effect of delay strongly argues that the RH advantage was specifically associated with a critical element of insight problem solving—overcoming an impasse. Finally, it should be noted that subsequent experiments using the same paradigm and calibration measure (i.e., unilateral presentation of target words and distractors) have repeatedly failed to reveal priming advantages with other tasks such as word-fragment completion. Thus, it seems that the RH differences observed are not simply an artifact of longer exposure duration, but rather reflect the unique sensitivity of the RH to information that can lead to insight solutions.

CONCLUSIONS

It appears that the RH may not be so dumb after all. Although clearly at a disadvantage in general language processing skills (a finding reflected in the preceding experiment by the longer exposure durations required to elicit comparable word identification), the RH nevertheless appears to contribute to critical processes involved in insight problem solving. Specifically, it appears that the RH may have unique abilities to avoid the inhibitory processes that promote fixedness and that reduce access to nondominant interpretations. In addition, the RH appears particularly suited to engage in global restructuring and, as the preceding experiment illustrates, to facilitate the recognition of critical problem elements that may appear in the environment.

In considering the evidence of RH involvement in insight problem solving it is important not to exaggerate its likely role. Insight problems typically require complex language-based processes; that is, one needs to comprehend the problem, which is typically presented verbally, and later report the solution, which is also typically verbally expressed. Thus, it seems that LH processes must be critically involved in at least some of the elements required for producing insight solutions. Put another way, it seems rather infeasible that the RH could be capable of insight problem solving on its own, that is, that commissurotomy patients would evidence effective insight problem solving with their separated RHs. Along this line, we would speculate that split-brain studies grossly underestimate RH contributions in normally integrated brain function. Nonetheless, our argument is rather that insight problem solving may particularly rely on an integration of LH and RH processes. In short, the RH may be involved in processes that are necessary, but probably not sufficient, to lead to insight solutions.

Ultimately, an understanding of the relation between brain lateralization and creativity and problem solving will require a deeper understanding of both the relation between the hemispheres and the relation between different types of problem solving processes. Although we have simplified our characterization of problem solving as either relying on insight or noninsight processes, in most everyday situations both types of processes are likely to be involved. It is very rare that a sudden moment of illumination results in the complete solution to a problem. Rather, most problems involve long and extensive logical reasoning, punctuated every now and then by an insight regarding an alternative way to proceed. Such hybrid problem-solving processes (cf. Davidson, 1995; Schooler, Fallshore, & Fiore, 1995) highlight the close integration that insight and noninsight processes may often entail. At the same time, however, these hybrid processes should not excessively detract from the fundamental differences (previously discussed) that distinguish them from one another. Rather, it seems insight and noninsight processes, although distinct, work together—a relationship rather reminiscent of the two hemispheres. Perhaps, then, it is more than a coincidence that the most creative of all creatures evolved the greatest degree of hemispheric specialization. We might speculate that as the LH increased its capacity for language and reasoning, the RH developed its own unique capacities, such as the ability to recognize creative alternatives, which, although often related to language, may critically depend on the ability to avoid the inherent constraints of language-based thought.

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