

Right-Hemispheric Damage and Verbal Problem Solving Behavior¹

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Patients with right-hemisphere damage, who ostensibly have no linguistic impairment, are relatively incapable of solving two-term series problems in which comparative adjectives in the premise and question are antonymic. This finding suggests that such verbal reasoning depends, in part, upon nonlinguistic imaginal processes subserved by the right hemisphere. In this manner, the right hemisphere is often required for the full elaboration of linguistic input.

There are conflicting notions about the processes by which subjects solve linear syllogisms of the sort, "A is taller than B, B is taller than C, who is tallest?" One theory² holds that subjects solve such problems by assigning the nouns of the premises to relative locations in a mentally constructed spatial array and by searching this unified representation or "image" for the answer: One of the items is end-anchored, the remaining are arrayed either vertically or horizontally from this spatial reference point. However, Clark (1969, 1971) has vigorously criticized this theory, insisting instead that the critical operations are essentially of a linguistic nature. In Clark's model, deep structure analyses are performed on each of the premises (e.g., (A is tall) more than (B is tall)). Then via a series of linguistic adjustments (e.g., setting "more" to "most"), information about each of the items is stored separately in terms of the item's possession of the pertinent attribute ("tallest,"

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² Actually there are two theories based on the notion that imagery is involved in the solution of linear syllogisms. However, since they differ only in detail and those differences are not relevant to the present work, we will consider the two as one. One theory is that of De Soto and his associates (De Soto, London & Handel, 1965; Handel, De Soto & London, 1968); the other is by Huttenlocher and her associates (1968; Huttenlocher & Higgins, 1971).

“taller,” “least tall,” if the adjective is unmarked; or, if marked—“shortest,” “shorter,” “least short”).³ Within this framework, the use of imagery is considered to be incidental.

Given these contrasting views, the problem is to determine whether or not the solution of linear syllogisms requires the use of spatial imagery. At a more general level, the issue centers about the extent to which language comprehension depends upon imaginal processes.

Our approach to this problem was to observe the performance of right-brain-damaged patients on syllogistic reasoning. It has been shown with considerable consistency that the right (non-dominant) hemisphere has few, if any, linguistic functions. The most it seems capable of is the identification of common concrete nouns—it cannot deal with verbs nor even with the most elementary grammatical relations (Gazzaniga & Hillyard, 1971). Moreover, and of greater importance to the present investigation, numerous studies have failed to find any impairment in verbal IQ and language processing consequent to right-hemispheric damage (Hecaen, 1967; Meyers & Jones, 1957; Milner, 1967; Satz, Richard & Daniels, 1967; Stark, 1961; Weinstein, 1962). On the other hand, there have been repeated demonstrations of the importance of an intact right hemisphere for the elaboration of spatial operations and visual imagery (Butters & Barton, 1970; Butters, Samuels, Goodglass & Brody, 1970; Hecaen, 1962).

Accordingly, seven male patients with damage at various sites in the right hemisphere were selected for testing from the neurological ward of the Boston Veterans Administration Hospital (BVAH) and the Massachusetts Rehabilitation Center.⁴

Deficits of a visual-spatial nature—mostly in the form of left-sided neglect and right-left confusion—were not infrequently noted in the clinical work-ups (parietal lobe batteries) of these patients. Of more importance however, although no standardized language tests were administered to the right-hemispheric patients, no instance of a language disorder was observed upon clinical examination; in fact, the neurologists charted the linguistic performance of each of the right-hemispheric

³ A full discussion of the unmarked-marked distinction is given in Greenberg (1966) and Clark (1969). Briefly stated, the distinction can serve to separate adjectives into those that label a dimension (unmarked) and those that express polarity on the dimension. For example, the unmarked adjective, *tall*, can be used in a neutral sense as in, “How tall are you?”, whereas its marked counterpart, *short*, used in the same frame clearly expresses a bias, “How short are you?” This difference is accounted for by the claim that the marked form carries an extra feature for polarity.

⁴ Lesion site was determined by brain scans and clinical evaluations in six of the seven cases. In one case lesion site was surgically verified. Six of the patients had anterior damage, the seventh, posterior. No discernible difference obtained between the posterior and anterior patients in our data.

patients to be well within normal limits. A control group of seven non-neurological male patients in the BVAH was also tested. The control and right-hemispheric patients were matched as closely as possible in terms of educational level and age.

The task used in the experiment consisted of a set of two-term series problems (e.g., If John is taller than Bill, who is taller?). Four types of problems were constructed. In two of the problem types the comparative adjectives in the premise and question were congruent (taller-taller) and in the other two they were incongruent (taller-shorter). Half of the congruent problems contained unmarked adjectives (taller) and the other half marked adjectives (shorter). For the incongruent problem set, half had the unmarked adjective in the premise and the marked adjective in the question, while in the other half the order of unmarked-marked adjectives was reversed (see Table 1). In all there were 56 problems, 14 of each type; each problem had a different attribute dimension (e.g., old, strong, good, etc.). Subjects were tested individually.

Before the actual experiment began, subjects were given practice in solving 12 two-term series problems and all demonstrated that they understood the instructions and could perform the task. An accuracy score that incorporates a correction for guessing was obtained for each subject by assigning a +1 to each correct response and a -1 for each incorrect response. Thus each subject was given a single score for each problem type by summing across his responses. A score of zero indicates chance level performance.

The results of the experiments are shown in Fig. 1. The left panel shows the mean accuracy score for each group as a function of adjective type in the premise and the question. As is immediately obvious from the figure, the groups differ only in their performance on the mixed adjective problems. The mean accuracy score for the congruent problem types are shown in the right panel of Fig. 1. An analysis of variance on these means revealed significant main effects both for groups ($F(1,12) = 4.79$, $p < .05$) and problem type ($F(1,12) = 15.56$, $p < .005$). The interaction of problem type by group was also significant

TABLE 1
PROBLEM TYPES WITH ASSOCIATED EXAMPLES

Congruent problems

- (a) Unmarked—John is taller than Bill, who is taller?
- (b) Marked—John is shorter than Bill, who is shorter?

Incongruent problems

- (a) Unmarked/marked—John is taller than Bill, who is shorter?
 - (b) Marked/unmarked—John is shorter than Bill, who is taller?
-

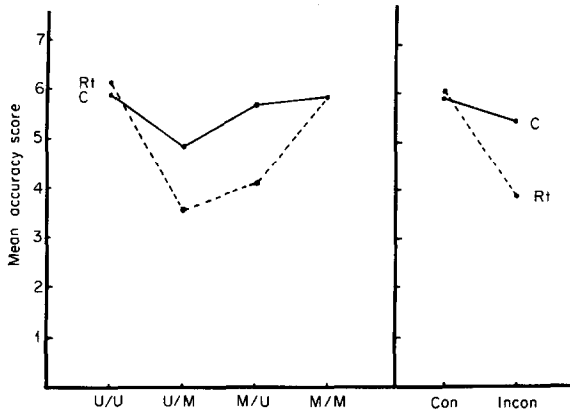


FIG. 1. Mean accuracy scores for right-hemispheric patients (Rt) and a control group (C) as a function of: (a) comparative adjectives in premise and question (unmarked-unmarked, U/U; unmarked-marked, U/M; marked-unmarked, M/U; marked-marked, M/M); and (b) congruent (Con) and incongruent (Incon) problems.

($F(1,12) = 4.76, p < .05$). Post hoc tests (Newman-Keuls) further revealed that the mean for the right-hemispheric patients group on the incongruent problems differed significantly from the other three means. No other significant differences were obtained, and in particular there was no difference between the congruent and incongruent problem types in the control group.

The most apparent finding, then, is that patients with right hemisphere damage are relatively incapable of solving two-term series problems in which the premise and question have antonymic adjectives, a finding made more striking by the fact that when the comparative adjectives in the premise and question are congruent, the right-hemispheric patients performed as well as the control group. There are at least two ways to interpret this pattern of results. We might conclude that one of the stages in the process of syllogistic reasoning involves a right-hemispheric based "conversion" operation-to-congruency of the comparative adjectives in the premise and question (Hunter, 1957). That is, it may be suggested that to solve two-term series problems with antonymic adjectives subjects must transform the adjective in the premise to be congruent with that in the question and that this transformation is essentially an imagery operation based on functions subserved by the right hemisphere. Alternatively, we might conclude that subjects construct spatial representations on the basis of the information supplied in the premise and then search the images for the answer. In this framework the interaction can be explained by hypothesizing that in the congruent problems an answer can be obtained directly from the linguistic assertion of the premise, thus bypassing the need for an image search. In the case of the incongruent

problems, on the other hand, subjects must now search the spatial representation in order to respond correctly. Whichever of these two interpretations may prove correct, both are predicated on the same factors—specifically, both are elaborated in terms of right-hemispheric functioning and nonlinguistic imaginal processes.

Of course, we cannot rule out the possibility that nonlanguage regions of the left hemisphere also participate in extralinguistic heuristics of the type described above. To do so we would have had to assess the problem solving abilities of non-aphasic, left-brain damaged patients. Nevertheless, since the data do indicate a relation between difficulties in the processing of linear syllogisms and right hemispheric lesions, it seems that damage to the right hemisphere is at least *sufficient* to disrupt verbal problem solving. Moreover, as a corollary, it would appear that the deficits associated with right-hemispheric damage extend beyond the concrete visual-spatial realm to a more formal level.

Our findings suggest, therefore, that verbal reasoning requires at some stage the formation of right-hemispherically based imagery—at either a visual or general cognitive level, and that in this fashion, the right hemisphere is often required for the full elaboration of linguistic input.⁵

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⁵ Whatever importance we have shown for the right hemisphere, the left hemisphere must still be regarded as the more important of the two for the processing of linguistic input. Five left-sided brain-damaged patients, all with aphasic involvement, were also tested on the series problems. All five of these patients presented a spontaneous speech output that was distinctly nonfluent and agrammatic; but they differed in their ability to comprehend spoken language: Two of the five patients showed noticeable comprehension deficits ($z < .5$) on the comprehension subtest of The Boston Diagnostic Aphasia Test, while the remaining three showed relatively intact comprehension ($z > .5$) on this measure (BDAT—Goodglass & Kaplan, 1972). One of the patients with relatively intact comprehension was capable of solving each of the four types of the two-terms series problems; the remaining four patients, however performed at or near chance level. Presumably, these four patients were incapable of anything more than a partial encoding of the comparative sentences. The fact that two of the patients who could not solve the series problems were assessed to have relatively intact comprehension suggests that although they could process simple subject-predicate relations—(A is tall) more than (B is tall), they could not carry out the more difficult task of specifying the exact relation between the two clauses. That is, although the present data cannot be used to prove the point, these two aphasics might have comprehended that both A and B are tall but not that A is taller than B.

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