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What Does Language Do for a Right Hemisphere?

Michael S. Gazzaniga and Charlotte S. Smylie

Introduction

It is of interest to determine how the presence of language in a neural network changes the cognitive capacity of that system. Disentangling cognition from language is always difficult. One approach is to establish a measurable level of cognitive skills in an organism and then see how it advances or retreats as a function of the independent introduction of language (Premack, 1982). Another is to study language-competent organisms that have fallen into disrepair and to look at changes in normal cognitive function (Goldstein, 1948; Luria, 1969).

Our approach is to look at what the presence of language does to a half brain that normally does not have language present (Woods, 1980; Rasmussen & Milner, 1977; Gazzaniga, 1983). This approach is possible in a select subset of patients who have undergone commissurotomy and who, postoperatively, with discrete lateralized testing, have demonstrated some kind of right-hemisphere language. It is possible to show in these special cases how the presence of language changes the more routine functions of that half brain.

Before describing how a brain system changes when it has language, it is important to observe that right-hemisphere language is rare (Gazzaniga, 1983). In brief, of the approximately 50 split-brain patients studied in America during the past 20 years, 5, to date, possess language of some kind in the right hemisphere. Of the 5, 2 have lexical knowledge, some syntax, and speech. Three patients have only lexical knowledge (Gazzaniga & Sperry, 1967; Gazzaniga, Bogen, & Sperry, 1967; Zaidel, 1977; Gazzaniga, Wilson, & LeDoux, 1977; Sidtis, Volpe, Wilson, Rayport, & Gazzaniga, 1981; Sidtis, Volpe, Holtzman, Wilson, & Gazzaniga, 1981).

In the following, we discuss three different kinds of split-brain patients: (1) those without right-hemisphere language of any kind; (2) those with right-hemisphere lexical knowledge but no speech; and (3) those with both right-hemisphere lexical knowledge, syntax, and speech.

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Cognition in the Absence of Language

As already described, most patients do not have language in their right hemisphere. A right hemisphere without language is a limited system that cannot perform complex cognitive tasks. In some patients, it can retrieve related as opposed to literal objects (Gazzaniga, Bogen, & Sperry, 1962), and, of course, it can carry out specialized tasks such as block design (Gazzaniga, Bogen, & Sperry, 1962, 1965), nonverbal tactile discriminations (Milner & Taylor, 1972), and other part–whole tasks broadly defined (Nebes, 1971; Levy, Trevarthen, & Sperry, 1972). It can react to visual stimuli and carry out simple motor commands that are presented in nonverbal terms (Volpe, Sidtis, Holtzman, Wilson, & Gazzaniga, 1982). In general, however, it is severely limited. In this regard, it is frequently forgotten that many studies on patients with left-brain damage and aphasia show greater impairment on traditional, so-called right-hemisphere tasks than do patients with left-hemisphere damage without aphasia, *and* patients with right-hemisphere damage (see LeBrun & Hoopes, 1974).

At this point in our studies, it is interesting to consider a possibly remarkable fact about these disconnected right hemispheres without language (e.g., cases S.F., S.W., L.R., and J.H.). Again, while some are capable of simple tasks, many to date are not. Indeed, those who are not appear unable to carry out tasks that a monkey could complete. Thus, it is a possibility that in such patients, all information-processing tasks were deferred to the left, language-dominant hemisphere during development in much the manner that an unwise child allows a friend to solve a new task. On isolation, the mental system in question is discovered to know nothing, and because of maturational finality, it is unable to learn new information. We are currently working on tests that will help to further elucidate the upper capacities of these languageless right hemispheres.

Cognition with Lexical Knowledge

The three patients that have demonstrated lexical knowledge in the separated right hemisphere are far more responsive to examination and allow for a set of observations on general cognitive processes. These are California patients L.B. and N.G., and Dartmouth patient J.W. In the following, we report on a series of tests carried out on J.W.

Word Knowledge and Causality

A half brain that possess the capacity to read or to understand spoken words takes on new dimensions. It can point to pictures that depict such nouns as *house, eggs, dishes* and *table*. It can also point to pictures that depict such verbs as *slice, write, melt,* and *burn*.

The right hemisphere of patients with lexical knowledge but no speech, however, is distinctly limited in its overall cognitive capabilities. In the three patients that manifest this state, there is a marked inability to carry out a command, whether it be axial or distal. Responses to such simple commands such as "smile," "hit," "tap," and "frown" are not possible (Gazzaniga *et al.*, 1967; Sidtis, Volpe, Holtzman, Wilson, & Gazzaniga, 1981). This lack of generative capacity, however, is not global. One of the patients in particular can consistently and easily draw pictures of line drawings flashed to the right hemisphere. Thus, presenting a picture of a bike to the right hemisphere will find the patient unable to say the word, but the left hand is quite able to draw the object (Figure 1).

The lexically competent right hemisphere also appears to be limited in the ability to apprehend causal relations, that is, to combine words in a correct superordinate response (Figure 2). Specifically, 40 sets of word pairs such as *hammer/vase* were flashed to each hemisphere of Case J.W. The subject was instructed after each trial to pick from a set of six words the one word that best described the consequence of the two words interacting. In the case of *hammer/vase*, for example, the appropriate answer was *break* as opposed to *fill*, *build*, *flat*, *swim*, or *travel*. The test was designed in such a way that making a simple associative response over the course of all the trials would yield a low score. J.W.'s left hemisphere was correct on 37 of 40 trials, while the right hemisphere was correct on only 12 of 39. An analysis of the errors revealed that when the right hemisphere was correct, it was making simple associative responses to one of the flashed words.

In this context, J.W. could correctly define the target words. Thus, a target word such as *fry* could be defined if separately presented to the right hemisphere even though J.W. could not choose *fry* if the two context words were *pan* and *fish*. Defining individual words is routine, but grasping potential interrelations is not.

J.W.'s inability to combine words is consistent with a series of electrophysiological studies carried out in collaboration with Steven Hillyard and Marta Kutas. By

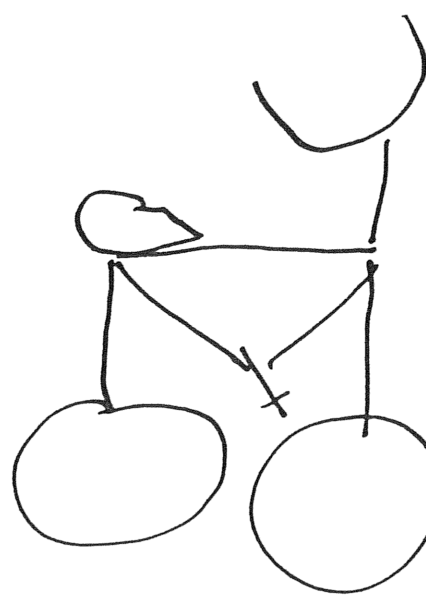

Figure 1. *Sample of left-hand drawing after J.W.'s right hemisphere was shown a picture of a bicycle. J.W. said that he saw nothing yet was able to draw this picture out of view. While drawing, he said he did not know what he was drawing.*

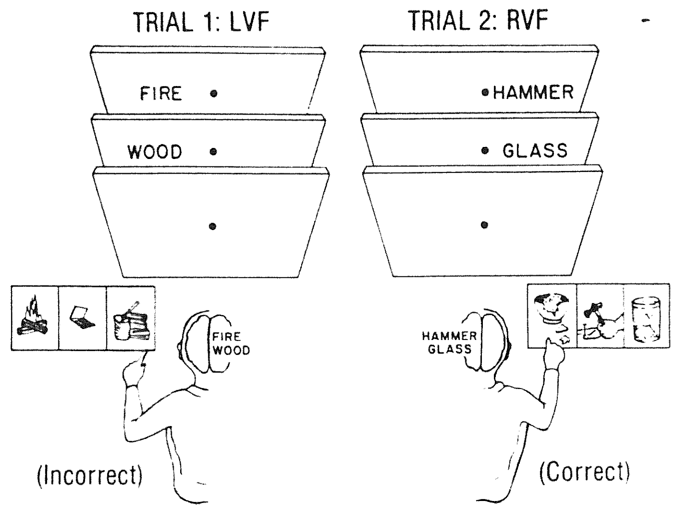

Figure 2. *J.W.'s semantically competent right hemisphere (LVF) is unable to combine two words into an action and pick the appropriate picture. The same is true if the choices are words or if the problem stimuli are pictures instead of words. His left hemisphere (RVF) is able to perform the task under all conditions.*

means of the N400 semantic-incongruity event-related potential they had discovered (Kutas & Hillyard, 1982), each hemisphere was assessed for language competence. The N400 wave is triggered when asemantic incongruity occurs, such as, "I take my coffee with cream and cement." When the sentence "I take my coffee with cream and sugar" is presented, there is no special brain wave. J.W. generated N400 waves out of the left, but not out of the right. The lexically bound hemisphere seems to recognize and process words only in the thin edge of the present and not to recognize their full interrelations.

Cognitive-Emotional Interactions

A right hemisphere that has only lexical knowledge can generate emotional reactions to pictures (Gazzaniga, 1970) and to words (Gazaniga & LeDoux, 1978). Recently, in conjunction with Jeffrey Holtzman, we were able to study other cognitive-emotional interactions in one of our patients both before her right hemisphere's later development of speech and after this skill appeared. Using an SRI eye tracker, a device that allows for the prolonged stimulation of a visual field, we were able to assess the ability of the left hemisphere to describe moods set up in the right by a series of movie vignettes that elicited emotional responses (Figure 3). This test demonstrated that a mute right hemisphere of a split-brain patient can communicate the emotional tone of a stimulus sequence to the opposite hemisphere. This transferred tone or mood is sufficient to allow the left hemisphere to try to reconstruct what the stimulus might have been, even though it has no direct knowledge of the stimulus sequence and thus

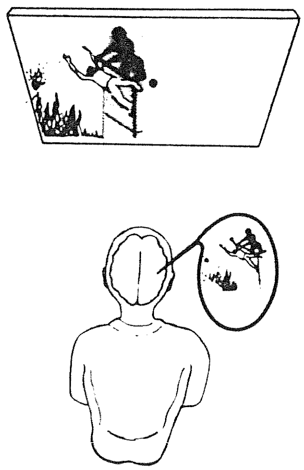

Figure 3. *By means of an eye tracker, a movie is shown exclusively to V.P.'s right hemisphere. Before the development of right-hemisphere speech, V.P. was unable to describe the movie veridically. She was able to convey only an emotional sense of what the movie might have been. As can be seen by her remarks, the left hemisphere constructed a story to give these feelings a context.*

is unable to describe the actual content of the film. V.P. was able to do this in at least five out of seven separate movie sequences, half of which displayed aggresssive moods and half more serene content, such as natural landscapes.

It should also be noted that the experimental manipulation of the mood system in this manner once again reveals the quick way in which the left hemisphere attributes cause to a particular mood state. The mood generated by the film sequence in figure 3 produced enough selective arousal so that V.P. sought an explanation for the feeling. This kind of response has been discussed in detail elsewhere (Gazzaniga & Ledoux, 1978; Gazzaniga & Volpe, 1981).

With the appearance of the right hemisphere's ability to access speech in V.P, there was a marked change in the descriptions of the film scenes. They became much more veridical and did not suffer from the indirectness exemplified earlier (Table 1).

Table 1. *Movie Filmstrips Shown to V.P.'s Right Hemisphere via the Eye Tracker*[a]

Actual filmstrip	V.P.'s response
1. Butcher shop with butcher wrapping meat	1. "Store with man behind counter selling stuff. He was wearing a white coat."
2. Children running, jumping, doing somersaults	2. "Children outside running around playing."
3. Children playing pool	3. "Children playing pool."

[a] After the development of right hemisphere speech she is now able to describe the movies accurately.

It remains unclear whether a right half-brain with no language can emote in a directional and specific way. It is possible that a right half-brain with language merely makes it simple to examine the question of whether both positive and negative emotions can be elicited. Our continuing impression is that a human brain system without language would be hard-pressed to distinguish between the emotions pity and sorrow, whereas it might be possible for it to both feel and produce the more robust emotion of, for example, rage. It also remains unclear how subtle the cross-interaction cues may be.

Interhemispheric Interactions

Recently, we have shown other, more subtle indications of interhemispheric interactions. In a series of experiments on split-brain patients (Holtzman, Sidtis, Volpe, Wilson, & Gazzaniga, 1981; Holtzman, Volpe, & Gazzaniga, 1982; Sidtis, Volpe, Holtzman, Wilson, & Gazzaniga, 1981; Sidtis, Holtzman, & Gazzaniga, 1981), it has been demonstrated that both attentional and perhaps also semantic interactions occur not only within the two cerebral hemispheres but also between the separated hemispheres. This suggests that either subcallosal pathways are able to access a common lexicon existing for both hemispheres, or that the separate lexicons of each hemisphere are in subcortical communication. These are the first studies that demonstrated that cognitively based information activated in one half of the brain can influence specific processes in the other. Prior to this work, interhemispheric interactions were linked to emotional aspects of the stimuli, as just described, and the spreading emotional tone helped the speaking hemisphere to narrow down the possible responses.

Cognition with Lexical Knowledge, Syntax, and Speech

When a right hemisphere does have a generative capacity, the cognitive skills appear slightly more enhanced than in a right hemisphere with only semantics (Gazzaniga & Smylie, in press). At the same time, it is clear that the right hemisphere is in no way an equal partner of the left in overall cognitive skill.

General Studies

Two patients, V.P. and P.S., have quite remarkably developed in their right hemisphere the ability to access speech (Gazzaniga, Volpe, Smylie, Wilson, & LeDoux, 1979; Sidtis, Volpe, Wilson, Rayport, & Gazzaniga, 1981). These patients were unique from their first postoperative day. On the basis of these two unique cases, one can predict almost immediately after the split-brain surgery whether a right hemishere will develop the capacity to speak, even though this capacity may not appear for months or years.

Both patients, immediately after complete callosal section, had the ability to carry out commands presented exclusively to the right hemisphere (Gazzaniga *et al.*, 1977; Sidtis, Volpe, Holtzman, Wilson & Gazzaniga, 1981). They could also understand grammatical relations, whereas the lexically competent patients just described could

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not (Gazzaniga, 1970). They could also detect semantic incongruity as measured by the N400 event-related potential. In short, the cognitive profile of a right hemisphere with language and speech seems greater in comparison to a right hemisphere with only semantics.

At the same time, it is important to note that the right hemisphere that responds as if it were linguistically competent (that is, as if it had a generative grammar as well as a rich semantic system), is not a half brain that equals the left half brain in more general cognitive skills. Like J.W.'s right hemisphere, V.P. also performed poorly on the two-word task requiring that an inference be made. The right hemispheres of both V.P. and P.S. could also not do simple math. In these tests, for example, a number was presented to either the left or the right hemisphere, and the request was to add, subtract, multiply, or divide the number flashed by a number stated before each trial. While both the left and the right hemispheres could easily name the number flashed, only the left could carry out the requested arithmetical operations.

A variety of additional studies are being carried out at this time that will further elucidate the cognitive difference not only between patients with and without language, but also between the "language-competent" left hemisphere and the "language-competent" right hemisphere. For now, we continue to be struck by the difference between the two half-brains in V.P. and P.S. Having linguistic competence does not ensure an in-depth cognitive system. Right-hemisphere cognition seems to have only a "surface" quality to it. It does not seem able to compute, to make inferences.

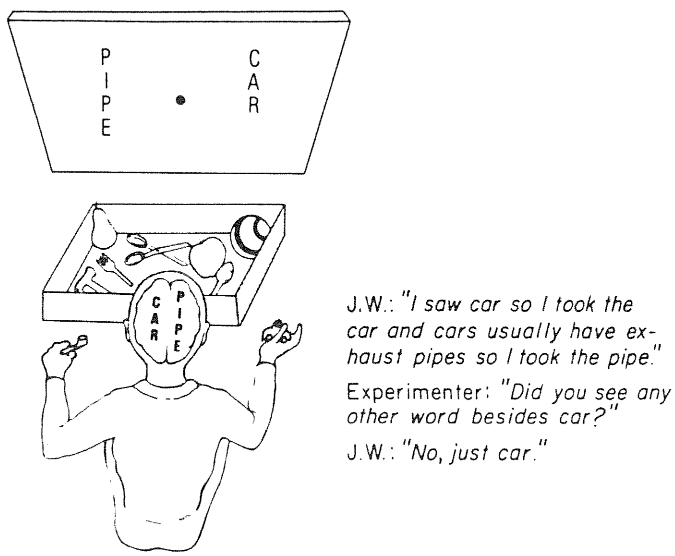

Figure 4. *J.W. is given a command in both hemispheres: "Pick up the ____." The left, verbal hemisphere knows why it picked up the car, but it then constructs a story about why the pipe was also retrieved. On this trial, after looking and seeing what was in his hands, J.W. said, "I saw the word car and all cars have exhaust pipes."*

Generative Capacity and Self-Awareness

When a brain system possesses the capacity to communicate verbally, it finds it necessary to explain the actions of the body. In a series of studies, we have shown how a hemisphere possessing language becomes compulsive about attributing cause to all body activities, whether they be overt or covert (Gazzaniga & LeDoux, 1978; Gazzaniga & Volpe, 1981). It is easy to demonstrate that only one hemisphere is accessing speech by simply structuring a testing situation so that the right, mute hemisphere is required to make a response. Under this kind of experimental condition, the left hemisphere, if asked, constructs a theory about why the right hemisphere's generated response occurred even though it does not, in fact, know (Figure 4).

When the right hemisphere develops speech, does it show the same behavior? Does it, too, construct a theory about behaviors independently generated from the left half-brain? Determination of this is difficult, as the left hemispehre still dominates all the spoken responses. Yet the right hemisphere can infrequently dominate a response. It would be on such trials that the phenomenon in reverse could be assessed.

Right-Hemisphere-Specialized Skills: Can They Coexist with Language?

In the foregoing, we have reviewed the right-hemisphere language competence of three split-brain patients. It is now clear that they are in the minority, and the amount of right-hemisphere language widely varies. The question arises whether other more traditional, right-hemisphere specialized skills are present in such cases. Does the abnormal presence of language in the right hemisphere predict a diminution of these skills?

In a series of recent studies, we have shown that the right hemispheres of all three language-competent patients also demonstrate a dramatic superiority in their ability to recognize unfamiliar faces and to carry out subtle line-orientation tasks (Gazzaniga & Smylie, 1983). In short, in tests that examine right-hemisphere-specialized skills, language-competent right hemispheres not only are capable of carrying out these tasks but perform the tasks better than right hemispheres without language. These data argue against any simple model of cortical function that claims that competition for cortical space would prevent the coexistence of the specialized skills of language and perceptual skills in one hemisphere.

A related phenomenon deals with the well-known perceptual disorders that occur with right parietal disease. Such patients commonly draw half clocks, houses, and stick figures of people when asked to draw such objects in their entirety. On finishing their drawings, they maintain that the drawings are full and complete. In previous tests on a patient with a right parietal lesion, we were able to show that while half clocks and the like were drawn and described as being complete, exposure of the drawing to the full right visual half-field, away from the constant midline fixation used under free-field viewing conditions, found the patient easily able to state that the drawing was incomplete and bizarre (LeDoux, Smylie, Ruff, & Gazzaniga, 1980). It was concluded that it was not that the left hemisphere was incapable of detecting a perceptual anomaly when such an anomaly was present, but that the left hemisphere inappropriately completed visual stimuli that fell at the border of visual capacity.

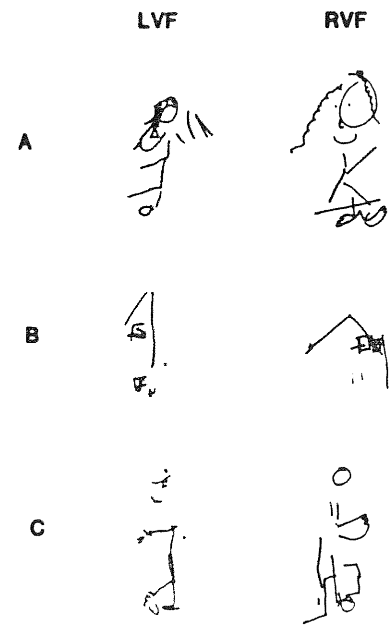

Figure 5. *Simple line drawings made by V.P. when half figures of a house and stick figures were presented to the left and right hemispheres. The left-hemisphere–right-hand response always showed bilateral markings, while the right-hemisphere–left-hand drawings did not. The markings indicating hair in the LVF picture (A) were put on after the picture was completed, as if the viewing left hemisphere asserted itself.*

These phenomena raise interesting questions about the split-brain patient. If the right hemisphere possesses some mechanism that inhibits an inappropriate completion response to stimuli that fall in the middle of the visual gaze, it would be suggested the left hemisphere would be prone to respond in this way, while the right would resist such conclusions. In fact, in two patients whom we have studied with reference to this issue, P.S. and V.P., we have found this to be the case. An example of one test is shown in Figure 5. V.P. was asked to "Draw what you see." While V.P.'s overall artistic skill is marginal, she consistently put bilateral markings on half picutres presented to the right visual field. Half figures presented to the left visual field yielded drawings that clearly denoted their incomplete nature.

In more simple tests in which half figures were presented to either the left or the right hemisphere, V.P. and P.S. reliably noted the left-field stimuli as "half of a boy," etc., while the half figures presented to the right field yielded the claim that a whole figure had been presented. Tests like these reveal a most remarkable aspect of these patients. The left, talking hemisphere has never complained that when it looks at a figure of something or somebody it sees only half the stimulus. With the left disconnected from the right hemisphere's ability to detect such anomalies, no complaints are forthcoming.

General Discussion

We have tried to demonstrate in the foregoing that a neural system that does not possess language is limited in its cognitive skills. Thus, when a brain system has no ability to read or to understand spoken language, it seems bound to carry out only the functions for which it is specialized, such as block design tasks and the like. It cannot carry out any kind of combinatorial activities, sequencing activities, and other basic cognitive acts.

A brain system that has a lexical knowledge moves beyond these limitations but is still cognitively impoverished. It can respond in an emotional dimension to words and pictures. It has a good memory and it has a preference structure. Still, this more impressive cognitive system can not make inferences about how semantically related items interact causally.

When a brain system has a generative capacity such that it can carry out printed commands, speak, as well as possess syntactical competence, it takes on more of the dimensions of a normal cognitive system. In the two patients with right-hemisphere access to speech, tests of cognitive competence reveal a somewhat better capacity. Yet it too is strictly limited.

It would appear from the present studies that when greater abstraction is required from language stimuli, these demands are not met by the language system itself but rather by other cognitive systems also located in the left hemisphere that carry out computations on the language stimuli. In this view the language system is considered to be a "dumb" system that acts more as a compiler of information. The "cognitive" activities of language are to a large extent performed by other brain systems.

It would appear that the conferring of a kind of language competence to a brain system does not necessarily mean that simple routine cognitive abilities are equally conferred. In the past, distinguishing how normal language is linked or not linked to other conceptual skills such as math or inferential reasoning has been extremely difficult to analyze in the aphasic patient, since the lesion producing the language disorder could also be injuring other computational systems specialized for specific cognitive acts. The present results suggest that when these are dissociated, such cognitive competencies are part of independent computational systems. Language usually reports on these computations with efficiency and accuracy, but the language is not the system that is carrying out the activities.

Finally, with our present state of knowledge about these processes, it is clear that we are unable to articulate fully the effect of introducing lexical, syntactical, and expressive skills on a human half-cerebrum. Although it clearly makes the half brain more responsive than it otherwise might be, it is striking how little general computational competence results from the presence of such a rich symbolic system.

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