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Right Hemisphere Language: Insights into Normal Language Mechanisms?

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Neurolinguistic research has focused on language disruption in aphasia as a laboratory for modeling normal language processes (1,3,5). The presence of language in the right hemisphere of some patients after section of the corpus callosum offers another neurological perspective on language processing (8,9,12). This linguistic ability is particularly interesting in light of the right hemisphere's extremely limited intellectual functioning (11). The right hemisphere cannot, for instance, correctly infer "fire" if shown a match and a pile of wood even though it can identify a picture depicting the referents of "wood," "match," and "fire"(11). Thus, in the case of semantics, a lexicon rich enough to accomplish straightforward referential naming tasks does not depend on a conceptual system developed enough to accomplish inferences similar to the match-wood-fire problem.

This chapter considers syntactic knowledge accompanying right hemisphere language. As with semantics, the relation between syntactic competence and more general intellectual competence is not fully understood. The study of right hemisphere language could shed some light on this issue. When exploring the level of syntactic competence of the right hemisphere, we search for those grammatical tasks the right hemisphere can accomplish and those with which it experiences difficulty. For us, any dissociation is particularly interesting because it may indicate which aspects of the linguistic system depend on a rich intellectual capacity. We admit, however, that such observations are correlational without any claim for causality.

This chapter reviews the extant literature on right hemisphere language before reporting our work on its syntactic competence.

J.W., V.P., AND THEIR ESTABLISHED LINGUISTIC COMPETENCE

The differences in right hemisphere representation of language skills among commissurotomy patients has been striking, ranging from an absence of any response to language tasks to a sophisticated vocabulary with limited production skills (8).

In this chapter we focus on two split-brain patients, V.P. and J.W., who have well-established right hemisphere lexical skills. V.P. appears to have language skills in her right hemisphere that often parallel those in her left hemisphere, whereas J.W.'s right hemisphere language has a more unusual profile.

V.P. is a right-handed female who began to experience recurrent major seizures after a febrile illness at age 9. These seizures were controlled with anticonvulsants, but by 1976 she was experiencing episodes of blank staring lasting for several seconds several times a day. In 1979, V.P. was referred to the Medical College of Ohio. The initial surgery was undertaken in April 1979, and the second stage carried out six weeks later. Following both surgeries, V.P. showed immediate evidence of language comprehension in the right hemisphere. She showed evidence of right hemisphere control of speech within one year. An MRI scan demonstrated some intact fibers in the splenium and the rostrum of an otherwise completely sectioned corpus callosum (10).

J.W. is a right-handed male who has had intractable epilepsy since age 19. He sustained a closed head injury at age 13 resulting in brief, infrequent absence attacks. These were not treated. At 19, he had his first major motor seizure. During the next seven years, J.W. was frequently hospitalized with seizures despite adequate serum anticonvulsant levels. In 1979 he was referred to Dartmouth Medical Center where the corpus callosum was sectioned in a two-stage operation. An MRI scan demonstrated a complete section of the corpus callosum but an otherwise normal brain (10).

Both V.P. and J.W. have a right hemispheric auditory vocabulary, which would seem to imply some phonological skill. However, in formal testing of phoneme discrimination in a standard categorical perception paradigm, Sidtis et al. (19) demonstrated poor right hemisphere performance on phoneme identification for both subjects, although V.P.'s right hemisphere performed above chance. When V.P. and J.W. were asked to select words that rhymed with targets presented tachistoscopically to their left hemisphere, V.P.'s right hemisphere again remained above chance, but J.W.'s did not. Sidtis et al. (19) argued that V.P. showed phonological competence with her right hemisphere, albeit at an impoverished level. They also cautioned that the negative results from J.W. cannot be used as evidence of a qualitatively different method of analysis of auditory input in his right hemisphere, but may demonstrate only a failure to respond in this paradigm.

It should be noted that the conclusions of Sidtis et al. differ from those of Zaidel (22,23) and of Levy and Trevarthen (14), who worked with different split-brain subjects. Zaidel (24) found a well-developed auditory lexicon in the right hemispheres of these patients. When Levy and Trevarthen (14) used a rhyming task to investigate their phonological skills, their results were uniformly negative. They concluded that "the right hemisphere lacks a phonetic analyzer that can generate phonetic images" and that "its verbal capacities depend on special right hemisphere processes." Clearly, better understanding of the difference between the two experimental groups is needed.

Semantic information appears to be available to the right hemisphere of J.W. and V.P. J.W. has demonstrated comparable vocabularies in his right and left

hemispheres on the Peabody Picture Vocabulary Test (12). Moreover, both V.P. and J.W. have demonstrated a right hemisphere ability to identify synonyms, antonyms, functional relations among words, superordinates, and subordinates, although V.P. responds more accurately (19). These results have been replicated for superordinate and subordinate relations and extended to include the identification of same-class items and attributes (12). Using a lexical decision paradigm with a very short rate of presentation (150 msec), V.P. shows semantic priming in both hemispheres over a variety of relations. J.W.'s results are less consistent, but indicate that whereas his left hemisphere can demonstrate normal facilitation for targets preceded by related words, there is no trace of this effect in his silent right hemisphere. This result is of particular interest because it corresponds with the presence of an N-400 in response to semantic incongruity in both hemispheres of V.P., but only in the left hemisphere of J.W. (M. Kutas and S. A. Hillyard, *this volume*).

Gazzaniga and Hillyard (9) found some indication that verbs were less represented in the right hemisphere lexicon, although Zaidel (21) found controlling for word frequency makes comprehension of verbs and nouns more similar. Both J.W. and V.P. were able to carry out commands (necessarily verbs) lateralized to their right hemisphere at greater-than-chance levels (19). It appears that both hemispheres have a lexicon that can be accessed to make a variety of semantic judgments. Both have some capacity to understand nouns and verbs, but J.W. has no demonstrated skill with function words. V.P.'s performance is generally better than J.W.'s, but a qualitative difference between these patients has yet to emerge.

The skills of J.W. and V.P. may reflect a pattern similar to that reported by Caramazza, Berndt, and Basili for some aphasics (4), i.e., relatively intact lexical semantics in the face of impaired phonology and (consequently) syntax. Little work, however, has been done on the right hemisphere's syntactic competence, although there is one relevant study.

The experiment (12) turned on the ambiguity of phrases such as "flying planes," which could mean either (a) "the act of flying planes" or (b) "planes that are flying." This ambiguity disappears with the addition of the article "the," so that "flying the planes" can only mean (a) and "the flying planes" can only mean (b). J.W.'s right hemisphere was unable to use the information carried by the article to distinguish these two meanings, whereas V.P.'s right hemisphere performed much like her left hemisphere. This result was interpreted to indicate that V.P. had access to some syntactic information in her right hemisphere, but J.W.'s right hemisphere gave no indication of such sensitivity. We follow up on this observation in the experiments in the next section.

FURTHER EXPERIMENTAL ANALYSIS OF SYNTACTIC COMPETENCE OF THE RIGHT HEMISPHERE

In the aphasia literature, different methods have been used to measure sensitivity to syntax. Although each task purportedly tapped syntactic competence, performance of aphasic subjects differed from task to task. For example, Schwartz, Saffran, and Marin (18) used a two-choice–picture-pointing paradigm to test the ability of agrammatic aphasics to understand semantically reversible active and passive sentences (e.g., the boy hit the girl; the boy was hit by the girl). Agrammatic aphasics were *unable* to choose correctly the picture that matched the sentence they heard. In other words, they could not use the syntactic constraints in the sentences to determine who hit whom. In contrast, Linebarger, Schwartz, and Saffran (15) found that aphasics who were unable to interpret correct active and passive sentences were able to judge accurately whether sentences were grammatical.

The Linebarger et al. result is important because it suggests that even though a patient may not be able to use a grammatical constraint in a comprehension task, he or she may still *know* something about grammar and be able to use this knowledge in other tasks, such as a grammaticality judgment task. Linebarger et al. (15), for instance, pointed out that agrammatics' grammaticality judgments indicate that they possess knowledge of a number of grammar rules or constraints, such as subcategorization requirements, sensitivity to functors, and an ability to keep track of syntactic dependencies across words and even clauses.

Thus, in assessing right hemisphere language, a variety of syntactic probes should be used. In this chapter we adapted both the Schwartz comprehension task and the Linebarger grammaticality task. Because V.P.'s right hemisphere had demonstrated some minimal capacity for speech production and syntax-dependent comprehension, we expected that she might perform well on both tasks. J.W.'s right hemisphere had demonstrated only semantic knowledge previously. Consequently, we expected poor performance on the comprehension task. We were uncertain whether J.W.'s isolated right hemisphere lexicon would include in it enough grammar to distinguish grammatical from ungrammatical sentences.

Comprehension of Active and Passive Sentences

We adapted the stimuli used by Schwartz et al. to tachistoscopic presentation by first pairing each sentence with, in one case, a picture that illustrated it, and in another, one that illustrated the opposite relation; that is, the sentence "The boy is touched by the girl." was paired both with a picture of a girl touching a boy and a picture of a boy touching a girl. There were 48 pairings, based on 24 sentences.

J.W. and V.P. were presented with a single picture. They then heard a sentence binaurally over earphones and were instructed to decide whether the sentence matched the picture. J.W. and V.P. were instructed to fixate on an asterisk displayed in the center of a CRT and the responses "YES" and "NO" appeared for 150 msec in different quadrants of the screen. Both were in either the right or left visual field, with their horizontal position randomly alternated. J.W. and V.P. had to point to the quadrant where the correct answer appeared. Responses were always with the left hand to maximize right hemisphere accuracy.

This task requires a large memory load, as subjects have to remember not only the correct answer, but the quadrant in which that answer was displayed in order

to respond correctly. Nonetheless, both V.P. and J.W. performed well above chance with their left hemispheres (Table 1). V.P. fell to chance with her right hemisphere on both active and passive sentences. On the other hand, J.W.'s right hemisphere response pattern demonstrated a surprising sensitivity to word order. Bever (2) has suggested that in the absence of a functioning grammatical system people may adopt the strategy of making the noun phrase before the verb the subject of the sentence and the noun phrase following the verb its object. If this strategy is used on active and passive sentences, active sentences would be interpreted correctly, but passive sentences would have just the opposite meaning. This pattern corresponds to that of J.W.'s right hemisphere responses.

Thus, J.W.'s performance suggests that the right hemisphere may in some instance represent and analyze the grammatical function of lexical items. V.P.'s inability to perform this task was surprising as prior work (10) indicated that she possessed some ability to use syntactic information to guide processing; however, differences in mode of presentation and in time span over which the elements must be processed may have contributed to her better performance in the prior work than in the present work. In the prior work, the three crucial lexical items were presented visually. In the present task, an entire sentence was presented aurally.

Grammaticality Judgments

We adapted a study done by Linebarger, Schwartz, and Saffran (15) with aphasics to the demands of split-brain research. Linebarger et al. showed that agrammatic

TABLE 1. *Semantically reversible active and passive sentences*

	RVF % (no.)	LVF % (no.)
V.P.		
Active	100 (24)[a]	46 (11)
Passive	88 (21)[a]	50 (12)
Combined	94 (45)[a]	48 (23)
J.W.		
Active	79 (19)[a]	75 (18)[a]
Passive	100 (24)[a]	38 (9)[b]
Combined	90 (43)[a]	56 (27)

RVF, right visual field; LVF, left visual field. Percent correct obtained matching binaurally presented sentences with pictures when the response choice is lateralized. Numbers in parentheses represent the number correct out of 24 for active and passive scores and out of 48 for combined scores.

[a]Binomial $p < 0.05$, better-than-chance performance.
[b]Binomial $p < 0.05$, less-than-chance performance.

aphasics can make judgments of grammaticality across a variety of sentence types, even though they cannot use grammatical constraints in the interpretation of sentences. Pilot work with J.W. indicated that not only could his right hemisphere make similar judgments, but his errors appeared to be on just those sentence types that Linebarger et al. (15) reported as difficult for the agrammatics. We decided to replicate these preliminary results on V.P. and retest J.W. We obtained copies of the original tapes used by Linebarger et al. (15). The two patients listened to each sentence individually as they were played back through earphones. As in the comprehension study, "yes" and "no" were presented tachistoscopically in four quadrants and V.P. and J.W. had to point with their left hand to a "yes" if the sentence was grammatical, "no" if it was ungrammatical. There were 10 different sentence types, and for each type, there were grammatical and ungrammatical examples. For instance, the grammatical rule known as subject-auxiliary inversion is correctly applied in the sentence, "Are you going to the store?", but violated in the sentence, "Are going you to the store?"

The results in Figs. 1 and 2 represent the response pattern for J.W. and V.P. for all 10 sentence types. Performance is measured following Linebarger et al. (15) using A′, which corrects for guessing. A′ varies from 0 to 1, with the larger the number the more accurate performance. The 10 different conditions represent grammaticality tests for the 10 different sentence types. The conditions in which Linebarger et al.'s original four aphasic subjects were consistently weakest were 5, 9,

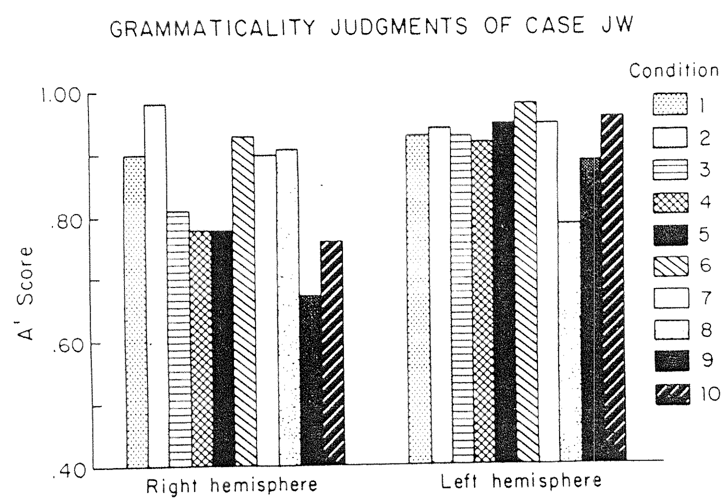

FIG. 1. A′ scores of J.W.'s right and left hemispheres compiled judging grammaticality of binaurally presented sentences when the response choice is lateralized. In each condition, grammaticality tests were given for sentences constrained by a particular grammatical rule (see text).

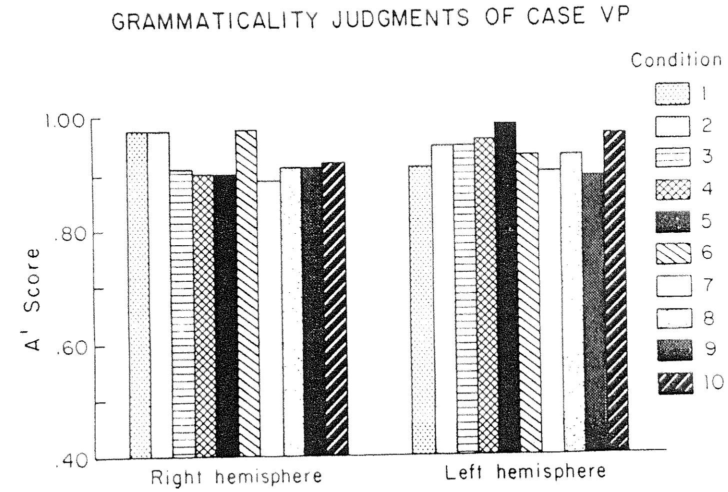

FIG. 2. A′ scores of V.P.'s right and left hemispheres compiled judging grammaticality of binaurally presented sentences when the response choice is lateralized. In each condition, grammaticality tests were given for sentences constrained by a particular grammatical rule (see text).

and 10. These conditions probed knowledge about three grammatical rules: (a) subject copying in the formation of a tag question ("Harry loved Mary, didn't it?"), (b) agreement between a reflexive pronoun and its antecedent ("Harry loves herself."), and (c) copying the auxiliary verb in the formation of a tag question ("Harry is waiting for Mary, doesn't he?").

As Fig. 1 illustrates, J.W.'s left hemisphere performs well. Although less accurate, his right hemisphere has the most difficulty with the same conditions as the agrammatic aphasics. Inspection of Fig. 1 also indicates that there is a much tighter relation between the pattern generated by J.W.'s right hemisphere and that generated by the aphasics. Moreover, the pattern of his left hemisphere appears to be distinct from that of his right hemisphere. The failure to find any interhemispheric similarity suggests that cross-cueing is not accounting for the good performance of the right hemisphere.

There is much less difference between the performances to the two hemispheres in V.P. than in J.W. (Fig. 2). V.P.'s and J.W.'s left hemispheres respond with similar accuracy (0.92 and 0.93, respectively), but V.P.'s right hemisphere is equally accurate (0.92), whereas J.W.'s mean accuracy falls to 0.84. The range of V.P.'s scores for her left hemisphere is from 0.89 to 0.99 and for her right hemisphere is 0.89 to 0.98. Moreover, the differences between the A′ scores of her two hemispheres in the comparable conditions range from only 0.01 to 0.09. In contrast, the between-hemisphere differences for J.W. range from 0.03 to 0.22, with the largest differences occurring in the crucial conditions of 5, 9, and 10.

What could account for J.W.'s accurate grammatical intuitions? Although he demonstrates accurate use of auditory information to decide whether a sentence is grammatically acceptable, he remains unable to use this information to derive meaning accurately from semantically reversible active and passive sentences.

J.W. is probably not using intonational cues when making grammaticality judgments. Berndt, Salasoo, Mitchum, and Blumstein (17) have demonstrated that normal and brain-damaged controls make accurate grammaticality judgments when the intonation contours are removed from sentences. Moreover, agrammatic aphasics are also able to make accurate grammaticality judgments without the information from the intonation contours and continue to demonstrate greater difficulty with sentences containing tag questions. The accuracy of grammaticality judgments by agrammatic aphasics, therefore, cannot be accounted for as the recognition of aberrant intonation cues in the ungrammatical sentences. As J.W.'s right hemisphere shows a similar pattern of performance it seems likely that it employs the same mechanism as that of the agrammatic aphasics.

V.P.'s results are more difficult to interpret because of the lack of a convincing difference between her left and right hemispheres. It is especially important to establish a difference in this subject because of the demonstration that some fibers of the splenium remain intact. Because V.P. has previously demonstrated greater right hemispheric syntactic competence than J.W. and because she appears to have some ability to generate speech from her right hemisphere, it would not be surprising that her right hemisphere would do well at this task. Without a greater dissociation of right and left hemisphere performance, little more can be said about V.P.'s performance at this time.

CONCLUSIONS

The most striking finding in these two commissurotomized patients with right hemisphere language is the dissociation between the ability to comprehend syntactically constrained sentences and the ability to judge their grammaticality. This dissociation can be found in two distinct populations, agrammatic aphasics and commissurotomy patients. Moreover, the presence of this dissociation in the intellectually impoverished right hemisphere suggests that grammaticality judgments may not depend on a developed intellectual capacity as much as the interpretation of sentences. The processing underlying grammaticality judgments may be automatic and data driven and, as a consequence, be independent of the adequate functioning of other cognitive systems, such as those involved in an inference task. Interpretation of syntactically constrained sentences may, however, require more interactive processing and depend crucially on inferential capacity.

We are not claiming that the processes responsible for grammaticality judgments are mediated solely by the right hemisphere [Berndt et al. (17) demonstrated that right hemisphere damaged patients are highly accurate in judging grammaticality]; nor are we claiming that the two hemispheres make grammatical judgments in the

same way. There may be alternate processes for determining the well-formedness of sentences. We did not measure reaction time in J.W. and V.P., but V.P. was aware that she took longer to make a left than a right hemisphere decision. As she put it, when responding with her left hand to a right hemisphere presentation she felt the hand being "drawn to the screen like a magnet" before she had made up her mind about the answer. Rather we are arguing that the dissociation observed in J.W. suggests that grammaticality judgments and sentential interpretation involve different processes and that the preserved ability to judge the grammaticality of a sentence may rest in part on its relative independence from a more general intellectual capacity.

Other explanations of the findings are possible. Zurif and Grodzinsky (25), for instance, have argued that grammaticality judgments can be made on a degraded structural representation that does not contain sufficient information to process for comprehension. What this position seems to imply is that a full structural specification is necessary for normal comprehension [but see (2,6,7,13,20)]. A rough structural specification could be rapidly and automatically constructed as part of the normal comprehension process and our only conscious access to that process is our grammatical intuition. This rough specification may be all that the right hemisphere computes. Consequently, it may be able to make accurate grammaticality judgments, but still not have enough syntactic information to interpret the sentence accurately.

The present research cannot determine whether the processing underlying grammatical intuitions depends on a different system than the processing underlying comprehension—on which is data driven, automatic, and independent of higher order cognitive functioning—or whether the two processes involve the same system, but merely depend on different levels of syntactic representation. Clearly, further exploration of right hemisphere language must be undertaken, but the value of developing a model of right hemisphere language should be clear. As this model develops, the components and processes driving normal language function will be better understood.

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