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Semantic Processing in the Right Hemisphere May Contribute to Drawing Inferences from Discourse

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After listening to multiple-episode stories that promoted coherence inferences, right hemisphere-damaged patients answered Inference questions about the stories less accurately than Explicit questions, whereas normal elderly subjects answered both question types equally well. In addition, while subjects listened to the stories they made lexical decisions to test words that were related to the promoted inferences or were unrelated to the stories. Right hemisphere-damaged patients responded more slowly to inference-related words than to unrelated words, whereas normal elderly subjects responded more quickly to inference-related words than to unrelated words. Furthermore, the episode boundaries did not affect either group's accuracy on Inference questions, and the boundaries equally affected both groups' lexical decision latencies, suggesting that the patients' inferencing deficit was not due to an impairment in organizing the mental substructures used to represent discourse. These results suggest that the right hemisphere-damaged patients lacked activation of semantic information necessary for drawing coherence inferences. © 1993 Academic Press, Inc.

When people read or listen to language, both hemispheres of their brains generally receive the language input. Yet, the left hemisphere (LH) alone seems specialized or dominant for language comprehension and production. For instance, people with damage to the LH often have profound language disturbances, but people with damage to the right hemisphere (RH) generally seem to process language well. If language input is equally available to the two hemispheres but only the LH can process

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it thoroughly, the two hemispheres must process incoming information differently. Examining the few aspects of language processing that depend on the RH could illuminate these processing differences.

Increasing evidence indicates that the RH is critical for understanding and controlling prosody, drawing inferences, revising interpretations, and building organized mental structures to represent discourse. In this paper, I examine right hemisphere-damaged (RHD) patients' difficulty in drawing coherence inferences. I consider two sources for this problem: (1) Poor organization of discourse into meaningful structures, and (2) Poor activation of semantic information necessary to draw coherence inferences.

RIGHT HEMISPHERE CONTRIBUTIONS TO DISCOURSE COMPREHENSION

When people comprehend written or spoken single words, blood flow and metabolism increase more in the LH than in the RH (Peterson, Fox, Posner, Mintun, & Raichle, 1988; Lechevalier, Petit, Eustache, Lambert, Chapon, & Viader, 1989; Lassen, 1979). This implies that the LH is more involved than the RH in the low-level decoding of words. However, because information flows between the hemispheres, such a difference at an early stage does not preclude the possibility that later stages of comprehension depend on the RH as well as the LH.

Indeed, the RH does seem to contribute to discourse comprehension more than to single word comprehension. Evidence for this assertion comes from several sources. First, indices of brain activity show greater metabolic activity in the RH of people when they comprehend complex discourse (e.g., Mazziotta, Phelps, Carson, & Kuhl, 1982; Phelps, Mazziotta, & Huang, 1982) than when they comprehend single words (e.g., Knopman, Rubens, Klassen, & Meyer, 1982; Phelps & Mazziotta, 1985; Peterson et al., 1988). For instance, when people listen to stories, brain metabolism increases bilaterally (Mazziotta et al., 1982; Lechevalier et al., 1989), and when listening to stories for later memory tests, some studies indicate that brain metabolism increases predominantly in the RH (Phelps, Mazziotta, & Huang 1982). Also, when people listen to dichotically presented word series, EEG recordings time-locked to the stimuli (Evoked Response Potentials or ERPs) reveal large responses over the RH. This is particularly true after some delay, when initial speech perception is presumably complete and some semantic processing has already occurred (Rothenberger, Grozinger, Foit, & Woerner, 1987). Moreover, ERPs over the RH are greater when people listen to word series that are sentence-like (. . . *king* . . . *swims* . . .) than when they listen to word series that are simple associates (. . . *king* . . . *castle* . . .) (Rothenberger et al., 1987). These data all suggest that the RH plays a role in understanding sentences.

The view that the RH contributes to discourse-level language comprehension does not contradict evidence from aphasia. Left hemisphere-damaged (LHD) patients often become severely aphasic, whereas RHD patients do not. This is usually cited as evidence of LH dominance for language (in most individuals). However, if early analysis of linguistic input depends almost entirely on the LH, then the RH may be deprived of input for subsequent processing in LHD patients. In contrast, RHD patients will be able to decode the input and process it at later stages in the LH and will only lack the late discourse-level contributions of the RH (Chiarello, 1990).

For instance, EEG-recorded alpha waves occur while subjects rest, so alpha suppression is considered a sign of brain activity. Whereas LHD dysfluent aphasic patients and normal comprehenders show the same RH alpha suppression during comprehension, poorly comprehending LHD fluent aphasic patients show less RH alpha suppression. This indicates that the RH contributes less to language processing in fluent aphasic patients than it does in normal comprehenders (Moore, 1987). Thus, the RH may normally process some information after initial reading or speech perception occurs in the LH, and this is prevented in LHD aphasic patients.

Comprehension difficulties experienced by RHD patients also indicate that comprehending complex discourse may require an intact RH. Whereas RHD patients generally pass simple linguistic tests, they often miss the point of complex discourse, particularly oral conversation. RHD patients have trouble organizing paragraphs, stories, and especially conversations (Delis, Wapner, Gardner, & Moses, 1983; Gardner, Brownell, Wapner, & Michelow, 1983; Huber & Gleber, 1982; Joanette, Goulet, Ska, & Nespoulous, 1986; Moya, Benowitz, Levine, & Finklestein, 1986; Stachowiak, Huber, Poeck, & Kerchensteiner, 1977; Weschler, 1973). For instance, RHD patients are sometimes unable to see how story events are related, and are thus unable to derive the gist or theme of what they hear or read (Hough, 1990). They also show impaired comprehension of idioms and metaphors and are sometimes described as responding too literally (Van Lancker & Kempler, 1987). For instance, when they hear the expression "he had a heavy heart," they may choose a picture of a man carrying a heart on his back to represent the statement (Winner & Gardner, 1977).

RHD Patients' Difficulties in Using Context to Interpret Phrases

RHD patients have difficulty using context to interpret conversational remarks (Kaplan, Brownell, Jacobs, & Gardner, 1990). In one study, positive or negative descriptions of two characters and the friendliness of the interaction between the characters biased a remark toward a particular interpretation. For instance, one story described a golfer, who played

poorly, and his partner, who liked him. The partner remarked "You're playing well today," which—given the context—should be interpreted as a sarcastic and humorous comment on his friend's golfing difficulty. Compared with normal control subjects, RHD patients inappropriately interpreted these remarks. This suggests that they did not integrate the context (e.g., the friendliness of the characters' interaction) with remarks in question (Kaplan et al., 1990).

RHD patients also have difficulty integrating story context and indirect requests, such as "Can you open the door?" (Weylman, Brownell, Roman, & Gardner, 1989). These questions usually should be interpreted nonliterally as requests, that is, "Will you open the door for me?" However, in a given context—for example, if the question is being asked of a person in a wheelchair—the literal interpretation is more appropriate. Given a context biased toward the literal interpretation of such requests, RHD patients often incorrectly interpreted the requests. Importantly, the RHD patients interpreted the requests nonliterally, whereas the previous literature suggested that RHD patient's difficulties were due to being overly literal (e.g., Winner & Gardner, 1977; Gardner et al., 1983; Van Lancker & Kempler, 1987). These results again indicate that RHD patients poorly integrate new input with earlier information from discourse.

RHD patients also have difficulty comprehending humor (Brownell, Michel, Powelson, & Gardner, 1983; Bihrle, Brownell, Powelson, & Gardner, 1986). According to Brownell et al. (1983), jokes contain two key ingredients: surprise and coherence. The punchline disconfirms expectations but still fits the premise. The punchline causes reinterpretation of the context, a case of accommodating old information to comprehend the new information (Molloy, Brownell, & Gardner, 1988). For instance, consider the following joke (from Brownell et al., 1983, pp.22–23):

> The neighborhood borrower approached Mr. Smith on Sunday afternoon and inquired: "Say, Smith, are you using your lawn mower this afternoon?" "Yes, I am," Smith replied warily. The neighborhood borrower then answered: "Fine, then you won't be needing your golf clubs. I'll just borrow them."

The punchline is surprising, but coheres with the context when the appropriate inferences are drawn—after all, the borrower got what he wanted. RHD patients have difficulty choosing "the funny ending" after hearing the opening lines of such jokes. RHD patients cannot choose correct punchlines as well as normals and are likely to select surprising but less coherent distractors (such as "You know, the grass is greener on the other side" for the above joke; Brownell et al., 1983). LHD patients also cannot choose correct punchlines as well as normals, but they are likely to select straightforward endings that are coherent and unsurprising, such as "Do you think I could use it when you're done?" (Bihrle et al., 1986). Despite their comprehension problems, the LHD patients maintain coherence, whereas RHD patients are less adept at doing so.

Altogether, these behaviors demonstrate that RHD patients do not integrate related elements of complex discourse.

Inferencing

One way to integrate elements of discourse is to connect them via inference. For instance, when normal comprehenders hear:

> Sally approached the movie star with pen and paper in hand. She was writing an article about famous people's views on nuclear power,

(from Brownell et al. 1986, p. 311) they generally infer that Sally was interviewing the movie star for the article. That is, they generate coherence inferences (e.g., Potts, Keenan, & Golding, 1988). RHD patients, on the other hand, may respond that Sally was getting an autograph, as if they are misled by the first sentence and cannot revise their initial interpretations to maintain coherence (Brownell, Potter, Bihrle, & Gardner, 1986). A brief review reveals some of the properties of coherence inferencing in normal discourse comprehension.

Normally, people can verify the truth of inferred information (e.g., *Sally interviewed the star*) as quickly and as accurately as they verify the truth of information that was explicitly stated (Singer, 1979, 1980; Singer & Ferreira, 1983). Indeed, comprehenders are sometimes unable to discriminate between inferred information and explicit information, suggesting that both are equally-well represented in their representations of discourse (Johnson, Bransford, & Solomon, 1973). For instance, comprehenders may mistakenly judge that they explicitly heard the statement *Sally interviewed the star*. Further, both children and adults include inferences when recalling verbal stories (Glenn, 1978; Paris & Lindauer, 1976) and picture stories (Baggett, 1975).

There are also less direct ways to assess inferencing in discourse comprehension. For instance, after reading the sentences about Sally, the movie star, and Sally's article, people recognize the word INTERVIEW faster than they recognize it after hearing sentences containing the same words but rearranged so that they do not imply that Sally interviewed someone (Potts et al., 1988). Subjects also rapidly recognize visual test words related to events inferrable from simultaneously presented auditory stories (Beeman & Gernsbacher, submitted for publication). Facilitated recognition of inference-related test words suggests that the inferences were drawn and that semantic information related to the inferences was highly active in memory.

Normal comprehenders appear to draw only coherence inferences, that is, inferences that resolve discrepancies or tie together the events of a story and thereby improve the story's coherence. Comprehenders do not appear to reliably draw predictive inferences, such as inferring that Sally would interview the star (or even get the star's autograph) as soon as

they read or hear that Sally approached the star (Potts et al., 1988; Duffy, 1986; McKoon & Ratcliff, 1986; O'Brien, Shank, Myers, & Rayner, 1988; Singer, 1979, 1980; Singer & Ferreira, 1983; Beeman, 1985).

RHD patients are more likely than normal comprehenders to falsely accept incorrect inference statements, such as "Sally was getting an autograph" (McDonald & Wales, 1986), and they draw fewer correct inferences than normal comprehenders do (Moya et al., 1986). These results indicate that RHD patients do not simply limit their interpretations to literal meanings but that they draw incorrect inferences. From previous studies (e.g., Brownell et al., 1986), it is impossible to tell whether RHD patients are poor at coherence inferencing because they draw predictive inferences, which then interfere with the correct coherence inferences. It is also possible that RHD patients just appear to draw predictive inferences because they cannot recall relations between the story elements (Hough, 1990).

RHD patients are relatively good at tasks that would be difficult if inferences were drawn. When RHD patients hear short scenarios such as the one with Sally and the movie star, they correctly deny having explicitly heard inferrable statements, such as "Sally was interviewing the movie star" (Grafman, Salazar, & Vance, 1983; cf. McDonald & Wales, 1986). LHD patients will often mistakenly judge that they heard or read inferred sentences (Grafman et al., 1983), and normal comprehenders will as well, after long delays (e.g., Johnson et al., 1973). It is not surprising that the RHD patients perform well at this task: Because they do not generate correct inferences in the first place, RHD patients *should be* less likely than normal comprehenders to think that they read or heard statements about these inferences.

At what stage of inferencing do RHD patients err? RHD patients may have difficulty drawing coherence inferences connecting discourse elements due to deficits at several steps. They may have difficulties: (1) Because they cannot remember the previous text, which contains the premise (*Sally approached the movie star*); (2) because they do not recognize when new input (*Sally was writing an article*) does not cohere well: (3) because they cannot see how the new and previous input could be related (movie stars can be interviewed, paper and pen can be used in interviews, interviews can be used in articles); (4) because they cannot select the appropriate concept to relate the new and old text (Sally interviewed the movie star); or (5) because they cannot integrate the inferred concept with their representation of the discourse.

I will concentrate on two potential deficits that could each affect several stages of inferencing. First, difficulties in recognizing and building the appropriate organizational structures to represent discourse could affect awareness of the premise, recognition that new input does not cohere well, or the final integration of an inference with the discourse.

Second, semantic processing deficits could affect awareness of how new and old information could be indirectly related, as well as affecting selection of an appropriate inference to connect new and old information.

Structure Building

RHD patients may not draw coherence inferences connecting discourse elements because they cannot comprehend the overarching organization or macrostructure of discourse, and thus do not know which parts of a story to connect via an inference. This idea is appealing because the RH is known to be important in constructional and visuospatial structuring tasks (Benton, 1979). Many studies have shown that the LH best perceives details within complex visual stimuli but that the RH is important for perceiving the gestalt or macrostructure of visual input (Van Kleeck, 1989). Analogously, most well-developed discourse representations comprise substructures and a macrostructure. Presumably, episodes of stories are represented in their own substructures, and these are eventually integrated into the macrostructure of the story representation.

Discourse elements are related by causal and temporal sequences, spatial relations, and other information that separate stories into logical chunks or episodes. Comprehenders structure their mental representations of discourse into substructures based on these episodes. Comprehenders easily perceive episodes of a story and can divide the story into episodes whether it is written (Mandler, 1978; Pollard-Gott, McCloskey, & Todres, 1979), spoken (Gernsbacher, 1984), pictured (Gernsbacher, 1985), or silently filmed (Baggett, 1979). Children and adults both typically recall stories in episodes (Mandler & DeForest, 1979; Gernsbacher, 1985; Bagget, 1979; Mandler & Johnson, 1977). In fact, stories are recalled in separate episodes even when the episodes were interwoven in the original stories (Mandler & DeForest, 1979). Usually, however, stories are told and written in clear episodes (Thorndyke, 1977). Stories organized by episodes are more easily comprehended and more fully recalled than stories that are less-well organized (Thorndyke, 1977; Mandler and Johnson, 1977).

Comprehenders organize their mental representations by episodes during comprehension. Comprehenders use the first input of discourse to lay a foundation to represent the whole body of discourse (Gernsbacher, Hargreaves, & Beeman, 1989). They then map new input onto the existing foundation according to the degree of cohesion between the new and the old input (Gernsbacher, 1990). For instance, if a noun phrase is repeated (literally or synonymously), the second occurrence will simply be mapped onto the representation for the first occurrence, so that both mentions of the noun are represented within the same structure. But when new information coheres less well with the previous text, people

may shift and initiate a new substructure. Shifting requires additional effort that is reflected in increased processing time, and shifting makes the information from the previous substructure less accessible (Gernsbacher, 1990).

People use new episode cues provided by speakers, writers, and picture story authors to appropriately shift and begin new substructures. When comprehenders encounter these cues in verbal or picture stories, they slow down (Gernsbacher, 1984; Haberlandt, 1980; Mandler & Goodman, 1982; Anderson, Garrod, & Sanford, 1983; Gernsbacher, 1983). Immediately after people encounter new episode cues, they have difficulty recalling information from previous episodes (Gernsbacher, 1984; Anderson et al., 1983; Gernsbacher, 1985). Thus, structure building, in addition to being a product of comprehension, reciprocally influences comprehension.

Structure Building and Coherence Inferencing

Normal structure building might be necessary to draw coherence inferences. If people do not understand that two story elements should be within a single substructure, they may not draw coherence inferences. For instance, 4- and 5-year-olds are less able than 6-year-olds to organize previously described pictures into single-episode stories. Instead, the younger children tend to partition the pictures into multiple episodes (Brown & Hurtig, 1983). The younger children also are less likely to draw global inferences that tie the whole story together; instead, they draw inferences only within the smaller subepisodes (Brown & Hurtig, 1983).

Comprehenders' skill at structure building can be improved through training and practice (Morrow, 1986). When it is, their skill at drawing coherence inferences also improves. Indeed, when trying to learn texts, children using structured study guides recall more implicit (inferential) information than children using less-structured study guides. The recall of explicit information improves less than the recall of implicit information with the use of the structured study guide (Risko & Alvarez, 1986).

These results suggest that drawing coherence inferences may depend on normal structure building. Perhaps RHD patients have difficulty drawing coherence inferences for the same reason that young children do: they might shift to initiate new substructures too often and hence have less access to the premise information, which they need to draw inferences.

Conversely, a lack of coherence inferencing may disrupt cohesive structure building (O'Brien & Myers, 1985; Thorndyke, 1976, 1977). One way to avoid the effort of initiating a new substructure is to increase coherence between the new input and the existing foundation by drawing an inference that connects them. Further, although people organize their

mental representation of discourse into separate substructures, they eventually integrate these substructures into an overall representation of the entire input. Drawing coherence inferences may increase coherence and thus facilitate integration of substructures into a macrostructure. For instance, if Brownell et al.'s (1986) RHD patients did not infer that Sally was interviewing the movie star, it would be surprising if they formed the same representational structures as normal comprehenders.

Clearly, structure building interacts with drawing coherence inferences. Thus, an examination of the source of RHD patients' inferencing deficits must consider structure building processes as well.

Structure Building in Right Hemisphere-Damaged Patients

RHD patients do not organize their recall of discourse as well as normal comprehenders do (Hough, 1990). For example, they have difficulty recalling the relations between elements of both stories and visual stimuli, but LHD patients do not (Moya et al., 1986). In one study, after reading short stories, RHD patients recalled fewer details and fewer relations between story elements (including spatial relations) than did other subjects. RHD patients were also impaired on all aspects of recalling figures such as the Rey–Osterrieth figure, which has a complex configuration and many details (Moya et al., 1986). Interestingly, the ability to recall details and correct relations and outlines of figures correlated with the ability to provide an overview (i.e., the title) of recalled stories for RHD patients, but not LHD patients or normal elderly subjects (Moya et al., 1986). These results suggest similar mechanisms for representing structural relations in figural and linguistic stimuli and a crucial RH role in these mechanisms.

When RHD patients recall narratives, they quickly forget the relations between story elements (Grafman et al., 1983) and may simply list the elements or provide plausible but incorrect relations between them, thus appearing to confabulate (Hough, 1990). They have difficulty stating the theme of a narrative, especially when the theme is presented at the end of the narrative (Hough, 1990). LHD patients also have difficulty recalling narrative information but seem able to organize the information that they comprehend—they can recall themes presented at the beginning or the end of narratives. It appears that RHD patients have difficulty deriving a framework for organizing their representation of discourse (Hough, 1990).

RHD patients may also have difficulty building structures of sentences, at least in a word insertion task when the insertion requires reassigning the relations between sentence elements (Schneiderman & Saddy, 1988). Finally, RHD patients may have difficulty imposing structure on lists of words. According to some studies, RHD patients are not as likely as

normal comprehenders to semantically cluster words when they recall lists of concrete words (e.g., recalling *pliers* and *hammer* together when they were separated by other words in the initial presentation) (Villardita, 1987; Villardita, Grioli, & Quattropani, 1988).

Semantic clustering in free recall of list items may depend on semantic overlap: Items that share semantic features cue each other and so are likely to be recalled together. This mechanism may also account for structure building in discourse comprehension. If so, then RHD patients may have difficulty drawing coherence inferences and organizing or building mental structures to represent discourse because they lack activation of some semantic features available to intact comprehenders.

Semantic Activation in the Right Hemisphere

When people comprehend words, they generally show an advantage (in speed or accuracy) for words presented to the LH compared to the words presented to the RH. However, the RH and LH may process semantic information in parallel, leading to two distinct patterns of semantic activation in response to input (Chiarello, 1988). Right hemispheric semantic processing has been studied in normal subjects and brain-injured patients. One common method is to lateralize visual input: Words viewed in the right visual hemifield (rvf) are received directly in the LH and must cross the corpus callosum to reach the RH. Words viewed in the left visual hemifield (lvf) are received directly in the RH and must cross the corpus callosum to reach the LH. When people view words in the rvf-LH, they respond quickly to test words related to the dominant or contextually appropriate meanings of preceding ambiguous words (e.g., the *money* meaning of *bank*) (Burgess & Simpson, 1988; see also Nakagawa, 1991). They respond slowly to test words related to the less frequent or inappropriate meanings (*river*). With longer delays after the ambiguous word, the response speed difference between the more and less frequent meanings increases. This effect is similar to the effects observed when people view ambiguous words centrally: All meanings are initially activated, but the dominant or contextually appropriate meaning is quickly selected, and the others are suppressed (Simpson, 1984; Onifer & Swinney, 1981; Swinney, 1982). In contrast, when people view words in the lvf-RH, they respond fastest to test words related to less frequent or contextually inappropriate meanings of the ambiguous words (Burgess & Simpson, 1988). This suggests that some semantic information related to words is activated in the RH but not in the LH.

Similar results have been obtained with RHD patients, who show less evidence than neurologically intact subjects of activating multiple meanings of ambiguous words (Burgess & Cushman, 1990; Rausch, 1981), whereas LHD patients can show less evidence of selecting a single inter-

pretation (Rausch, 1981). RHD patients also have difficulty accessing the connotative or metaphoric meanings of words (Brownell, 1988).

Together, these results imply that when people derive word meaning, unique semantic information resulting from RH processing may be available to enhance comprehension. According to Taylor (1988, p. 324), "the RIGHT [hemisphere] proposes, and the LEFT [hemisphere] disposes" interpretations. The RH may *coarsely code* semantic input, so that one comprehended word activates many semantic features, but each only weakly—so that only a vague interpretation can be made. 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, such as production (Beeman, submitted for publication).

After comprehending individual words, people must integrate discourse coherently and build on semantic information to draw inferences and structurally organize the information into a coherent representation. If comprehending words causes coarse coding of semantic input in the RH and fine coding of semantic input in the LH, the optimal use of semantic overlap for coherence inferencing and structure building may depend on the RH as well as the LH.

EXPERIMENT DESIGN

The experiment examined the interaction between coherence inferencing and structure building in RHD patients and normal elderly subjects. Subjects listened to stories that promoted coherence inferences. The episodes around which inferences could be drawn were manipulated to induce the formation of mental substructures: Inferences could be drawn within episodes or across episode boundaries. After each story, subjects answered questions specifically addressing the inferrable events, along with questions about explicit story information. Subjects also recalled four of the stories, and the numbers of inferrable events they included were counted.

Based on previous research (Brownell et al., 1986), RHD patients should have more difficulty answering Inference questions than normal elderly subjects do. If RHD patients have specific problems with coherence inferencing, they will perform more poorly than the normal elderly subjects do on both True and False Inference questions, but they will perform as well as the normal elderly subjects do on the Explicit questions. If RHD patients merely respond too literally, then they should perform poorly on the True Inference questions, but they should perform well on the False Inference questions, relative to normal elderly subjects.

If RHD patients have difficulty with inferences because they poorly organize their representations of discourse, then they might be more af-

fected by the episode boundaries than the normal elderly subjects. However, by the time they answer questions at the end of the stories, subjects might have integrated separate substructures into one coherent structure. Thus, an on-line measure of inferencing during comprehension might be more sensitive to structure building effects. Such an on-line measure should also be sensitive to momentary inferences that were drawn but never integrated into the representation of stories, if any such inferences occur.

Because word pronunciation depends so heavily on the LH (Zaidel, 1983 for review), the experiments presented here used lexical decision latencies as the on-line measure of inferencing. In contrast to pronouncing words, lexical decisions seem to be made reasonably well when words are presented primarily to the RH (Gazzaniga, 1983, p. 526). In addition, people make lexical decisions more slowly than they pronounce words, allowing more time for semantic processing to influence responses. When word pronunciation times are slowed, semantic relatedness effects resemble the effects observed in lexical decision latencies (Chiarello, Burgess, Richards, & Pollock, 1990).

Lexical decision test words were shown to RHD patients and normal elderly subjects listening to stories that promoted coherence inferences. If subjects draw the intended inferences, they should respond faster to inference-related words than to unrelated words. The interesting comparison is between the amount of inference-related facilitation in the normal elderly subjects and the amount of facilitation in RHD patients. If the RH contributes to inferencing because it activates information necessary to draw appropriate inferences, then normal elderly subjects should show stronger facilitation of lexical decisions for inference-related test words than will RHD patients. If the RH contributes to inferencing because it is involved in building or organizing mental structures, then new episode cues may affect inference-related facilitation differently in the groups.

Method

Subjects. All subjects volunteered for the experiment and received $5.00 per hour. Eight patients (aged 50–80) who had had cerebral vascular accidents in the RH were compared with eight normal elderly subjects (aged 59–79). Each RHD patient is described in more detail in Appendix A. The groups were matched for education (RHD patients mean = 14.5 years, normal elderly subjects mean = 14.1 years) and raw scores on the Information subtest of the Wechsler Adult Intelligence Scale-Revised (RHD patients mean = 20.4, normal elderly subjects mean = 18.9). Further tests (described below) were administered to provide descriptions of the individual subjects.

Eleven patients were referred for study by various neurologists, psychologists, and speech pathologists informed about the study. All patients had a single known lesion, verified by CT or MRI scan. The scan reports were reviewed for all patients, and in most cases the scans themselves were used to further specify the damaged area (see Appendix A). Ten RHD patients had suffered cerebral vascular accidents (strokes) of the right middle cerebral artery; one additional patient with a right cerebellar infarct was excluded. Four of

TABLE 1
Raw Scores (Means and Ranges) on Battery of Standard Tests for Eight Normal Elderly (NE) Subjects and Eight Right Hemisphere-Damaged (RHD) Patients

Group	Education	Age	Information	Digit span	Block design	Logical memory I	Logical memory II	CFL fluency	Animal fluency	Boston Naming
NE										
Mean	14.1	70.1	18.9	16.1	28.1	26.4	24.6	47.9	19.2	55.5
Range	12–20	59–79	11–23	13–19	20–40	17–35	17–31	33–64	12–26	52–58
RHD										
Mean	14.5	60.8	20.4	13.8	11.1	23.4	17.6	32.6	16.3	55.4
Range	12–17	50–80	11–28	6–19	0–20	10–31	9–26	28–38	9–20	52–60

these 10 patients had lesions that did not appear to involve cortex. Two of these patients were excluded because a radiologist judged that the infarcts only affected subcortical areas such as the basal ganglia. Two other RHD patients (P.D. and D.B.) with subcortical strokes were included because the radiologist judged that the infarcts damaged deep white matter subjacent to the cortex (i.e., the axons carrying signals to and from the cortex).

As a group, the RHD patients had generally large lesions that varied anatomically, but all affected the temporoparietal cortex or subjacent white matter. No auditory or visual perception problems resulted (except for mild left-sided neglect), as self-reported and judged from the medical records and screening interview. One RHD patient was tested 5 months after his stroke, another was tested 10 months after his stroke, and six patients were tested at least 1 year after their strokes. All patients had all been living at home for at least 3 months at the time of testing.

Test Battery. All RHD patients and normal elderly subjects were administered a set of standard neuropsychological tests within 1 week of the subjects' participation in the experiment (except patient R.N., who had been administered some of the tests 3 months prior to the time he participated in this experiment; because he declined to return for retesting, his earlier scores are reported). The group results are illustrated in Table 1, and individual results are listed in Appendix B.

The Information subtest of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) has one of the highest correlations with Full-Scale IQ, and especially Verbal IQ obtained on the WAIS-R (Wechsler, 1981). Scores on this test were used with education levels to match subjects for approximate level of general cognitive functioning. The Block Design asks subjects to use colored blocks to reproduce a pictured abstract pattern. It is generally recognized as an excellent index of RH functioning and visual–spatial abilities, which are often impaired in RHD patients (Lezak, 1983). All other tests were used simply to describe how the subjects performed on a variety of cognitive tasks related to the experimental task. The Digit Span subtest of the WAIS-R requires subjects to repeat (forward or backward) a string of numbers. The Logical Memory (I and II) subtests of the Wechsler Memory Scale-Revised (WMS-R) require immediate and delayed recall of short stories. The CFL test asks subjects to name as many words as they can that begin with C, F, or L. The "Animals" test asks them to name as many animals as they can. The Boston Naming test asks them to name 60 pictured objects.

Both raw scores and age-scaled (or age percentile) scores were obtained. The RHD patients and normal elderly subjects were statistically equivalent (all $ps > .15$) on raw scores for all tests except the Block Design and the CFL test. The RHD patients were reliably less accurate on the Block Design than were the normal elderly subjects (Scheffe's $F(1, 14)$

= 11.74, $p < .05$) and produced reliably fewer words beginning with C, F, or L (Scheffe's $F(1, 14) = 6.9$, $p < .05$).

There were some qualitative differences between the groups. Overall, the patients performed somewhat more poorly than the normal elderly subjects. Moreover, the normal elderly subjects were older, on average (70.1 years), than the RHD patients (60.7 years), although this difference was not reliable (Scheffe's $F(1, 14) = 2.02$, $p > .10$). Despite these group differences, the within-groups comparison should be informative: Normal elderly subjects should answer Inference questions as well as Explicit questions, whereas the RHD patients should answer Inference Questions less accurately than Explicit Questions.

Materials

Stories. Experimental stories were based on the two-sentence coherence inference scenarios used by Potts et al. (1988), plus some similarly constructed scenarios. The first sentences of these 40 scenarios provided a premise (e.g., *George left the bathtub water running*). The second sentences provided information that only cohered to the first if an inference was drawn (e.g., *George cleaned up a mess in the bathroom*). The second sentences will be called the inference-inducing sentences because they promote coherence inferences (e.g., OVERFLOW).

Pilot studies ensured that the potential inferences were drawn and that they actually connected the inference-inducing sentence to the premise. Naturally, if subjects drew the inferences from the inference-inducing sentence alone, the relative ease of drawing inferences within a single substructure against the ease of drawing inferences across substructures could not be compared.

To avoid this pitfall, three groups of pilot subjects read the scenarios and described "What happened?" In one version of each scenario, subjects read the inference-inducing sentence alone; in three versions, they read the premise plus the inference-inducing sentence. After the first two rounds of pilot studies, scenarios were modified if few subjects included the inferrable event when given the premise plus the inference-inducing sentence. Scenarios were also modified if several subjects included the inferrable event when given the inference-inducing sentence alone.

After the third round of subjects reading the scenarios, 32 scenarios were selected. For the selected scenarios, 92% of the last group of pilot subjects included the inferrable events when they read the versions with the premise plus the inference-inducing sentence, whereas 11% of the subjects included the inferrable events when they read the inference-inducing sentences alone. Thus, the pilot subjects made the expected inferences, but only when they read both the premise sentences and the inference-inducing sentences.

The 32 scenarios were combined to yield two inference-inducing scenarios for each of 16 stories, like the one in Table 2. When possible, events described in the stories were written to be relevant to the general population. Furthermore, sex stereotypes were not maintained (e.g., police officers and doctors were women, and a man rather than a woman was rescued by a lifeguard). However, these roles were not so unusual that they disrupted comprehension (based on feedback from pilot subjects). Finally, because many of the inferrable events occurred in tragic scenarios (bombs exploding, personal injuries, and objects breaking), an effort was made to accentuate positive outcomes whenever possible.

There were two versions of each story: In one version, the coherence inference for the first scenario had to be drawn across an episode boundary, whereas in the other version it could be drawn within the same episode. The intervening episode boundaries were signalled by different cues, for example: changing the time or location of the setting beyond the expected physical or temporal limits for an episode, introducing a new character (e.g., *George's son*) or new event (e.g., *doing homework*), beginning a sentence with an adverb (e.g., *Meanwhile, . . .*), and reducing argument overlap (i.e., not repeating words).

TABLE 2
Story 14 Promoted Two Coherence Inferences

George and his friends hiked up a mountain trail. They had a great view of the huge mountain to the north that had * been in the news. From a distance, the campers watched as the great mountain rumbled angrily. [BOOKEND / pleasant]
c. They had never witnessed anything like this before.
n. Meanwhile, George's son did his History homework.
After the explosion, fields of black tree stumps remained where the beautiful virgin forest had been, * and the campers were amazed. When he got home, George started the bathwater, [HAD / *volcano*] then turned on the news. After the news was over, George turned off the * TV. Then he went into the bathroom and discovered that he had left the bathtub water running. [DUK / cuj]
c. He had forgotten about it while watching the news.
n. Meanwhile, George's son did his History homework.
The mess took him a long time to mop up, * but when he was all done, he was warm and relaxed. [*OVERFLOW* / operate]
When his son was done with his homework, George promised to take him hiking that * weekend. [STOUD / banjc]

True or False questions
(True Inference) George saw a volcano. or (False Inference) George saw a bomb.
(False Inference) George spilled some milk. or (True Inference) The bathtub overflowed.
(True Explicit) George promised to take his son hiking.
(False Explicit) George and his friends went to a lake.

Note. The lexical decision test items are in brackets beneath the location (marked with asterisks) where they appeared. Half the subjects saw the test words on each side of the brackets. Subjects heard the Inference questions on the left when they saw the test words on the left. Sentences labeled (c.) continued an episode, sentences labeled (n.) contained new episode cues. HAD and OPERATE were control words, related to inferences promoted in Story 6.

Sentences that continued episodes and sentences that contained new episode cues were neutral with respect to the promoted inferences. Their neutrality was confirmed in the first pilot study because subjects drew the inferrable events equally often after hearing the continuation sentences, after hearing the sentences with new episode cues, or after hearing neither (in addition to the premise and inference-inducing sentences).

Words associated to the inferrable events were generally eliminated from the scenarios, although a few words associated to the inferrable events occurred early in the stories (e.g., *mountain* may be weakly associated to the inference VOLCANO). No words describing the inferrable events were mentioned later in the stories because they could influence subjects' recalls and their responses to questions about the inferences.

Questions. After each story, subjects answered four True/False questions, arranged to preclude guessing strategies. Two questions tested explicit knowledge. True Explicit statements restated information explicitly mentioned in the text (e.g., *George promised to take his son hiking*), and False Explicit statements contradicted information explicitly mentioned in the text (e.g., *George and his friends went to a lake*). For each potential inference, two True/False questions were written. True Inference statements included the inference being promoted (e.g., *George saw a volcano*). If subjects drew the inferences promoted by the stories, they should have accepted these statements as true. When subjects made lexical decisions to unrelated words (e.g., HAD), they heard the True Inference statements after

the stories. False Inference statements (e.g., *George saw a bomb*) were culled from the pilot subjects' responses when they read the inference-inducing sentences alone. When subjects made lexical decisions to inference-related words (e.g., VOLCANO), they heard the False Inference statements after the stories. If subjects drew the intended inferences, they should have rejected these statements as false.

Test words. Test words chosen for each inference were those words that pilot subjects used most often to tell what happened in the scenarios. Eight test words each were three, four, and five letters long, and another eight words were six to eight letters long.

There were 48 filler lexical decision test items, and 40 of them were nonwords. Filler words were not related to the stories in any way. Filler nonwords were created by changing one or two letters of real words that were three to eight letters long. About half of the nonwords were pronounceable. Filler items never occurred during premise sentences, the sentences that continued episodes, or the sentences that introduced new episode cues.

There were two factors for the lexical decisions task: relatedness (inference-related or unrelated) and episode (within an episode or across episode boundaries). Each test word appeared in each condition, yielding eight (test word × episode) material sets.

Procedure

Subjects listened to the stories narrated by a male voice over headphones and were asked several times whether they could hear the stories. Subjects were tested individually in front of a monitor and two response buttons for question and lexical decision responses. The response buttons triggered an Apple IIe computer to collect responses and latencies.

Subjects were informed that they had several tasks to perform. First, they had to answer True/False questions after each story. Subjects were told that the questions were "tricky" and they were likely to get some wrong, but to continue to answer the best that they could. Subjects heard the questions immediately after 12 of the stories and after recalling 4 other stories. As each True/False statement ended, the words TRUE and FALSE appeared near the bottom of the screen, on the left and right sides, respectively. Subjects answered by using their right hands to press the left key, labeled YES (TRUE), or the right key, labeled NO (FALSE). Subjects were allowed to respond to the questions verbally if necessary. This occurred on about 10% of RHD patient's responses (due mostly to one patient) and 2% of other subjects' responses.

The subjects' second task was to recall some stories verbally after listening to them. The four stories to be recalled included one inferrable event from each of the eight conditions and were the 4th, 9th, 11th, and 14th stories presented. Subjects' recalls were recorded, transcribed, and then scored (by agreement of two scorers) for whether they included the inferrable events.

The subjects' third task was to decide whether letter strings that appeared on the screen were words and respond by pressing YES or NO, using the same keys they used to answer the questions. The test words remained on the screen until the subjects responded, for a maximum of 3 sec.

Because clausal structures may affect the way subjects respond to a secondary task—whether due to processing differences (e.g., Gernsbacher et al., 1989; Chang, 1980; Tyler & Marlsen-Wilson, 1982) or subject strategies—all of the experimental test words occurred at clause breaks and were followed by at least four syllables of text before the sentence ended. Patients with left visual field neglect were reminded to cue their eyes left when the test words appeared. The few patients with strong neglect were all trained and adept at this strategy. Subjects practiced making lexical decisions while listening to the taped instructions. They also made lexical decisions and answered comprehension questions for two practice stories prior to the experimental stories.

Subjects were tested at the Wheeler Institute of Cognitive Neuropsychology at Good

Samaritan Hospital, except four RHD patients who were tested in their homes. All subjects heard taped instructions, which were verbally previewed beforehand and clarified afterward when necessary. Two normal elderly subjects and two RHD patients were given short rest breaks between stories.

RESULTS

Whether subjects drew coherence inferences was examined by: (1) How accurately they answered Inference versus Explicit questions, (2) How many inferrable events they included when they recalled the stories, and (3) How fast they made lexical decisions for inference-related versus unrelated test words that they saw while they listened to the stories. Structure building in both subject groups was examined by analyzing all three of these dependent measures when the inferences had to be drawn across episode boundaries versus within episode boundaries.

True/False Questions

Subjects' accuracies to True and False Inference versus Explicit questions are displayed in Figs. 1 and 2. Subjects answered True and False questions equally well, and this did not interact with group nor with type of question (all $ps > .15$).

Overall, subjects responded less accurately to Inference questions than Explicit questions ($F(1, 15) = 9.54$, $p = .008$). This main effect reliably interacted with group (RHD patients versus normal elderly subjects)

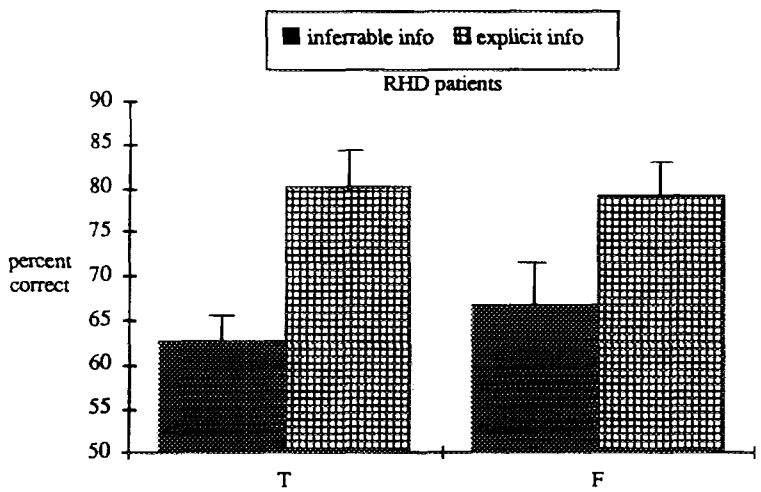

FIG. 1. Right hemisphere-damaged patients' percentage of correctly answered True versus False questions about information inferrable from stories versus information explicitly mentioned in stories (bars represent standard errors).

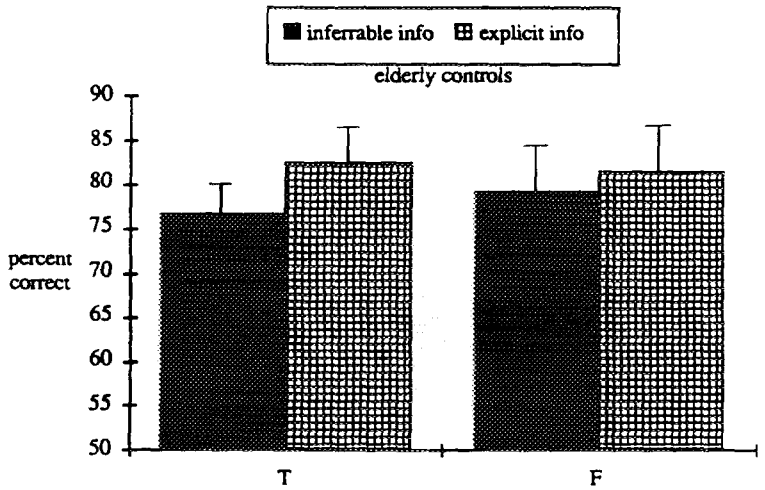

FIG. 2. Elderly control subjects' percentage of correctly answered True versus False questions about information inferrable from stories versus information explicitly mentioned in stories (bars represent standard errors).

($F1(1, 14) = 7.2, p = .02$). RHD patients were considerably less accurate at answering Inference questions (64.6%) than Explicit questions (79.6%) ($F(1, 7) = 44, p = .0003$). As for the normal elderly subjects, they were slightly less accurate at Inference questions (77.9%) than Explicit questions (81.9%), but this difference was not reliable ($p > .15$). Normal elderly subjects answered Inference questions more accurately than RHD patients did ($F(1, 14) = 5.17, p = .04$), but the two groups answered Explicit questions equally well ($ps > .15$). Thus, RHD patients had difficulty answering Inference questions, but did not have difficulty answering Explicit questions.

As illustrated in Figs. 3 and 4, both the RHD patients and the normal elderly subjects answered Inference questions equally well within and across episode boundaries ($ps > .15$). RHD patients answered Inference questions poorly even when the inferences could be drawn within episode boundaries, and normal elderly subjects answered Inference questions accurately even when the inferences had to be drawn across episode boundaries.

Story Recall

Figures 5 and 6 illustrate the percentage of inferred events included in recall by RHD patients and normal elderly subjects when the subjects viewed inference-related versus unrelated test words, and when infer-

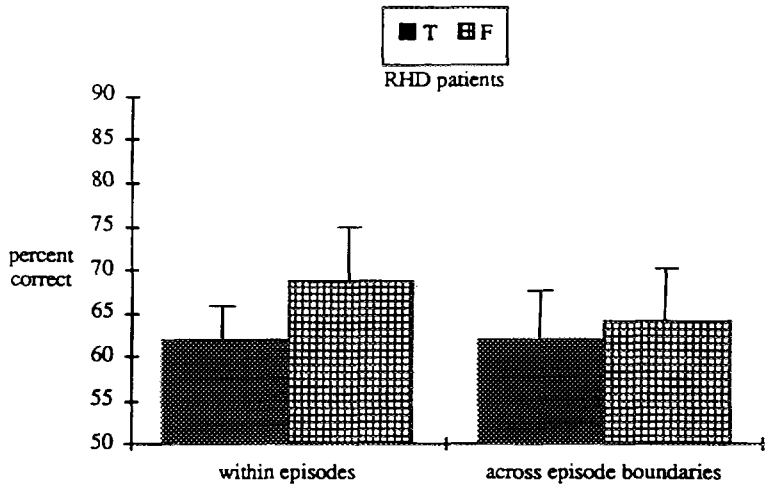

FIG. 3. Right hemisphere-damaged patients' percentage of correctly answered True versus False questions about information inferrable from stories, when inferences could be drawn within episodes versus across episode boundaries (bars represent standard errors).

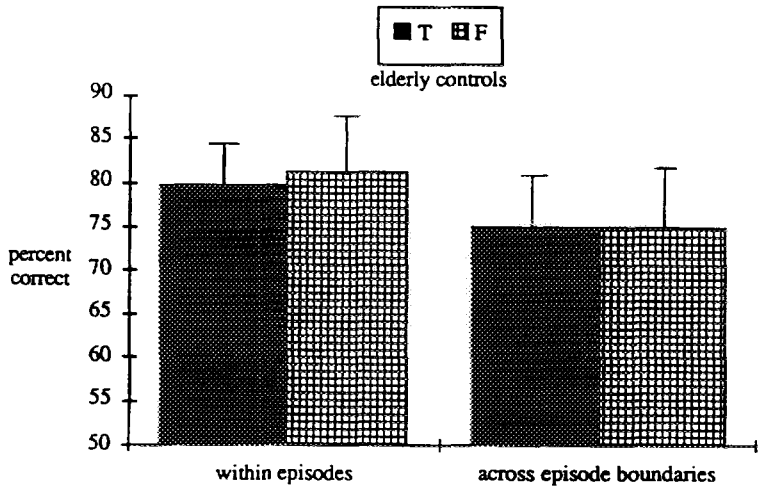

FIG. 4. Elderly control subjects' percentage of correctly answered True versus False questions about information inferrable from stories, when inferences could be drawn within episodes versus across episode boundaries (bars represent standard errors).

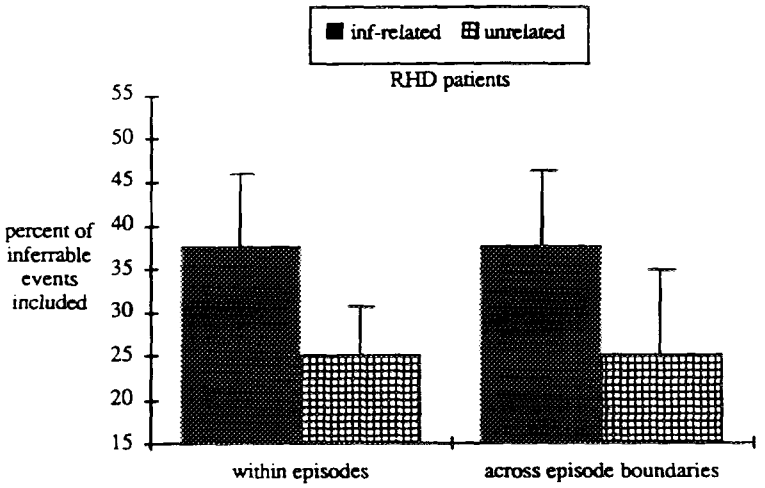

FIG. 5. Percentage of inferred events that right hemisphere-damaged patients included when they recalled stories, when subjects saw inference-related versus unrelated test words, and when the inferences could be drawn within episodes versus across episode boundaries (bars represent standard errors).

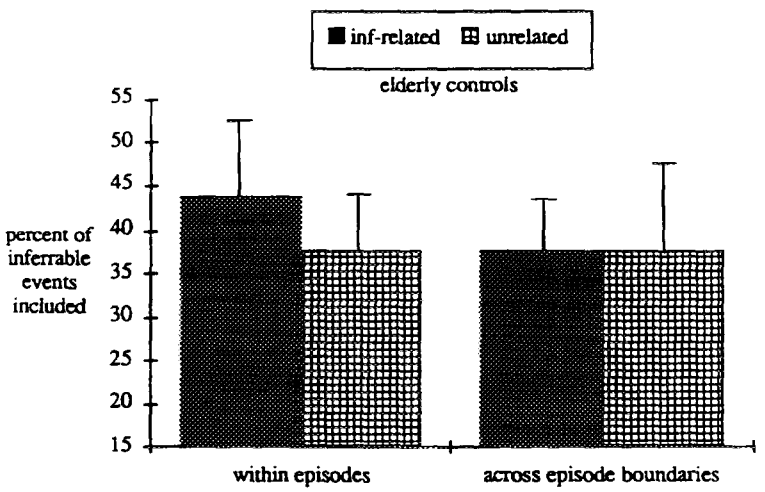

FIG. 6. Percentage of inferred events that elderly control subjects included when they recalled stories, when subjects saw inference-related versus unrelated test words, and when the inferences could be drawn within episodes versus across episode boundaries (bars represent standard errors).

ences could be drawn within episodes versus across episode boundaries. On average, RHD patients included 31% of the eight inferred events (two events per four stories), and normal elderly subjects included 42% of the inferred events, but this difference was not reliable (all $ps > .15$). Both groups included equal percentages of inferred events whether inferences were drawn within episodes versus across episode boundaries, and whether they viewed inference-related versus unrelated test words while listening to the stories.

Lexical Decisions

Normal elderly subjects made more correct lexical decisions (97% for words, 92% for nonwords) than RHD patients (82% for words, 65% for nonwords). The low accuracy among the RHD patients was primarily due to one patient's (R.N.) near-chance performance on all items, and two others' (R.R. and B.H.) poor performance on nonwords. In general, accuracy reflected decision time and will not be discussed further.

The subjects' mean lexical decision times for target words presented during the inference-inducing sentences are illustrated in Figs. 7 and 8. The subjects' data were submitted to a crossed factor ANOVA with subjects as the random variable (F1 analyses) and with three factors of two levels each: Group (normal elderly subjects versus RHD patients), Episode (within episodes versus across episode boundaries), and Relatedness (inference-related versus unrelated test words). The subjects' data were also submitted to separate group analyses (also F1 analyses). The mean decision times for each item occurring in the four conditions for both groups were submitted to analogous ANOVAs with items as the random variable (F2 analyses).

RHD patients made lexical decisions more slowly than the normal elderly subjects did ($F1(1, 14) = 4.22, p = .06$; $F2(1, 62) = 65, p < .001$). RHD patients and normal elderly subjects were differently affected by relatedness, as revealed by a between-groups interaction ($F(1, 14) = 8.84, p = .01$; $F2(1, 62) = 5.87, p < .02$). RHD patients responded to inference-related words 148 msec more slowly than they responded to unrelated words ($F1(1, 7) = 4.44, p = .07$; $F2(1, 31) = 4.48, p = .04$). In direct contrast, normal elderly subjects responded to inference-related words 49 msec faster than they responded to unrelated words ($F1(1, 7) = 13.62, p < .01$; $F2 = 1.4, p > .20$).

Neither the lexical decision latencies of RHD patients nor those of normal elderly subjects were reliably affected by the episode boundaries (all $ps > .15$). However, episode boundaries and test word relatedness marginally interacted when the latencies from both groups were considered together ($F1(1, 14) = 2.92, p = .10$; $F2(1, 62) = 2.10, p = .15$). This marginal interaction occurred because decisions for test words were less facilitated—or more inhibited, in the case of RHD patients—when

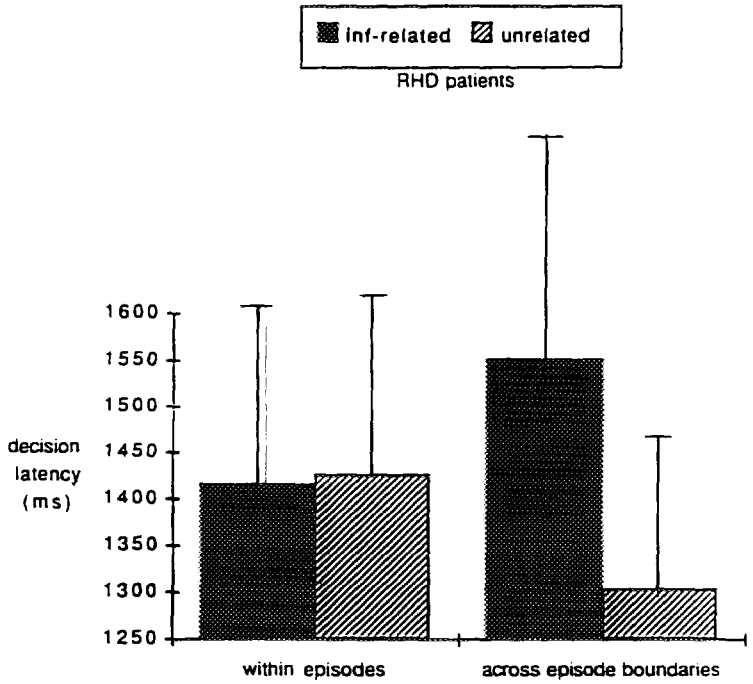

FIG. 7. Right hemisphere-damaged patients' lexical decision latencies to visual test words when the test words were related versus unrelated to inferrable events and when the inferences could be drawn within episodes versus across episode boundaries (bars represent standard errors).

the inferences had to be drawn across episode boundaries. This indicated that subjects' sensitivity to the relation between the test words and the inferrable events was somewhat modulated by episode boundaries. The episode boundary X relatedness interaction did not interact with group (all $ps > .15$), indicating that the effect of the episode boundaries did not differ between the RHD patients and the normal elderly subjects.

Normal elderly subjects and RHD patients responded with different mean latencies, so it is difficult to compare the observed effects using raw decision times. To facilitate comparison across groups, the decision latencies for each condition are presented as Z scores in Figs. 9 and 10. Normal elderly subjects' data are quite similar to those obtained with college students (Beeman & Gernsbacher, submitted for publication), whereas the RHD patients' data are radically different.

Qualitative Descriptions of Patients

Group studies of brain-damaged patients have been criticized for lumping heterogeneous patient groups together under a syndrome label (Cara-

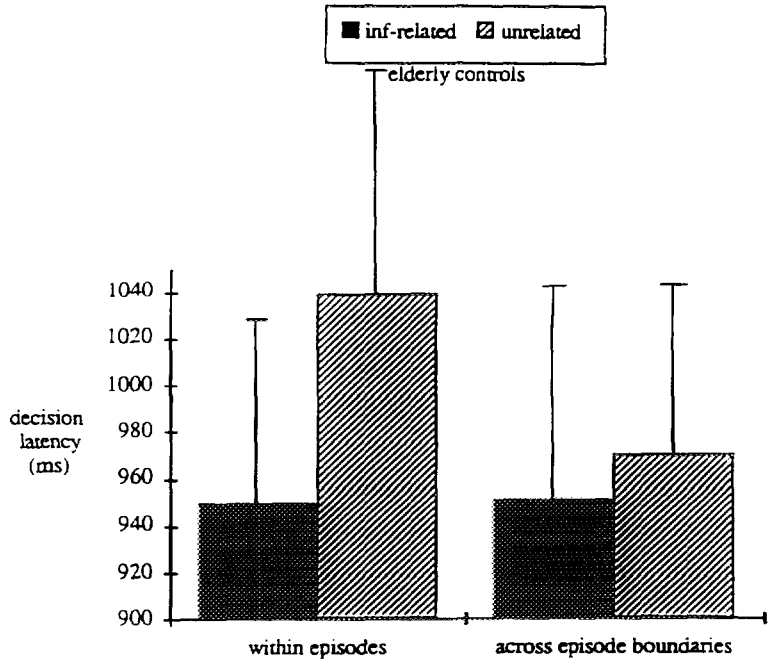

FIG. 8. Elderly control subjects' lexical decision latencies to visual test words when the test words were related versus unrelated to inferrable events and when the inferences could be drawn within episodes versus across episode boundaries (bars represent standard errors).

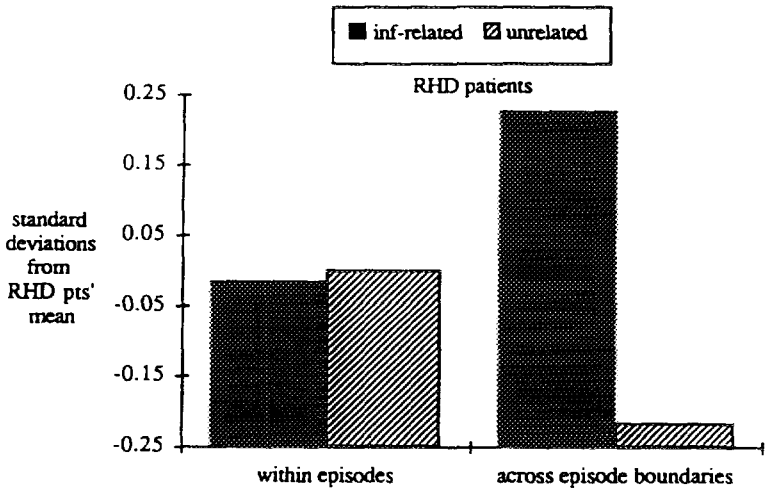

FIG. 9. Right hemisphere-damaged patients' lexical decision latencies (in Z scores) to visual test words related or unrelated to inferrable events, when the inferences could be drawn within episodes versus across episode boundaries.

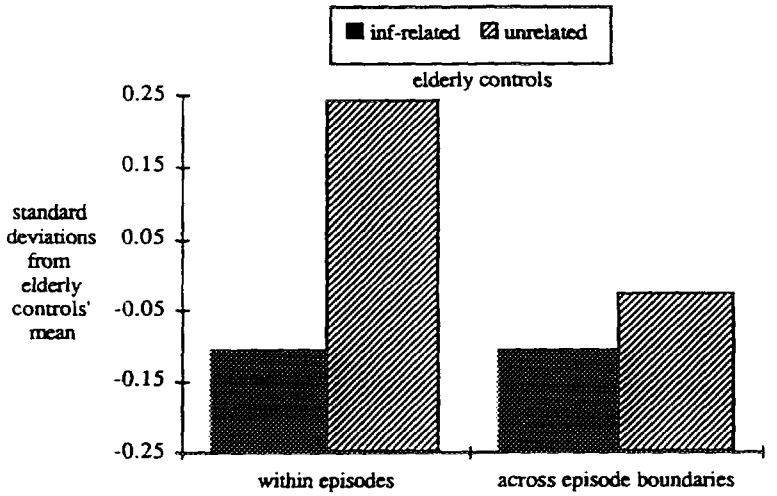

FIG. 10. Elderly control subjects' lexical decision latencies (in Z scores) to visual test words related or unrelated to inferrable events, when the inferences could be drawn within episodes versus across episode boundaries.

mazza, 1984). Patients with different lesions may demonstrate a particular pattern as a group that none of the individual patients demonstrate. This argument must be considered here. Although only patients with lesions due to strokes in the right middle cerebral artery were examined, the etiology and size of the lesions varied among the RHD patients (described in Appendix A).

The patients' current intellectual capacities also varied a great deal, according to neuropsychological tests (see Table 1 and Appendix B). Because the normal elderly subjects were matched to the patients on the Information subtest and education, the normal elderly subjects also varied on the other standard measures, but not as greatly as the patients did. The RHD patients also varied in their beliefs about their current language abilities. During the screening interview, patients were asked if they had had any changes in their thinking abilities since their strokes. Specific inquiries were made about reading and understanding language. Half of the RHD patients responded that they were functioning as well as ever. Patient P.D. claimed that his abilities had improved since his stroke, and he cited the specific example of his improved memory for jokes (and he graciously tendered a few examples). This is surprising, considering that an inability to understand jokes often accompanies damage to the RH (Brownell et al., 1983).

On the other hand, several RHD patients—especially those functioning at the highest levels—noted that they had difficulty "keeping up" with conversations. Some blamed both their problems outside the laboratory

and their incorrect responses to Inference questions during the experiment on poor attention. Patient W.K. offered that he could not read "multi-character novels, because I can't put it all together," despite his ability to read straightforward texts and summaries of novels. Patient D.B., who had returned part time to his profession within a year of his stroke, complained that he no longer understood "the complex mosaic of meaning that is language, even though I understand the words." During the experiment, most of the RHD patients complained that they had difficulty following the stories.

Patients also varied on their performance on the experimental tasks. At the extreme low end, R.N. answered story questions and lexical decision items near chance levels. He complained that he could not follow the stories because the test items distracted him. Although the buttons were labeled YES and NO, R.N. had difficulty remembering which buttons to push to answer the questions (I accepted verbal responses). On the other hand, RHD patient DB responded as quickly and as accurately to both the comprehension questions and the lexical decision test items as the normal elderly subjects did.

Despite these variations, the patients had two things in common. Every RHD patient had damage in the temporoparietal area of the RH, and every RHD patient answered Inference questions less accurately than Explicit questions. R.N. correctly answered only 14 of 32 Inference questions, but 21 of 32 Explicit questions. D.B. correctly answered 24 of the Inference questions, but 32 of 32 Explicit questions (the only subject in several experiments to do so). Five of the eight normal elderly subjects answered Explicit questions more accurately than Inference questions.

One possible explanation for the RHD patients' inferencing difficulties is that it results from the age difference or from a general cognitive performance difference between the groups. To examine this possibility, split-half and covariate analyses were performed, based on the RHD patients' and normal elderly subjects' ages, their scores on the standard neuropsychological tests, and their overall lexical decision latencies. The analyses revealed that these group differences were not strongly related to group differences on the experimental measures.

It is important to consider whether any brain damage could result in poor inferencing. To informally test this, two LHD patients, two amnesic patients, and one patient with RH frontal lobe damage were also examined: K.D. had Broca's aphasia, and E.A. had conduction aphasia (or impaired phonological working memory). W.S. and S.C. both had profound anterograde amnesia. S.H. displayed a classic set of frontal lobe symptoms.

These patients are described in more detail in Appendix A. These patients' accuracy on the Inference and Explicit questions is illustrated in Table 3. Together, these five subjects correctly answered 72.8% of the

TABLE 3
Accuracy of Other Brain-Damaged Patients on Inference and Explicit Questions

			Percentage correct	
Patient	Lesion	Deficit	Inference	Explicit
K.D.	LHD frontal	Broca's aphasia	66	60
E.A.	LHD parietal	Conduction aphasia	85	90
W.S.	Encephalitis	Amnesia	78	84
S.C.	Hypoxia	Amnesia	66	78
S.H.	RHD frontal	Frontal syndrome	69	72
Total			72.8	76.8

Inference questions and 76.8% of the Explicit questions. So, it is unlikely that inferencing deficits result from all types of brain damage.

DISCUSSION

Patients with damage to the RH were less able to draw coherence inferences than normal elderly subjects: The RHD patients responded to the Inference questions at or near chance. They were much better at remembering information explicitly mentioned in the text: They responded to Explicit questions as accurately as the normal elderly subjects did. These data replicate previous evidence of inferencing deficits in a different group of RHD patients, using different materials and procedures (Brownell et al., 1986; cf. Joanette & Goulet, 1987). Further, the RHD patients' decision times for words related to the inferrable events also indicate that they have difficulty drawing inferences: The RHD patients recognized words related to inferences more slowly than they recognized unrelated words.

Normal subjects also show evidence of RH activity when drawing inferences during comprehension: People who generally move their eyes leftward during comprehension—presumably indicating RH activity—respond more accurately to Inference questions than people who generally move their eyes rightward—indicating LH activity (Dunn, Bartscher, Turaniczo, & Gram, 1989). Finally, the results from this experiment are also consistent with the previously described difficulty experienced by RHD patients in using context to make interpretations of new input (Kaplan et al., 1990; Weylman et al., 1989).

The inferences promoted in these stories were coherence inferences, the type of inferences most reliably drawn by normal comprehenders (e.g., Singer & Ferreira, 1983; Potts et al., 1988; McKoon & Ratcliff, 1986). Yet, RHD patients had difficulty answering questions about these inferences. Although the RHD patients had much more difficulty answer-

ing Inference questions than did the normal elderly subjects, they had no more difficulty answering the Explicit questions; therefore, attention and memory deficits cannot account for these data in a straightforward manner. RHD patients' difficulties have previously been attributed to a pragmatic comprehension strategy in which RHD patients generally believe the speaker (e.g., Joanette, Goulet, & Hannequin, 1990). If so, then the patients in the current study should have rejected both True and False Inference questions. Instead, they had difficulty with both True Inference questions and False Inference questions; therefore, different criterion for evaluating the truth of the True/False statements cannot account for these data.

Drawing coherence inferences comprises several steps. First, comprehenders must note that new information does not map directly onto—and may even contradict—their representation of the previous discourse. Then comprehenders may search their representation for information that would increase coherence. Failing to find direct coherence (such as noun repetition or synonymy), they may draw an inference and connect it to their representation of the discourse.

Why do RHD patients have difficulty drawing inferences? The RHD patients were not more sensitive to episode boundaries than the normal elderly subjects. Like the normal elderly subjects, RHD patients' performance on Inference questions was unaffected by episode boundaries. In addition, the RHD patients were unable to connect two elements of inferrable events, even when the connections could occur within episodes: They were unable to answer Inference questions even when the relevant inference could have been drawn within an episode.

The RHD patients often incorrectly accepted False Inference statements as true, suggesting that they tried to draw inferences, but often guessed wrong. However, it is unlikely that their difficulties were only in selecting the correct inference or connecting it with the discourse representation. If RHD subjects had these difficulties, but also had strong activation of the inferrable information, then their lexical decisions should have shown inference-related facilitation; they did not. Thus, the RHD patients apparently failed to activate the information from which inferences could be drawn.

To draw inferences, comprehenders may examine less salient semantic features of words in the discourse to detect semantic overlap between new and old information. For instance, the information that bathwater left running can overflow and that overflowed water requires mopping can lead to the inference that the bathtub overflowed. If one element of the discourse is changed—say, the mess was cleaned by sweeping—then the overlap of semantic features changes, and a different inference results.

The features composing the inferrable event may not be activated

strongly enough from individual elements of the discourse to be represented in memory. However, in adept comprehenders, the confluence of activation from several elements on the set of features composing the inferrable event may cause the event to be represented with the discourse. Therefore, the chance of an inference being represented may be proportional to the summed activation of semantic features that contribute to the inference.

The comprehension problem may be circumscribed, arising only when multiple interpretations are possible (Joanette et al., 1990) or when initial interpretations must be revised (Molloy et al., 1988). The current experiment was not designed to test these assumptions. However, the context preceding the inference-inducing sentences generally favored the intended inferences, so if incorrect inferences were initially drawn, then some semantic information was either missing or ignored when the inferences were drawn.

RH semantic processing may activate semantic features not activated by LH semantic processing. When comprehending single words, the LH selects a single interpretation of ambiguous words (Burgess & Simpson, 1988; see also Nakagawa, 1991); it might also maintain just a limited subset (or semantic field) of semantic features related to words in a story. The RH maintains multiple word meanings (Burgess & Simpson, 1988; Nakagawa, in press); it might also maintain a wider set of semantic features, given that RHD patients have difficulty noting some semantic relations (Chiarello & Church, 1986). According to this proposal, fine semantic coding in the LH results in focused semantic fields whereas coarse semantic coding in the RH results in diffuse semantic fields (Beeman, submitted for publication). For instance, when a comprehender encounters the words *bathwater* and *mopped*, the subsequently activated semantic fields vary across hemispheres, as illustrated in Fig. 11. Coarse semantic coding would be useful to detect semantic overlap: Widely distributed fields of semantic activation are more likely to intersect. For instance, the concept OVERFLOW is activated following coarse coding of *bathwater* and *mopped*, but not following fine coding of these words. Thus, the coarse coding of the RH is necessary to derive appropriate inferences, especially when the inferences hinge on overlap of seemingly less relevant semantic features of words.

If the right and left hemispheres process different aspects of discourse, then semantic information is probably eventually shared by both hemispheres. If interhemispheric processes occur during ongoing comprehension, then the responses to lexical decision test words should reflect processing from both hemispheres. Thus, although the information necessary to draw coherence inferences may be most active in the RH, the LH may capitalize on this information to actually generate the inference or connect it with the representation of the discourse. The LH's ability to

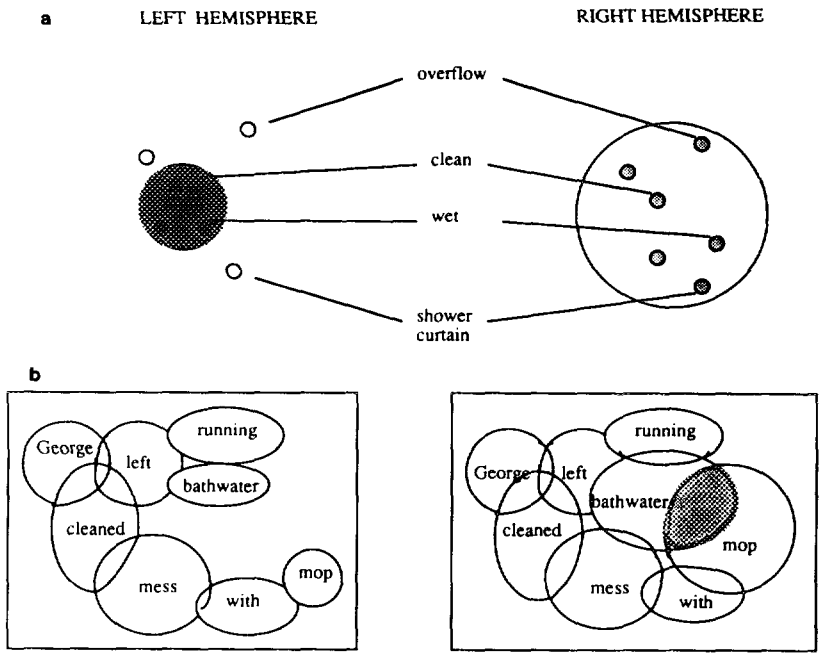

FIG. 11. (a) Representation of the semantic features activated following processing of the words *overflow* and *mop*, in the left hemisphere and in the right hemisphere (b) Representation of the semantic fields activated during processing of the sentences "George left the bathwater running" and "George cleaned up the mess with the mop," showing the area of overlap that could activate the inference OVERFLOW. (For clarity, only the words *overflow* and *mop* have broader semantic fields in the right hemisphere. In actuality, all words should have broader, weakly activated semantic fields in the right hemisphere).

strongly activate subsets of information would be more efficient in this process than would the RH's tendency to maintain multiple interpretations.

This interhemispheric processing proposal is consistent with Taylor's Bilateral Cooperative Model of Reading (1988). According to Taylor "the [RH] proposes, the [LH] disposes" (1988, p. 324). The multitude of interpretations available in the RH must be sorted through, and only the most likely interpretation (or inferrable event) selected by the LH for inclusion in the representation of the discourse. In this way, when the LH's discourse representation lacks coherence, it can adopt information from the RH to restore coherence.

The proposal of coarse and fine semantic coding in the RH and LH, respectively, is consistent with diffuse RH responses and focused LH responses to other types of input. For instance, tactile stimuli on the left side of the body elicit diffuse somatosensory ERPs over the RH; whereas tactile stimuli on the right side of the body elicit focused ERPs over the

LH (Trotman & Hammond, 1989). Further, RHD patients suffer more diffuse sensory–motor deficits suffered than do LHD patients (Semmes, 1968). RH coarse coding and LH fine coding of information have also been used to explain the RH's superiority in some visual judgement tasks, but not others (Kosslyn, Chabris, Marsolek, & Koenig, 1991). Finally, coarser coding of information seems consistent with the higher ratio of white to gray matter in the RH than in the LH (Gur, Packer, Hungerbuhler, Reivich, Obrist, Amarnek, & Sackheim, 1980), because coarse coding is associated with high interconnectedness (Malonek & Spitzer, 1989).

CONCLUSIONS

The RH is useful for drawing coherence inferences. RHD patients were worse at answering questions about inferred information than questions about explicitly stated information. The RHD patients were not affected by the episode boundaries any more than were the normal elderly subjects, indicating that the RHD patients' inferencing problems were not due to impaired structure building. They also showed no facilitation when responding to words related to the promoted inferences, suggesting that they lacked semantic activation of information needed to draw the inferences. The RH may be necessary for drawing coherence inferences because the RH coarsely codes the semantic information of discourse. Diffuse activation is well-suited for detecting relations between concepts: The diffuse semantic fields active in the RH are more likely to overlap than the focused semantic fields active in the LH.

Patients with damage in the RH have the straightforward meanings of words available to them. However, they do not have the full semantic information necessary to apprehend the distant relations between concepts (Kaplan et al. 1990; Weylman et al. 1989), to derive the gist meaning when it is not given to them up front (Hough, 1990), or to draw inferences to increase coherence (Brownell et al., 1986). As described by D.B., RHD patients are "missing the complex mosaic of meaning that is language."

APPENDIX A

Patient Descriptions

On the following pages are descriptions of patients, their relevant history, and their lesions. All patients had lesions verified by scans, and the information reported here about the lesions was taken from the Computed Tomography X-ray (CT) and/or Magnetic Resonance Imaging (MRI) scan reports, and consultation with a radiologist. For one RHD patient (C.M.), the scan was unavailable, and the lesion is described from the radiologist's report. For the remaining seven RHD patients, the images of the brains presented in Figs. 12 and 13 were traced from the scans themselves. This avoids interpretive problems of fitting different-shaped brains with different-angled slices into brain templates. The level and angle of the traced slices are indicated on the adjacent saggital view, also traced from the scans

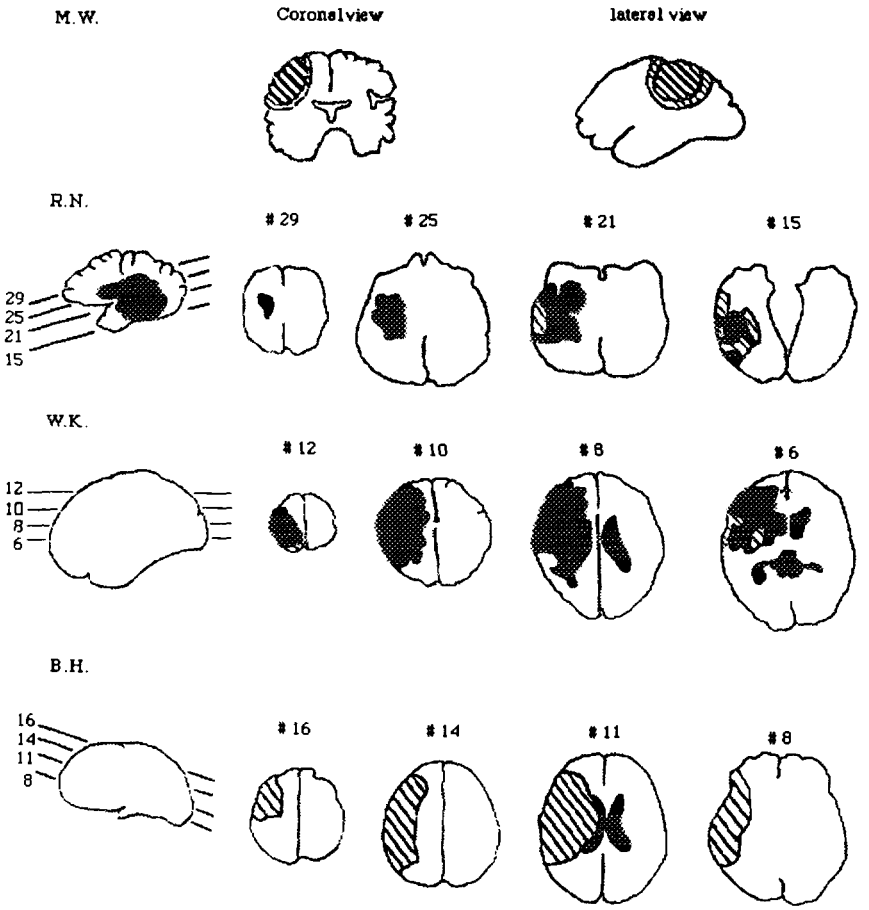

FIG. 12. Images of brain scans of M.W. (from angiograph, corroborated by MRI and CT scan reports), R.N. (from MRI scan), W.K. (from CT scan), and B.H. (from CT scan). For the latter three patients, the leftmost image shows the slices represented in the succeeding images.

themselves. When the areas of lesions were unclear (as when CT scans were done close to onset of the stroke), the damaged areas are striped in the pictures presented here. When the areas of damage are relatively clear, the areas are blackened. The ventricles are only included when identifiable on the scans and were near the area of damage.

M.W. Right hemisphere-damaged patient: Fifty-year-old female college graduate, formerly a school teacher and vice principal. Prior to her stroke, M.W. wrote with her left hand, but did "nearly everything else" with her right hand. There was no familial history of left-handedness. M.W. had a history of breast cancer before and after her stroke. Medical records concerning the initial incident and evaluation, 5 years before she participated, were not available. M.W. reported that she felt a strange sensation running down her back, and called a friend. She then collapsed; she remained semi-conscious, with slurred speech,

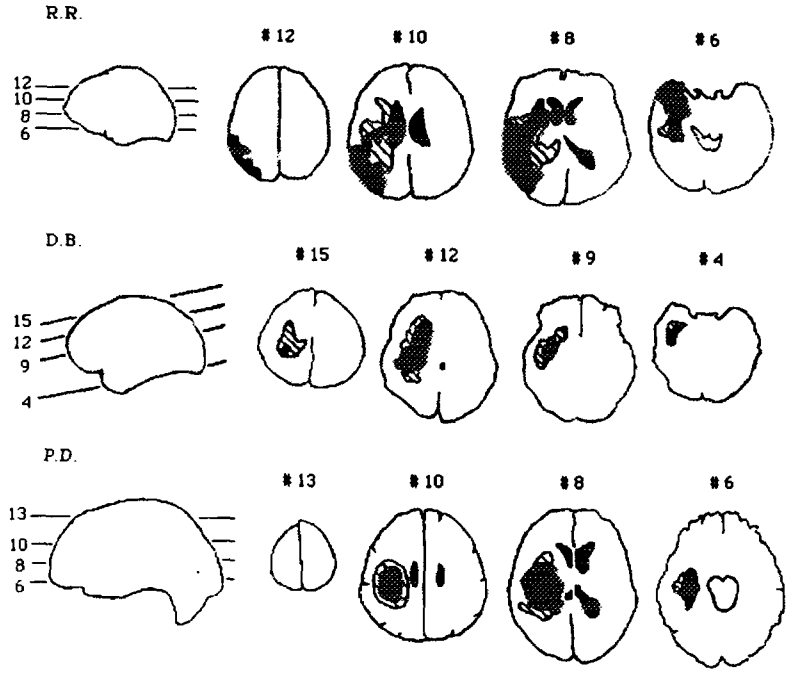

FIG. 13. Images of CT brain scans of R.R., D.B., and P.D. The leftmost image shows the slices represented in the succeeding images.

when her friend brought her to the emergency room. M.W. was diagnosed to have a right intracerebral hematoma, involving the right middle cerebral artery, and craniotomy was performed to evacuate the bleeding. An unenhanced CT study revealed "low density area with minimal mass effect" in the right frontotemporal area, and a "ring-like shadow which can occur during resolution phase of infarction," illustrated in Fig. 12 (drawn from angiographs). Later angiography, CT, and MRI scans revealed enlarged ventricles consistent with right-sided atrophy. At the time she was tested, M.W. was cooperative and friendly. She reported that her "long term memory [was] fine, but short term memory [was] not always so hot." She reports occasionally getting lost, but only in unfamiliar places. Otherwise, she feels she has no cognitive problems related to her stroke, and continues to improve.

R.N. Right hemisphere-damaged patient: Sixty-six-year-old married right-handed male graduated from a 2-year college, recently retired from a management position at a manufacturing company. Five months before he was tested, R.N. collapsed while golfing. Initial CT scan without contrast revealed no evidence of CVA, but 4 months later, follow-up MRI revealed a large lesion in the distribution of the right middle cerebral artery as illustrated in Fig. 12. Damage was primarily in the frontoparietal and temporal deep white matter, with some cortical involvement as well. Neuropsychological testing done 2 months postonset revealed scores in the low normal to abnormal range on all tests. At the time of testing, R.N. exhibited profound left hemifield neglect, confusion, extreme depression, and frustration. Because R.N. had taken some of the tests in the battery for this experiment 3 months earlier, he was not retested immediately, and declined to return for later retesting. R.N.

performed the experiment with great difficulty. He needed several breaks and had difficulty responding to the questions with the appropriate buttons. Halfway through, verbal responses to the questions were allowed.

W.K. Right hemisphere-damaged patient: Seventy-two-year-old right-handed male who had been sales manager for 35 years prior to his stroke. Initial records were not available, but the follow up records and CT scans indicated that W.K. had a history of high cholesterol, high blood pressure, and bilateral carotid artery occlusion, and had subsequent bilateral carotid endarterectomies. Within 6 months of those procedures (15 years before he was tested), W.K. had a massive right-sided stroke. Eight years later, CT scan revealed an old infarct "involving the posterior aspect of the frontal lobe, and anterior aspect of parietal lobe and extending up to near the vertex," as illustrated in Fig. 12. The right temporal lobe was virtually spared. (The scan is taken at such an angle that the damage which appears in slice number six is actually in the frontal lobe; the damage appeared to be anterior and superior to the temporal lobe, according to a radiologist.) No neuropsychological testing was performed prior to his participation in the experiment. At the time he was tested, W.K. exhibited severe left hemifield neglect. He ran a large volunteer organization and had controlled his hypertension and cholesterol. He was cheerful and cooperative. He complained of only one cognitive change since his stroke: Whereas he used to read a lot, he now said he could not follow "multi-character novels." However, he reported he was able to read shorter stories, especially if only one character, or "one plot" was involved.

B.H. Right hemisphere-damaged patient: Fifty-five-year-old right-handed male high school graduate who had been general manager of a large company prior to his stroke. B.H. had a history of heavy smoking, medically controlled hypertension, and self-reported episodes of dizziness just prior to onset. Two and a half years before he was tested, B.H. collapsed, but did not lose consciousness. CT scan without contrast done at the time (no follow-up CT was performed) revealed "a large vague area of decreased attenuation involving much of the right hemisphere and the middle cerebral artery distribution," as illustrated in Fig. 12. No hemorrhaging or focal mass lesion was seen. Diagnosis was a large infarct in the early stages. Neuropsychological evaluation reported no abnormalities other than lethargy, but during the screening interview for this experiment, B.H. reported that he had been unable to return to work, as he reports confusion executing multiple-step directions. He is severely hemiparetic on the left side, and as a result lives in a retirement home. B.H. was tested in his home.

R.R. Right hemisphere-damaged patient: Sixty-three-year-old right-handed male, who had graduated from a 2-year business college and had been steadily employed for 20 years prior to onset. R.R. had a history of depression and bilateral carotid artery occlusion and subsequent endarterectomies. Ten months prior to testing, R.R. slumped in his chair. He noticed nothing unusual, but his wife noticed disuse of his left arm and dysarthric speech and brought him to the hospital. By that time, left hemiparesis had extended to his legs. The report of the CT scan performed 4 months after onset revealed a large infarct in the frontoparietal and temporal distribution of the right hemisphere, mostly in the cortex, with some involvement of the deep white matter as well, illustrated in Fig. 13. At the time of testing, R.R. was depressed and frustrated. He reported that his ability to reason, read, calculate, and remember were all intact. Previous neuropsychological evaluations (5 months prior to his participation) reported mild left-hemifield neglect and poor performance on spatial tasks, such as copying or recalling the Rey-Osterreith figure. He was reported to perform within the normal range on tests of verbal skills.

D.B. Right hemisphere-damaged patient: Fifty-year-old married right-handed male, a professional prior to his stroke. D.B. had a history of excellent health, except for mild hypertension, but he experienced rapid onset of left hemiparesis while running, 13 months prior to testing. His speech remained fluent but dysarthric throughout the incident. CT scan revealed large right-sided hemorrhage that extended from the ventricles laterally through the basal ganglia, and extended superiorly into white matter and some parietal cortex and inferiorly

and laterally into the deep white matter of the temporal lobe, illustrated in Fig. 13. Neuropsychological evaluation revealed high-average to superior performance on all verbal tasks (such as the verbal section of the WAIS-R) and low-average to impaired performance on visuospatial tasks. D.B. also exhibited mild left-hemifield neglect. At the time of testing, D.B. was pleasant and lucid. He had returned part time to his profession. He complained that he could not remember names of old friends or new acquaintances, although he could recognize their faces. He also reported that it was very effortful to follow conversations and that he missed "the subtleties, the complex mosaic of meaning that is language." He also complained that this impaired his job performance.

P.D. Right hemisphere-damaged patient: Eighty-year-old right-handed married male high school graduate who worked as a mail carrier. Three years prior to testing, P.D. returned from a bike ride and collapsed. He experienced severe hemispatial neglect and asked his wife "who's lying next to me?" as he pointed to his leg, according to self-report at the time of the incident. CT scan revealed a right sided intracerebral hematoma in the temporoparietal area, as illustrated in Fig. 13. P.D. was tested in his apartment. Phone calls interrupted presentation of both stories on the Logical Memory subtest, so no scores could be obtained for these. The phone was disconnected for the remaining tests. During the pretest interview, P.D. reported that his memory had improved, particularly for jokes, and he offered a few examples. He also claimed that his mood had improved since his stroke.

C.M. Right hemisphere-damaged patient: Fifty-five-year-old right-handed male military officer, who had a history of smoking and hypertension when he suffered a heart attack at the age of 38. Three days later, he underwent triple bypass surgery, and during the procedure, he had a stroke due to embolism. This was confirmed by CT scan, although the scan was not available for this experiment. The CT scan report indicated an intracerebral hematoma in the territory of the right middle cerebral artery. As a result of his stroke, C.M. was nearly comatose for 3 weeks, and he remains left paretic, particularly in his left arm. The military determined that he was unable to work, so C.M. retired and has been unemployed since. However, he has since attained two degrees from a 2-year college and has occasionally volunteered for several positions. He has been offered jobs, but declined them. At the time of testing (12 years postonset), C.M. was extremely cheerful and cooperative. He claims to be more extroverted since his stroke and to be generally optimistic except for occasional crying jags. He reported few cognitive problems, except that he felt his short-term memory was not good. He continued to read as much as ever, but reported that he was "a bit slow to pick up on things."

Other brain-damaged patients:

K.D. Left hemisphere-damaged patient: Fifty-two-year-old right-handed married female high school graduate. K.D. was performing normal household duties prior to her stroke and has returned to those now. Ten months prior to testing, K.D. collapsed but did not lose consciousness. She was completely unable to speak or move her right limbs. CT scan revealed massive hemorrhagic stroke in the area of the left middle cerebral artery. K.D. has recovered some use of her right limbs and some ability to speak. Her speech pathologist classified her as a dysfluent aphasic patient.

E.A. Left hemisphere-damaged patient: Sixty-three-year-old college-educated woman. E.A. reported that she was "ambidextrous" until she broke her left arm at age 5, then began using her right hand nearly exclusively. Fifteen years before she was tested, E.A. suffered a stroke that produced right-sided sensory deficits and language impairments. A CT scan performed 7 years after her stroke revealed a large lesion in the area of the left temporal and parietal lobes that extended posteriorly almost to occipital lobe and superiorly into the superior parietal lobule. E.A. has been extensively tested in the Cognitive Neuropsychology Lab at Good Samaritan Hospital. These studies concluded that E.A. has conduction aphasia that disrupts phonological processing (e.g., Friedrich, Glenn, & Marin,

1984). These problems remain today, and E.A. cannot reliably reproduce strings of three digits. In contrast, E.A. recalls stories normally.

W.S. Amnesic patient: Thirty-five-year-old male former industrial engineer. Two years prior to testing, D.W. experienced seizures, loss of vision, and general muscle weakness. He was diagnosed with encephalomyelitis, probably of viral origin. Extensive neuropsychological testing revealed generally average to above-average cognitive performance, with selective impairments of recall and recognition.

S.C. Amnesic patient: Thirty-four-year-old college-educated professional woman. S.C. apparently suffered an hypoxic brain injury subsequent to a skydiving accident. Initially she showed no symptoms, but she later deteriorated into a coma and upon recovery was left with selective amnesic symptoms. Her WAIS-R IQ score was 99, considered average performance. In contrast, her WMS-R subtest scores were within the moderately to severely impaired range (except her scores on the attention/concentration subtests).

S.H. RH frontal lobe-damaged patient: Thirty-nine-year-old college-educated professional man. Nineteen years prior to testing, S.H. received closed-head injury in an automobile accident. Upon recovery, he continued his education and career; however, he has received poor job evaluations due to poorly sustained concentration and inappropriate behavior. Neuropsychological testing revealed low average to average performance on a variety of tests and mildly impaired performance on the Wisconsin Card Sorting test. S.H. has some difficulty with long-term visual memory and does not retain names well. He displays inappropriate emotion and behavior, including physical contact with female coworkers.

APPENDIX B

Individuals' Scores on Standard Tests and Experimental Measures

					Info		D.Sp.		B.D.		LM I		LM II		CFL												
Subject	Group	Education	Age	Sex	raw	AA	raw	AA	raw	AA	raw	per	raw	per	raw	per	An.s	BNam	# infs	ICRT	UCRT	INRT	UNRT	ITper	IFper	ETper	EFper
SH	EC	20	65	m	23	14	16	12	28	12	26	72	21	70	39	69	26	58	3	910	941	854	981	69	50	86	71
NM	EC	12	67	f	11	7	16	11	28	12	21	60	17	48	47	82	13	53	4	910	808	973	1114	94	81	93	76
VL	EC	15	63	f	19	12	13	14	28	12	32	90	27	87	33	58	22	56	3	682	727	592	667	69	88	73	88
BJ	EC	14	73	m	20	13	16	12	22	12	20	78	24	74	64	98	23	57	6	730	856	805	802	75	75	93	82
JB	EC	12	78	f	17	10	19	14	35	16	35	98	31	98	49	87	20	58	2	767	752	697	713	88	88	93	94
DK	EC	16	59	f	22	12	19	13	40	15	28	80	29	95	49	87	18	55	3	1057	1279	1020	1032	91	78	93	100
EM	EC	12	77	f	21	12	17	13	24	12	17	62	20	52	46	80	20	55	1	1207	1329	1358	1252	75	88	80	76
JM	EC	12	79	f	18	10	13	10	20	11	32	98	28	86	56	96	12	52	3	1340	1627	1306	1203	69	63	47	65
Mean		14.1	70.1		19	11	16.1	12.4	28.1	12.8	26.4	79.8	24.6	76.3	47.88	82.13	19.25	55.5	3.125	950.38	1039.9	950.625	970.5	78.75	76.375	82.25	81.5
SD		2.85	7.62		3.8	2.2	2.3	1.41	6.64	1.75	6.52	14.8	4.93	18.8	9.508	13.37	4.803	2.204	1.458	234.98	330.28	272.826	221.87	10.57	13.658	16.08	11.86
MW	RHD	16	50	f	19	10	14	10	16	7	21	34	10	14	33	34	19	57	2	2326	2265	2685	1801	56	56	80	76
RN	RHD	15	66	m	11	7	8	6	·	·	15	19	9	16	·	·	·	·	0	1902	1862	1921	1722	44	44	67	65
WK	RHD	16	72	m	21	12	12	9	0	3	29	87	23	82	28	17	20	54	2	1738	1600	1467	1687	76	37	87	45
BH	RHD	12	54	m	19	10	18	12	12	6	25	57	18	42	34	34	14	53	4	814	775	773	651	75	88	80	94
RR	RHD	14	63	m	19	10	15	11	2	4	18	27	16	37	33	35	9	53	2	1510	1940	2248	1537	56	62	60	82
DB	RHD	17	50	m	28	16	18	12	20	8	31	83	26	78	38	57	20	59	4	781	846	810	770	69	88	100	100
PD	RHD	12	80	m	20	12	6	4	8	7	·	·	·	·	29	50	13	52	3	1439	1312	1380	1442	62	75	87	76
CM	RHD	14	51	m	26	14	19	13	20	8	25	57	21	62	33	35	19	60	3	813	796	1123	816	63	81	80	94
Mean		14.5	60.8		20	11	13.8	9.63	11.1	6.14	23.4	52	17.6	47.3	32.57	37.43	16.29	55.43	2.5	1415.4	1424.5	1550.88	1303.3	62.63	66.375	80.13	79
SD		1.85	11.3		5.1	2.8	4.8	3.16	8.15	1.95	5.77	26.7	6.4	27.6	3.309	12.87	4.309	3.207	1.309	574.03	580.46	684.785	476.81	10.74	19.69	12.35	18.01

Note. Info, Information subtest of Wechsler Adult Intelligence Scale-Revised (WAIS-R) (raw and age-adjusted scores); D Sp, Digit Span subtest of WAIS-R (raw and age-adjusted scores); BD, Block Design subtest of WAIS-R (raw and age-adjusted scores); LM I raw, Logical Memory I subtest of Wechsler Memory Scale-Revised (raw score and age-based percentile); LM II, Logical Memory II subtest of Wechsler Memory Scale-Revised (raw score and age-based percentile); CFL raw, Number of words beginning with C, F, or L, produced in 60 sec (for each letter); CFL per, Age and education-adjusted percentile scores for CFL; An.s, Number of animals produced in 60 sec; BNam, Boston Naming test number of pictures correctly named, out of 60; # infs, Number of inferrable events included in four story recalls, out of eight; ICRT, Decision times for test words related to inferrable events, when the inferences could be drawn within episodes; UCRT, Decision times for test words unrelated to stories; within episodes; INRT, Decision times for test words related to inferrable events, when the inferences had to be drawn across episode boundaries; UNRT, Decision times for test words unrelated to stories; across episode boundaries; ITper, Percentage of True Inference questions correctly answered; IFper, Percentage of False Inference questions correctly answered; ETper, Percentage of True Explicit questions correctly answered; EFper, Percentage of False Inference questions correctly answered.

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