

Preserved Visual Lexicosemantics in Global Aphasia: A Right-Hemisphere Contribution?

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Extensive testing of a patient, GP, who encountered large-scale destruction of left-hemisphere (LH) language regions was undertaken in order to address several issues concerning the ability of nonperisylvian areas to extract meaning from printed words. Testing revealed recognition of superordinate boundaries of animals, tools, vegetables, fruit, clothes, and furniture. GP was able to distinguish proper names from other nouns and from nonwords. GP was also able to differentiate words representing living things from those denoting nonliving things. The extent of LH infarct resulting in a global impairment to phonological and syntactic processing suggests LH specificity for these functions but considerable right-hemisphere (RH) participation in visual lexicosemantic processing. The relative preservation of visual lexicosemantic abilities despite severe impairment to all aspects of phonological coding demonstrates the importance of the direct route to the meaning of single printed words. © 2000 Academic Press

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INTRODUCTION

The perisylvian region of the left hemisphere (LH) is involved in the majority of language processes in right-handed people (Broca, 1863; Wernicke, 1874) and in most left-handers (Milner, Branch, & Rasumussen, 1964). What is less well known is the extent to which various linguistic processes can be performed by regions located outside the classic language cortex. One of the processes cited consistently in discussions about potential nonperisylvian—and particularly right hemisphere (RH)—contributions to language is visual lexicosemantic processing, or accessing the meaning of single printed words (Bradshaw & Nettleton, 1983; Chiarello, 1988; Coltheart, 1980a; Millar & Whitaker, 1983; Zaidel, 1985). Limited evidence for RH lexicosemantic pro-

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cessing has come from research conducted with hemispherectomy patients (Patterson, Vargha-Khadem, & Polkey, 1989; Zaidel, 1982), split-brain patients (Bogen, 1985; Zaidel, 1983), and patients with large LH lesions (Cossu, da Prati, & Marshall, 1995; Cummings, Benson, Walsh, & Levine, 1979). In general, such research suggests that the RH can process the meaning of frequent imageable words presented visually.

Several issues concerning the RH's role in visual lexicosemantics remain to be addressed: Can the RH distinguish words on the basis of *superordinate category*? Can the nondominant hemisphere distinguish *proper names* from other nouns? Can the RH distinguish words representing *living things* from those denoting *nonliving things*? How *precise* is visual lexicosemantic processing in the RH?

In this article we describe the case of a patient, GP, who demonstrated a global aphasia following intracerebral hemorrhage encountered during adulthood. Language testing revealed greater than usual ability to match pictures and drawings with their written-word correspondences for this type of patient. Further testing demonstrated a strikingly preserved capacity to draw semantic inferences about pictured objects. GP's relatively preserved lexical access combined with his intact semantic processing of pictorial material raised questions about the extent of his visual lexicosemantic processing.

In a series of experiments, we explored GP's ability to distinguish printed words along several well-known lexical category dimensions and investigated the degree of precision in his visual lexicosemantic processing. GP's lexical and sublexical processing skills were also examined. At a minimum, data from GP is likely to reflect inherent abilities and limitations of regions located outside the classic language cortex in the processing of words from the visual modality. GP's case may also have implications for visual lexicosemantic processing in the normal RH for several reasons. First, in-depth language testing revealed a pattern of processing remarkably consistent with what is known about RH language processing. Second, due to the late onset of his CVA, and the absence of any prior brain damage, GP is likely to have undergone normal language lateralization (Zaidel, 1985). Finally, minimal cerebral reorganization is expected because brain plasticity is thought to decrease with age (Lennenberg, 1967; Zaidel, 1985).

CASE REPORT

GP is a 52-year-old native English-speaking right-handed man with no familial history of left-handedness. He has 15 years of formal education, including a B.Sc., with a major in physics. In October of 1992, at the age of 45, GP suffered a cerebral hemorrhage of unknown etiology. Subsequent neuroimaging revealed the destruction of a considerable portion of cortical and subcortical regions of the LH.

Following his hemorrhage, GP demonstrated a global aphasia and mild

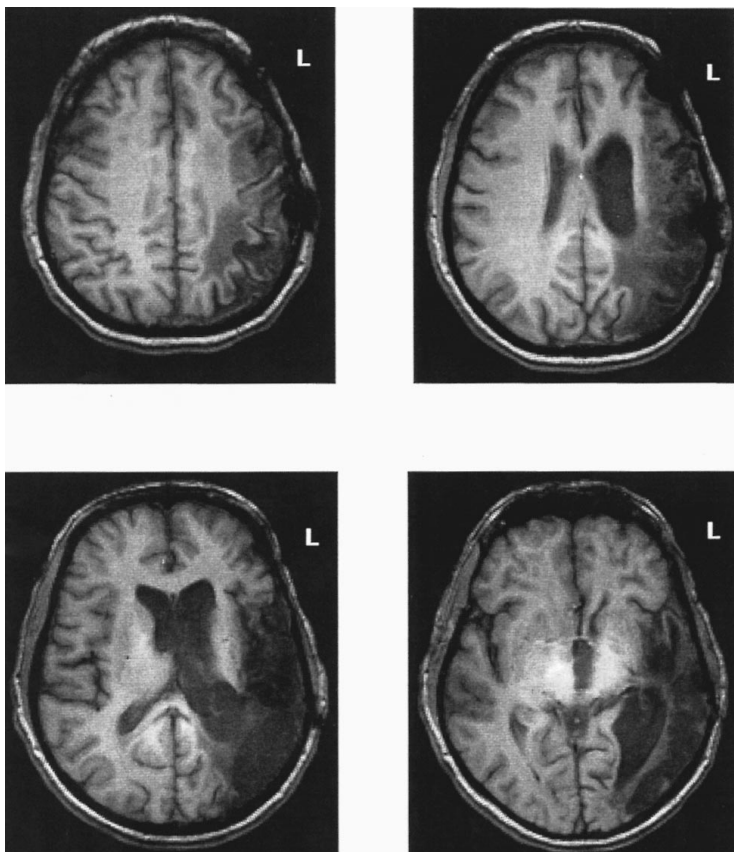


FIG. 1. MRI scan demonstrating the destruction of the temporal lobe, and damage to the parietal and occipital lobes, of the LH (see text for details).

right hemiparesis. He received individual speech and language therapy for approximately 2 months. When he was first discharged from the hospital, GP lived with his brother and sister-in-law. He has since moved into an apartment of his own, in a supervised facility for the disabled. GP is able to take public transportation, shop for groceries, and to cook simple meals. He has recovered from the mild right hemiparesis and remains right-hand dominant. GP continues to be globally aphasic with poor auditory-verbal comprehension and speech output limited to expletives and stereotypic utterances as well as to a few meaningful phrases and clichés.

A recent MRI scan revealed a massive LH infarct (Fig. 1). Lesion localization was performed with reference to an anatomical atlas of computerized brain images (Damasio, 1995). GP's infarct encompasses almost the entire left temporo-parietal region, posterior frontal and lateral occipital areas. Damaged LH regions are the inferior frontal gyrus (BA 44), precentral gyrus

TABLE 1
GP's Scores on WAB across Two Administrations

	April 1996	March 1999
Information content	0	1
Fluency	1	1
Auditory-verbal comprehension	1.9	1.5
Repetition	1	1.6
Naming	0	0
Reading	1.9	3.4
Writing	2.2	3.6
Aphasia Quotient	7.8	10.2

Note. Subscores are out of 10; Aphasia Quotient is out of 100.

(BA 4 and 6), postcentral gyrus (BA 1–3), supramarginal gyrus (BA 40), angular gyrus (BA 39), superior temporal gyrus (BA 42), middle temporal gyrus (BA 22), the superior portion of the inferior temporal gyrus (BA 21), and lateral portions of the superior occipital gyrus/cuneus (BA 19). Damaged LH deep structures are the temporal isthmus, insula, putamen, caudate, external capsule, internal capsule, and subcortical white matter. The *ex vacuo* enlargement of the left lateral ventricle is also evident. Intact areas of the LH are the majority of the prefrontal cortex and medial portions of the occipital lobe, including the cuneus, lingual gyrus, and fusiform gyrus. Remaining LH brain structures, and the entire right hemisphere (RH), are within normal limits for age without significant sulcal widening.

APHASIA ASSESSMENT

GP was assessed in our department in May of 1996 and again in March of 1999. On both occasions, the Western Aphasia Battery (WAB) (Kertesz, 1982) was administered in order to assess the extent of his language impairment. Table 1 provides a summary of GP's scores on subscales of the WAB over repeated assessments. All subscales are of 10. As can be seen in Table 1, GP's scores improved very little from May of 1996 to March of 1999. In 1996, GP's aphasia quotient (AQ), an index of the overall severity of language disturbance (maximum = 100), was 7.8; in 1999 his AQ was 10.2. However, selective improvement was observed in the comprehension of written words on the reading section of the WAB (which does not factor into the AQ).

Upon reassessment in 1999, GP continued to demonstrate nonfluent spontaneous speech restricted to stereotypic utterances. GP's recurring utterances included "particles" ("maybe") as well as out-of-context, frequently used, and well-articulated stereotypic phrases ("I want to make ice cream"). He described a drawing by pointing to its various characters, saying "boom"

(signaling the beginning of a response), and then pantomiming actions intended to approximate the activities of characters. GP's auditory-verbal comprehension was extremely impaired for yes/no questions, word recognition, and sequential commands. On the other hand, he seemed to comprehend actions, gestures, attitudes, and emotions. He was far more responsive and communicative through nonverbal channels than most global aphasics.

GP's repetition also remained severely impaired. He was able to pronounce correctly only three of the six single words presented to him and was unable to repeat accurately any of eight spoken phrases. On repetition, GP's responses were difficult to distinguish, and those that were distinguishable were marked by literal paraphasias (e.g., "steadall" for "snowball"). GP's was severely anomic. He was unable to name any of 20 common objects, although he was able to demonstrate function. Nevertheless, GP's inability to name objects on confrontation was not mitigated by either tactile or phonemic cues. GP could not generate words in a semantic category of animals, scoring 0 (normal score 20).

GP's reading and writing skills were slightly better preserved than his auditory comprehension and verbal output, but severely impaired nonetheless. GP failed to match spoken words (2/4) or spoken letters (0/6) with written correspondences. He failed also to spell words verbally from oral presentation (0/6) and was unable to write on dictation. Conversely, he was able to write letters of the alphabet sequentially (24/26) and to match both pictures (6/6) and drawings (6/6) with their written-word correspondences, suggesting some improvement in orthographic components of single-word processing. GP was unable to comprehend written commands (0/20). Similarly, his performance on the multiple-choice reading-comprehension task (14/40) was only slightly above chance (10).

NONVERBAL COGNITION

GP's nonverbal intelligence remained intact. He was able to draw simple objects from memory (25/30), perform basic math (24/24), and to solve each of the four spatial block designs presented to him (9/9) on the WAB subtests. GP excelled on the Raven's Coloured Progressive Matrices, scoring 34/36, ranking at the 95th percentile.

The picture condition of The Pyramids and Palm Trees Test (Howard & Orchard-Lisle, 1984; Howard & Patterson, 1992) was administered to assess GP's ability to draw semantic inferences about pictorial material. The Pyramids and Palm Trees Test requires the matching of drawings to a semantically associated probe that is presented alongside a semantic foil. In a picture condition, a target picture is presented (e.g., pyramid) above two probe pictures (e.g., a palm tree and a pine tree). The subject must indicate which of the two probe pictures is more closely associated with the target picture. GP's score on this task (49/52; 94%) was above the cutoff for norms established on brain-injury patients (>90%; Howard & Patterson, 1992).

ORTHOGRAPHIC AND PHONOLOGICAL COMPONENT SKILLS

Aphasia assessment demonstrated extreme impairment of phonological skills with a relative retention of orthographic coding abilities. A series of more specific tests were administered to assess in greater detail GP's residual letter- and word-processing abilities. Tasks used included four measures developed by Rumsey, Horowitz, Donohue, Nace, Maisog, and Andreason (1997) in order to segregate orthographic and phonological components of single-word pronunciation and identification.

Letter Identification

Method. Individual lowercase (26) and uppercase (26) letters were printed onto 3-cm white cards. The total group of 52 cards were then placed before GP, who was asked to match letters that were "the same" to assess knowledge of the orthographic forms of letters. GP was then instructed to match single lowercase letters with their corresponding sounds, spoken by the experimenter, to assess his awareness of letter-to-sound correspondences.

Results. GP's matching of lowercase letters with uppercase letters was perfect (26/26). His ability to match letters with their corresponding sounds (2/26) was significantly worse, $t(25) = 11.73$, $p < .0001$. The only letters that GP was able to identify accurately from auditory-verbal input were "a" and "e."

Single-Word Pronunciation

Although language screening had already demonstrated extreme impairment of verbal output, it remained possible that GP retained selective ability to pronounce irregular words and/or pseudowords. Two tasks were administered to test this possibility.

Method. The Orthographical Pronunciation Task (Rumsey et al., 1997) consists of words with irregular spellings or inconsistent pronunciations (e.g., hymn and corps). Correct pronunciation of words on the orthographic task is thought to draw heavily upon stored lexical information because irregular words violate the phonetic rules of English. The Phonological Pronunciation Task (Rumsey et al., 1997) consists of pseudowords, constructed not to resemble real words (e.g., huce and taulst). Accurate pronunciation of pseudowords is thought to require subvocal phonological processes because items are novel and thus cannot draw upon stored lexical information. GP completed 60 items from each of the two tasks. His responses were recorded on audiotape and scored independently by two experimenters as either correct or incorrect.

Results. GP produced correct pronunciations for only 7 of the 60 irregular words (11.7%) from The Orthographical Pronunciation Task and only 2 of the 60 pseudowords (3.3%) from The Phonological Pronunciation Task. A paired t test indicated that these differences were not significant ($p > .05$).

Single-Word Identification

Failure to find differences in GP's pronunciation of irregular words and pseudowords was likely due, in part, to the severity of his motor speech

programming impairment. It remained possible, however, that a relative dissociation of orthographic and phonological components of language processing existed at the subvocal level of processing. To examine this possibility, we administered two tasks designed to tap orthographic and phonological components of single-word identification.

Method. The Orthographical Decision-Making Task (Rumsey et al., 1997) consists of words paired with their pseudohomophones, matched for initial consonant and length (e.g., hole/hoal and coin/coyn). GP was asked to circle the "real word." Lexical decisions on this task are likely based on orthographic coding because items have identical pronunciations. The Phonological Decision-Making Task (Rumsey et al., 1997) consists of pseudohomophones paired with pseudowords, closely matched for initial consonant and length (e.g., baik/bape and moast/moost). GP was asked to circle the item that "sounds like a word." Decisions on The Phonological Decision-Making Task are likely based on a process of "sounding out" letter strings because items are novel. GP completed 90 items from each task.

Results. GP performed significantly better on The Orthographic Decision Making Task (88.6%) than on The Phonological Decision Making Task (53%), $t(87) = 5.88, p < .001$, demonstrating that his impaired phonological processing is evident even when overt speech is not required.

Discussion. GP performed well on two of three orthographic tests and poorly on each of the phonological tasks. Taken together, the results indicate that GP's grapheme-phoneme conversion (GPC) skills are extremely impaired and that he retains considerable ability to process letters and words through visually based orthographic coding.

VISUAL LEXICOSEMANTIC PROCESSING

GP's lexicosemantic abilities were assessed with tasks designed to probe some of the word class distinctions that have emerged from the semantic processing literature. Selective impairment/preservation of word classes that have been reported include (1) superordinate category boundaries (e.g., Shallice, 1987), (2) living versus nonliving things (e.g., Farah, Hammond, Mehta, & Ratcliff, 1989), (3) proper names versus other nouns (e.g., McKenna & Warrington, 1978), (4) nouns versus verbs (e.g., McCarthy & Warrington, 1985), and (5) fine-grained semantic distinctions between word category members (Patterson et al., 1989). Because we were interested in gaining an estimate of GP's lexicosemantic abilities independent from his impaired auditory comprehension, instructions for all tests were provided until such time that the experimenter was satisfied that GP comprehended the nature of each exercise. Instructions were presented using a combination of verbal, written, and gestural modalities.

Semantic Categorization

Method

GP's ability to categorize words according to semantic class was assessed with three sorting tasks, one forced-choice task, and one word-to-picture matching task to acquire an assessment of his lexicosemantic processing skills independent from his impaired naming.

Tasks. The first two sorting tasks used 60 single words corresponding to line drawings compiled by Snodgrass and Vanderwart (1980). The 60 words represented categories of animals, tools, vegetables, fruit, clothes, and furniture, with a total of 10 items per category. The third and fourth tasks examined GP's ability to distinguish proper names (typed in lowercase) from common nouns and from nonwords, respectively. In these two tasks, items ranged from four to seven letters. Proper names were evenly represented across gender in each task, with an equal number of male and female names used. The third task, a name-noun sorting test, used 40 proper names (e.g., chris, tony, and walter) that were matched for first letter and total length with 40 high-frequency, high-imageable, regular words from the Alexia Battery (Bub, Black, Howell, & Kertesz, 1987) (e.g., chair, tree, and winter). None of the proper names were real words (i.e., pat and sunny). In a fourth task, a name-nonword decision test, 20 nonwords (e.g., kanen, brint, and roneld) were created by modifying one letter of each of 20 new proper names (e.g., karen, brent, and ronald). Names were paired with nonwords and printed on a single page. Names were presented to the left side of nonwords in half of the paired items.

A final task, the Word Comprehension subscale from the Apraxia Test (Kertesz & Ferro, 1984), was administered to examine GP's knowledge about nouns and verbs. The Word Comprehension subscale is a measure of the ability to identify drawings corresponding to nouns and those corresponding to verbs. The subscale is presented in a multiple-choice format in which single words are paired with four drawings (response options). For example, in one item, the word "razor" must be paired with a drawing, with choices (1) a razor, (2) a hammer, (3) shaving cream, and (4) an eraser. Half of the words on the Word Comprehension subscale (25) are nouns (e.g., razor, eraser, hammer, and balloon) and half are verbs associated with those nouns (e.g., shaving, erasing, hammering, and blowing).

Procedure. For each of the sorting tasks, single words were typed in lowercase on 6-cm white cards. In the first sorting task, GP was instructed to arrange the 60 cards into "piles that go together" to assess his knowledge about superordinate boundaries and class membership. Cards were then rearranged randomly in the deck. The entire set of cards was then placed in front of GP once again. In a second sorting task, GP was asked to arrange cards into piles of "things that are alive" and "things that are not alive." In the name-noun sorting task, GP was asked to place cards into piles representing "peoples' names" and "other words." In scoring the sorting tasks, 1 point was given for each word placed into its proper category. The placement of a word into an incorrect category did not result in the deduction of a point. On the name-nonword decision task, GP was asked to circle "peoples' names." On the Word Comprehension subscale, GP was instructed to point to the drawing that best describes each word.

Results

GP's responses on the category membership sorting task are given in Table 2. GP successfully sorted words into categories of animals, 9/10; tools, 10/10; vegetables, 10/10; fruit, 9/10; clothes, 10/10; and furniture, 9/10. GP sorted the same target words into categories of "living" versus "nonliving" things with 100% accuracy. GP's score on the name-noun sorting task was 37/40. His errors came on the item student/shirley. GP's score on the name-nonword decision task was 17/20. Errors were committed on the items carol/catol; carolyn/caralyn; phillip/phillap (GP's responses are italicized). Finally, when asked to point to drawings corresponding to words, GP identified correctly 18/25 (72%) of the nouns, but only 9/25 (36%) of the verbs. A

TABLE 2
GP's Responses on Word Sorting Tasks

Categories	Correct items	%	Incorrect items
Animals	Dog, elephant, cow, bear, cat, rabbit, kangaroo, zebra, monkey	90	
Tools	File, pliers, nail, ruler, saw, scissors, hammer, axe, screwdriver, saw	100	Stool
Furniture	Lamp, sofa, chair, desk, stove, table, dresser, crib, bed	90	Camel
Clothes	Dress, tie, sock, shirt, coat, hat, blouse, pants, shoe, skirt	100	
Vegetables	Mushroom, pepper, cabbage, onion, tomato, carrot, lettuce, corn, celery, potato	100	Watermelon
Fruit	Orange, lemon, grapes, strawberry, banana, apple, pineapple, cherry, pear	90	

paired *t* test indicated that this difference was significant, $t(24) = 3.17, p < .004$.

Semantic Discrimination

Method

Two tasks were used to assess GP's ability to make decisions requiring more precise lexico-semantic knowledge than the sorting tasks.

Tasks. The first task assessed GP's ability to identify real objects from printed lexical correspondences. Stimuli were 40 common, prototypical objects from the semantic aphasia battery (Kertesz, Davidson, & McCabe, 1998). Success on this task required more precise semantic information because it was not enough to know that the word "screwdriver," for example, represents "a tool." A correct response required the knowledge that the word "screwdriver" was a specific kind of tool, with a particular shape, and different from a "hammer," "can opener," or "paintbrush." The final task, the written-word version of The Pyramids and Palm Trees Test (Howard & Orchard-Lisle, 1984; Howard & Patterson, 1992), was administered to assess GP's ability to draw fine distinctions about semantically related words. The test consists of a target word and two probe words, and the subject is required to select the probe that shares a closer semantic association with the target word. Success on this task requires a precise understanding of each of the three words within an item because the two response options of each triad are themselves semantic associates (e.g., target "caterpillar"; response options "butterfly" and "dragonfly").

Procedure. For the object-word correspondence task, all 40 objects were arranged on a table in random order. White cards containing printed words of each of the 40 objects were then presented one at a time to GP, who was asked to point to the object corresponding to each word. On the Pyramids and Palm Trees Test, GP was asked to point to the word that was "more like the word on top."

Results

Table 3 presents GP's errors and his percentage of correct responses on the two semantic discrimination tasks. GP matched correctly 37 of the 40

TABLE 3
GP's Responses on Semantic Discrimination Tasks

	Errors	% correct
Word-Object matching	paper clip → safety pin elastic band → band aid safety pin → paper clip	93
Pyramids and Palm Trees	carrot → <i>lamb</i> donkey crook → <i>mice</i> sheep hands → <i>gloves</i> <i>slippers</i> cross → church <i>castle</i> tent → fire <i>radiator</i> stethoscope → <i>tongue</i> heart acorns → <i>donkey</i> pig	87

Note. For Pyramids and Palm Trees GP's (incorrect) responses are italicized.

objects from the semantic aphasia battery to corresponding printed words. GP score was quite high, but below what is expected of a non-brain-damaged control (100%). As can be seen in Table 3, his mistakes occurred on compound words. GP's score on The Pyramids and Palm Trees Test was also quite high, 45/52, but below the cutoff for norms on non-brain-damaged controls ($>47 = 90\%$; Howard & Patterson, 1992). As shown in Table 3, several of GP's mistakes on this task were made on items requiring literary abstractions rather than purely semantic knowledge, while others came on fairly simple items.

DISCUSSION

GP's case demonstrates that a considerable amount of visual lexicosemantic processing can be performed without the involvement of perisylvian language regions, including the angular gyrus, supramarginal gyrus, and the majority of the temporal lobe of the LH. The considerable overlap between GP's pattern of language functioning and an "RH profile" that has emerged from research with hemispherectomy and split-brain patients suggests RH contributions to GP's semantic processing. In general, such research indicates that the RH is limited in phonological skills (Burklund & Smith, 1977; Patterson et al., 1989; Zaidel & Peters, 1981) and syntactic abilities (Dennis, 1980; Gazzaniga & Hillyard, 1971), but capable of processing the meaning of frequent imageable words presented visually (Bogen, 1985; Zaidel, 1983, 1982). Another dimension upon which GP's pattern of functioning appears to overlap with an "RH profile" is the relative ability to process words orthographically. Based upon their extensive testing of two commissurotomy patients, Zaidel and Peters (1981) concluded that the RH reads "ideographically, recognizing words directly as visual gestalts without intermediate phonetic recoding or grapheme-to-phoneme translation" (p. 205). Split-field lexical decision studies with normal subjects also have demonstrated that the

RH is able to read words despite being insensitive to their phonological properties (Bradshaw & Gates, 1978; Cohen & Freeman, 1978). For example, Cohen and Freeman (1978) found a pseudohomophone effect (the slowing down of lexical decisions involving nonwords pronounced like words) when stimuli were presented selectively to the LH, but no effect when stimuli were presented selectively to the RH.

GP demonstrates preserved ability to distinguish proper names from frequent nouns matched for initial letter and length and from nonwords differing from names by a single letter. Elsewhere, Van Lancker and Klein (1990) have reported that a group of four global aphasic patients were able to match the written names of famous people with their photographs equally well as normal control subjects, despite extreme impairment in the ability of aphasics to recognize common nouns. However, unlike the names of celebrities, proper names that have not become synonymous with famous persons do not possess an automatic link with any one referent. For example, while the name "Charlie Chaplin" is overlearned and therefore linked automatically with a particular individual, the name "William" (particularly when the initial letter is presented in lowercase; "william") is not. The ability to distinguish names from other nouns, and from nonwords differing by a single letter (e.g., william/walliam), requires lexical knowledge about non-descriptive, purely referential words. Surprisingly little research has examined the ability to identify proper names from the visual presentation modality. By way of contrast, the ability to retrieve proper names corresponding to photographs has been examined extensively in aphasia, and selective impairment of this capacity has been linked with damage to the left temporal lobe (Harris & Kay, 1995; McKenna & Warrington, 1980; Papagno & Capitani, 1998; Semenza, 1997; Semenza & Zettin, 1989; Verstichel, Cohen, & Crochet, 1996). Data from GP indicate that, unlike the ability to recall proper names from memory, the ability to recognize proper names from the visual modality is not abolished as a result of large-scale damage to the temporal lobe of the LH. The possibility that the right hemisphere may play an important role in the recognition of personal names would fit with that hemisphere's role in processing stimuli that are of social and emotional relevance (Gardner, Brownell, Wapner, & Michelow, 1983).

GP displays knowledge about several other semantic categories of words. He can differentiate printed words representing living things from those representing nonliving things. A number of cases of impaired ability to draw distinctions between living versus nonliving things from pictorial and auditory presentation modalities have been reported (Farah et al., 1989; Farah, McMullen, & Meyer, 1991; Warrington & McCarthy, 1983; Warrington & Shallice, 1984). The individuals reported in these studies showed impaired knowledge about living entities without deficit of general visual processing, suggesting a deficit at the semantic level of analysis. Similar impairment to the living-nonliving semantic dimension has yet to be reported involving

printed words. The present finding that the ability to categorize words presented visually along living–nonliving lines is not impaired substantially as a result of large-scale damage to LH perisylvian regions opens the possibility of a significant RH contribution in the processing of this semantic dimension.

GP recognizes, generally, the superordinate boundaries delineating animals, tools, vegetables, fruit, clothes, and furniture even though he cannot name or provide definitions for these items. Knowledge about an item's superordinate category is typically the most resistant to decline in cases of semantic impairment among focally brain-damaged populations (Shallice, 1987; Warrington & McCarthy, 1983). When sorting by superordinate category, two of GP's three errors involved the misplacement of words into categories sharing a considerable degree of overlap with target categories ("watermelon" in the vegetables category and "stool" in the tools category). Thus, large-scale damage to the language cortex does not appear to impair significantly visual lexicosemantic knowledge about frequent words related by functional contiguity.

GP shows selective impairment of the ability to process verbs compared to nouns from the visual presentation modality. The loss of verb processing with a relative preservation of noun comprehension is a well-known feature of agrammatical aphasia (Goodglass, 1976; Miceli, Silveri, Nocentini, & Caramazza, 1988; Miceli, Silveri, Villa, & Caramazza, 1984). Several of GP's correct responses to noun items on the Word Comprehension task were incorrect on corresponding verb forms. For example, GP pointed to the correct picture in response to the words "comb" and "hammer," but failed to locate the drawings corresponding to the actions "combing" and "hammering." The testing of commissurotomy patients revealed a similar result: patients were unable to process verbs with the suffix "-ing" when delivered selectively to the RH (Zaidel, 1983). The finding that particular word forms can be selectively available for semantic but not syntactic processing supports the view that analyses of meaning of words representing objects and those representing thematic/action are subserved by distinct brain mechanisms (Caramazza & Hills, 1991; Hills & Caramazza, 1995). Evidence of such a dissociation comes also from cases reporting the opposite effect, the relative preservation of verb processing in spite of the loss of meaning of common nouns (Kertesz et al., 1998; Zingeser & Berndt, 1988). Of course, it would not be unreasonable to assume that a significantly poorer performance identifying verbs compared to nouns on word–picture matching tasks is the result of increased difficulty of the former procedure, as opposed to a genuine word class effect. Although it has been suggested that lower scores on word–picture matching tasks on verb—compared to noun—processing are attributable to increased difficulty involved in interpreting dynamic events from static pictures, this hypothesis was considered but ultimately rejected by Zingeser and Berndt (1990).

As to the issue of precision, GP's case suggests that the accuracy of lexico-

semantic decision making involving response options from the same semantic field may be dependent upon involvement of the LH language cortex. GP was able to match common objects with their lexical correspondences at a rate of 93%, demonstrating a fair degree of referential processing of objects from printed words, and his mistakes were committed on compound words rather than on single words (paper clip, elastic band, and safety pin). Nevertheless, these errors would not be expected from non-brain-damaged individuals. On The Pyramids and Palm Trees Test, GP selected the correct of two semantic associates at a rate of 87%. Although some of GP's mistakes were committed on items requiring literary abstractions rather than purely semantic knowledge (e.g., crook → *mice* sheep; acorns → *donkey* pig; GP's responses are italicized) his score was below the cutoff norms for non-brain-damaged control subjects.

Not surprisingly, results from GP suggest that the process of extracting meaning from sentences requires the involvement of LH perisylvian regions. The presence of a category-based impairment in the ability to process verbs observed in GP, and characteristic of the RH, undoubtedly plays a role in the inability to process sentences. Bock's (1987) model of sentence production holds that poor access to verbs disrupts the ability to organize words into coherent sentences, and the dependency of sentence production on verb knowledge has been demonstrated in the verbal response modality (Zingeser & Sloan, 1990). On the other hand, the presence of single-word morphosyntactic processing skills would not guarantee sentence processing. The ability to map thematic roles (agent and theme) onto grammatical categories (subject and object), and vice versa, may also be an essential component of sentence comprehension (Saffran, Schwartz, & Marin, 1980) and is also likely impaired in GP.

GP's case provides support for theories suggesting that orthographic processing represents the dominant route to the meaning of single words presented visually (Coltheart, 1980b; Fleming, 1993; Jared, McRae, & Seidenberg, 1990; Taft, 1991). Orthographic theories suggest that visual processes involving feature and pattern analysis enable the mapping of word forms directly into a "lexical dictionary." GP was able to derive the meanings of frequent words presented visually with a high degree of accuracy despite a total lack of grapheme-to-phoneme conversion skills. Thus, data from GP support the view that "prelexical" conversion, or phonological recoding, of orthographic information into corresponding sound-based representation is unnecessary to access semantic representations of frequent words.

GP's orthographic processing appears to be mediated primarily by his RH. Data from the clinicoanatomical literature and the results of a recent neuroimaging study suggest that the LH regions most strongly associated with orthographic processing are largely unavailable to GP due to the location and extent of his infarct. Based upon a review of the clinicoanatomical data, Henderson (1986) suggested that normal reading involved both superior and

ventral pathways connecting the visual association cortex to language regions and that these pathways were of differential import to phonological and orthographic component processes. The ventral route thought to be involved in orthographic processing consisted of a pathway connecting the visual association cortex to the inferotemporal cortex and outputs from the inferotemporal cortex to the temporoparietal cortex (including the superior temporal gyrus and angular gyrus) of the LH. Evidence in support of the importance of the ventral route in orthographic processing was that damage to this region was associated with pure alexia, a reading disorder in which the ability to process letters visually is impaired despite otherwise intact visual perception and intact writing and spoken language (Henderson, 1986). GP retains considerable orthographic abilities despite the fact that his infarct encompasses the inferotemporal and temporoparietal cortices of the LH.

The results of a recent neuroimaging study suggest that lateral regions of the occipital lobes are involved in the initial stages of letter-form processing (Pugh, Shaywitz, Shaywitz, Constable, Skudlarski, Fulbright et al., 1996). Pugh et al. compared activation patterns associated with letter processing to those resulting from judgments about line orientation. Peak activation resulting from this comparison was seen in lateral aspects of the middle and inferior occipital gyri, bilaterally. GP's infarct encompasses the middle and inferior occipital gyri of the LH. We thus expect that GP's ability to identify words through visual feature processing draws on lateral occipital regions of his RH with possible contributions from other RH regions. The notion of orthographic coding mediated by the RH is consistent with data from commissurotomy patients (Zaidel & Peters, 1981).

GP's semantic processing of lexical material from the visual modality appears also to be mediated by his RH. In a recent fMRI study, we recorded GP's brain activation patterns using functional magnetic resonance imaging (fMRI) while he engaged in semantic and orthographic tasks (Gold & Kertesz, 2000). In the semantic task, modeled on the Pyramids and Palm Trees Test, GP made decisions about word triads presented visually. A target word was positioned above two probe words, and GP was asked to decide (using button-presses) which of the probes shared a closer semantic association with the target. In an orthographic control task, GP made decisions about the spellings of the same words. The semantic-orthographic comparison activated primarily RH perisylvian and extrasylvian temporal regions, with activation of intact LH prefrontal and basal temporal regions becoming apparent only when significance levels were lowered.

We suspect that GP's RH also plays a dominant role in other visual lexico-semantic tasks and that he gains access, via direct orthographic coding, to a "lexical dictionary" within the RH. Research involving similar cases using fMRI should be able to specify further the nondominant hemisphere's involvement in visual lexicosemantic processing.

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