

## SELECTIVE IMPAIRMENT OF SEMANTIC MEMORY AFTER TEMPORAL LOBECTOMY\*

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**Abstract**—The impairment of semantic memory in patients with unilateral anterior temporal lobectomy was examined 1–21 yr after operation. Patients were asked to classify line drawings of objects or object names that appeared at a rate of one every 0.75 sec. Patients with left temporal removals were impaired at classifying objects as living or man-made, regardless of whether the objects were represented by drawings or by words. Classification of objects as larger or smaller than a chair was not impaired. The patients were also asked to name line drawings of objects presented at a similar rate, with or without a letter cue. Left temporal patients were impaired at naming uncued drawings. Patients with right temporal removals showed no deficits. The results were interpreted as suggesting that semantic memory is dissociable into verbal–amodal and non-verbal–pictorial components, the former being impaired following left temporal lobectomy.

It is well established that anterior temporal lobectomy impairs human memory for specific events and experiences. The effects of this operation on semantic memory, that system which deals with knowledge of facts or concepts rather than of events [1], have received little study. Such evidence as does exist suggests that nontransient deficits in semantic memory occur only rarely after anterior temporal lesions [2, 3]. The purpose of the present study was to re-examine the possibility that semantic, as well as experiential or episodic memory [1], is permanently impaired after anterior temporal lobectomy.

The selective impairments of verbal and non-verbal memory that have been demonstrated after left and right temporal lobe lesions, respectively [4], could be described as deficits in episodic memory. The question remains whether corresponding deficits in semantic memory can also be found.

In the experimental literature semantic memory has typically been investigated using elementary classification tasks and two such tasks were chosen for the present study. In the first, common objects were classified as larger or smaller than a chair. This classification was chosen because there is evidence that the classification of the size of an object is mediated by a non-verbal analogue system [5,6] the operation of which might depend more on right than left-hemisphere function. In the second task, objects were classified as living or man-made, a classification which cannot be performed on the basis of perceptual features alone and which can reasonably be thought of as involving verbal representation, possibly mediated more by

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the left than by the right hemisphere. Both "verbal" and "non-verbal" classifications were performed twice, once with the objects represented by line drawings, and once with object names as stimuli.

The stimuli were presented in rapid succession while the subject attempted to classify each object as it appeared. It was hoped that this pacing technique would reduce intersubject variability because, unlike the more widely used latency measure, it does not leave subjects free to place differential emphasis on speed or accuracy of responding.

Another reason for using the pacing technique concerned the second purpose of the study: an investigation of naming ability. This investigation was motivated by the fact that patients with left temporal lesions often have word-finding difficulty immediately after their operation. Although a year later any speech trouble they may have is usually too slight to be detected by conventional tests of dysphasia [2,3], permanent deficits may nevertheless remain. Since ROCHFORD and WILLIAMS [7] have shown that under conditions of paced stimulus presentation even neurologically intact subjects make naming errors, a paced naming test was chosen as being an appropriately sensitive measure of any residual difficulty. In the first of two tests, line drawings of objects were presented together with a cue consisting of the initial letter of the object's name. In the second test no such cue was provided. It was hoped that comparison of naming performance in the cued and uncued conditions would enable any naming deficit to be attributed to perceptual or response components.

There were thus two object-naming tests, and four classification tests. All tests were given with similar presentation speeds and similar response conditions so that each test served as a control for the others. Any deficit observed in some but not all of the tests can, therefore, be attributed to the subset of cognitive processes that underlie those tests.

As will be shown, a left anterior temporal-lobe removal leads to long-term impairments in naming and classifying objects as living or made, but has no effect on size-classification. This result provides partial support for the claim that there are at least two systems of semantic representation that can be neurologically and functionally dissociated.

## METHOD

### Subjects

The detail of the patient groups is summarized in Table 1. All preoperative epileptogenic lesions were atrophic, dating from birth or early life. Seven patients were not strongly right-handed but they nevertheless had speech represented in the left hemisphere, as determined preoperatively by speech testing after intracarotid injection of sodium amobarbital (sodium amyltal)[8]. The temporal lobe removals involved the partial or complete destruction of the following structures: Heschl's gyrus (13 cases), amygdala (20 cases) and hippocampus (18 cases). The Wechsler-Bellevue intelligence ratings were obtained at least 1 yr after operation and no more than 6 yr before the present tests were administered.

Table 1. Detail of patients groups\*

Group	Sex		Age	Yr post op.	Size of removal (cm)		Wechsler I.Q.		
	M	F			Superior margin	Inferior margin	Full scale	Verbal	Performance
Left temporal	8	5	30	5	4.8	5.7	113	109	116
			(21-56)	(1-21)	(4-6)	(4.5-6.5)	(86-130)	(77-138)	(99-125)
Right temporal	7	2	31	5	6.6	6.9	116	116	114
			(20-44)	(1-12)	(5-8)	(5.5-8)	(106-128)	(96-131)	(95-126)

\*Ranges are shown in parentheses.

Ten male and 7 female hospital employees or relatives of the patients were tested as control subjects. Their intelligence was not assessed but an attempt was made to match their age and educational level with those of the patients. Two patients in the left temporal group and 2 control subjects were French speaking.

#### *Procedure*

The subjects sat in front of the 23 × 15 cm screen of a video monitor at a distance of about 1 m. The 16 stimuli in each test (drawings or words) were pre-recorded on video tape and appeared at a rate of 1 every 0.75 sec. They were preceded by the numbers 1, 2, 3, which were presented in sequence at the same rate as the stimuli and served as a preparatory cue. The subject attempted to classify or name each stimulus as it appeared. He spoke his responses into a hand-held microphone and they were recorded using the audio-dub facility of the video recorder. All the line drawings except one (a drawing of a house) were taken from those used by CAROL and WHITE [9]. They were approximately balanced across tests for the frequency of occurrence of the object name as estimated by the Thorndike-Lorge frequency count, as well as for the age at which the name is acquired, as estimated by Carol and White. Only drawings that were named with a high degree of consensus by Carol and White's subjects were used. They were magnified to the point at which the largest of the drawings filled the screen. The object names appeared in lower-case typescript with letters 2.5 cm high, justified to the left along a horizontal mid-line of the screen.

Prior to the first test in the battery (the cued-naming test) the subject was shown, by way of example, a line drawing of an octopus with the letter 'O' beneath it, and he was asked to name the drawing. He was told that he would see a series of drawings of objects one after the other. It was explained to him that in the first test, but not in any of the others, a letter would appear beneath each drawing; it would serve as a hint because it was the first letter in the object's name. (French-speaking subjects were told to ignore the letter. They performed the test simply as practice.) Each subject was told that he was required to name the drawings as quickly as possible and if he could not name one to move on to the next. He was told that they appeared one after the other at a rate of 3/4 sec each and the experimenter demonstrated the rhythm. The tests were then presented in the following order.

(1) *Cued-naming.* The following drawings were shown: PIE, KNIFE, BALL, ANCHOR, SPOON, CUP, BASKET, NAIL, EAR, FLASHLIGHT, ROPE, FISH, PENGUIN, BLOUSE, WHALE and MOUSETRAP. Beneath each drawing was the first letter of the object name which appeared in upper case, 2.5 cm high on a vertical midline of the screen.

(2) *Living/man-made drawings.* The subject was instructed to say "living" if the drawing represented an object that was "living, or growing or part of a living thing", and "made" if the object was "manufactured or made by a person". To ensure that the subjects understood the concepts involved they were questioned before the test about the classification of an ashtray, an elephant, a television set, a pear and a shrub. The following drawings were used: CACTUS, LEAF, WINDOW, KANGAROO, TURTLE, CLOCK, AEROPLANE, TREE, BOOK, GLOVE, CIGARETTE, HORSE, SNAIL, TABLE, BUS and APPLE.

(3) *Uncued naming.* The following drawings appeared: IRON, DOG, FAN, ARROW, KEY, FORK, HAMMER, SNAKE, PIG, BALLOON, PIPE, KITE, DOORKNOB, FROG, SHOE and PUMPKIN, and the patient was simply required to name each object as it occurred.

(4) *Larger/smaller drawings.* The patient was shown the following drawings: LION, RABBIT, TENT, POLICEMAN, EYE, DRUM, WINDMILL, GIRAFFE, HORSESHOE, TYPEWRITER, CAKE, BEAR, PARROT, BICYCLE, HOUSE and CAT, and he was asked to say "larger" if the object was larger than a chair, and "smaller" if it was smaller than a chair. Two examples, an elephant and a match, were given before the test was run.

(5) *Living/man-made words.* The following object names were classified as "living" or "made" as before: CANOE, ZEBRA, ONION, SHACK, WILLOW, SCARF, DESK, MOUSE, ROBIN, BEAVER, COUCH, DEER, KETTLE, MULE, PENCIL and WALLET.

(6) *Larger/smaller words.* The following object names were classified as "larger" or "smaller": TRUCK, WOMAN, CROW, STOVE, CAMEL, PURSE, DOOR, DAISY, GRAPE, SKUNK, CABIN, BIRCH, CANDLE, TIGER, SHIRT and PLATE.

The words used in the fifth and sixth tests were balanced for Thorndike-Lorge frequency with the names of drawings used in the previous tests. A French version was used with the 4 French-speaking subjects. The order of the 6 tests, which was kept constant so as to reduce inter-subject variance, was chosen so that the effects of practice would interfere as little as possible with the comparison of conditions.

After the above tests had been performed, the patient was asked to read 2 sets of 16 words presented at a rate similar to that used previously. All subjects read at least 14 words correctly, apart from 1 patient with a left temporal lobectomy, and 2 patients with a right, who were excluded from the study. After the reading test, the patients were shown all the drawings again, including those used in the object naming tests, but this time at a very slow rate: 1 every 2.5 sec, or longer if the patients required it. They were asked to name or classify each drawing as before, so as to ensure that each patient could in fact perceive the object and classify or name it correctly given ample time. None of the patients made more than two mistakes in all of these unpaced tests.

### Scoring

The audio-dub facility of the video-recorder enabled subjects' responses to be correlated with the stimuli. A score of 1 was given for each correct response and half credit for every mistake that was corrected before the response to the next stimulus. On those rare occasions when the matching of a stimulus with its response was not obvious from the responses to neighbouring stimuli, the item was scored so as to increase the scores of the left temporal group on the living/man-made classification and increase the scores of the right temporal group on the size classification. Any bias introduced from the scoring cannot, therefore, account for the findings that will be described.

## RESULTS

### Classification

The mean scores for patients and normal control subjects on the classification of drawings and names appear in Table 2. As will now be shown, the left-temporal group was selectively impaired at classifying objects as living or man-made, regardless of whether the objects were represented by drawings or words; the right-temporal group showed no significant impairments.

Table 2. Mean classification scores\*

	"Living-made"		"Larger-smaller"	
	Drawings	Words	Drawings	Words
Left temporal	12.1	12.3	13.1	13.3
Right temporal	14.4	13.6	13.1	11.4
Normal control	14.5	14.4	12.9	12.5

\*Maximum score—16, Average chance score—8.

A 3-way analysis of variance, with subject group (left temporal, right temporal, and control), classification type (living/man-made, larger/smaller) and stimuli (drawings, words) as factors, yielded a significant effect of classification type,  $F(1,36)=5.38$ ,  $P<0.05$ , and a significant interaction between classification type and subject group,  $F(2,36)=5.74$ ,  $P<0.01$ . None of the other main effects or interactions approached significance. A Newman-Keuls test of scores on the living/man-made classification (collapsed across the two levels of stimuli) indicated that, at the 5% level, left-temporal performance was poorer than that of the right temporal and control groups. There was no significant difference between the latter groups. A similar analysis of scores on the size classification failed to reveal any differences between groups.

### Naming

The mean scores for English-speaking subjects are shown in Table 3.

Table 3. Mean naming scores\*

Group	Without cue	With cue
Left temporal	11.4	11.6
Right temporal	13.3	12.6
Normal control	14.7	13.9

\*Maximum score=16.

The patients with left-temporal removals were significantly impaired at naming uncued drawings. A one-way analysis of variance revealed a significant difference between groups,  $F(2,32)=4.36$ ,  $P<0.05$ , and a subsequent Newman-Keuls test attributed this effect to a

difference between left-temporal and control groups. A comparison between cued and uncued conditions was achieved by means of a 2-way analysis of variance with cue condition and subject groups as factors. The analysis failed to reveal any significant main effects or interactions.

*Effects of stimulus material, recovery time and lesion size*

In an attempt to determine whether the above effects would obtain with different stimulus material, the proportion of correct responses for each stimulus item was calculated for each group. When the items in each condition were compared, the left-temporal group's deficits on the living/man-made classifications and on the uncued naming test were highly significant ( $P < 0.01$ , sign test). These analyses have shortcomings [10] but suggest that the present results are not due solely to the present choice of stimulus material.

The correlation between response accuracy and the number of years intervening between operation and testing was significant only for the left-temporal group on the living/man-made classification ( $r_s = +0.73$ ,  $P < 0.001$ ). Neither of the patient groups showed a significant correlation of performance on any test with the length of removal cavity along the Sylvian fissure, or with the extent of hippocampal resection.

## DISCUSSION

Patients with left anterior temporal-lobe excisions had difficulty naming objects and classifying them as living or man-made. They had no difficulty classifying similar objects as larger or smaller than a chair. The results are summarised in Tables 2 and 3. The performance of the left-temporal group on the living/man-made classification is poorer than it may appear. The mean score of 12.2 on the 2 tests corresponds to the 5th percentile of normal control performance.

The left-temporal group's deficit on the living/man-made classification cannot be attributed to perceptual processes: not only was the deficit equally large for perceptually disparate stimuli (drawings and words) but performance on the size classification, a more difficult task for control subjects, was normal. Since the perceptual and response demands of the 2 classification tasks were similar, it appears that the deficit on the living/man-made classification results from a selective impairment in semantic memory. That part of semantic memory necessary for performing the size classification was obviously unaffected. This suggests that removal of the anterior left temporal lobe leads to a disruption of semantic systems that involve verbal or lexical representation, but leaves intact those systems that involve visual or analogue representations. As will now be shown, such an interpretation has the advantage that it can accommodate 1) the left-temporal group's deficits at naming objects observed in the present study, and 2) left-temporal patients' deficits in learning verbal material that have been reported elsewhere [4].

(1) *Naming deficits.* The name of an object is not simply an arbitrary label attached to a configuration of perceptual features; it exists as an integral part of the semantic representation of the object. Consequently, any impairment of semantic systems that are based on verbal representation must disrupt the ability to name objects. As in the case of the classification task, the deficit observed in naming following left temporal lobectomy cannot be attributed to an impairment of perceptual processes since the naming of perceptually more complex material that included the initial letter of the object was unimpaired.

(2) *Learning deficits.* It has been known for some time that learning of verbal material is impaired by left temporal lobectomy, and nonverbal by right. If the material is to be learned

and recalled efficiently, encoding and retrieval processes, which involve semantic memory, must operate smoothly. It is, therefore, parsimonious to attribute the deficits in the learning of verbal material to the disruption of verbal semantic systems postulated above. Whether this is a sufficient explanation for the learning deficits associated with left anterior temporal lesions is an open question. The present semantic deficits were observed under stressful conditions and even then they appear to be relatively mild compared with deficits in episodic memory. They are certainly not as severe as the deficits that result from damage or stimulation of left posterior temporal and parietal areas [11,12]. Furthermore, the impaired ability of patients with right temporal-lobe removals to learn non-verbal material, if it is due to semantic deficits at all, must be due to deficits other than those revealed in the present study.

Tulving has proposed a functional dissociation of semantic memory from so-called "episodic memory" (i.e. memory for autobiographical events). No correspondingly strong neurological dissociation has been found in the present study: left temporal-lobe lesions that are known to impair episodic memory have been shown to disrupt semantic memory as well, although possibly to a lesser extent. However, an alternative division of memory into systems which rely on verbal representation and those which do not [4] has received further support. As the present study shows, the verbal/non-verbal division appears to apply to semantic as much as to other forms of memory and it exists at a level beyond that at which perceptual factors can contribute. It follows that current attempts to distinguish the nature of the semantic representation of objects by manipulating the perceptual attributes of the stimuli by which the objects are represented [5] may miss more fundamental divisions of semantic systems.

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Résumé :

On a examiné 1 à 21 ans après l'opération le déficit de la mémoire sémantique chez des malades ayant subi une lobectomie temporale antérieure unilatérale. On a demandé aux malades de classer des dessins d'objet ou des noms d'objet apparaissant chaque 0,75 de seconde. Les malades avec ablation temporale gauche montraient un déficit de la classification des objets en tant qu'êtres animés ou faits par l'homme, indépendamment du fait que les objets étaient représentés par des dessins ou par des mots. Il n'y avait pas de trouble de la classification des objets en tant que plus grands ou plus petits qu'une chaise. On demandait également aux malades de nommer des dessins d'objet présentés à la même vitesse avec ou sans lettre comme indice. Les malades avec ablation temporale gauche étaient déficitaires dans la dénomination des dessins non indicés. Les malades avec ablation temporale droite ne montraient pas de déficit. On interprète ces résultats en faveur d'une dissociation de la mémoire sémantique en composantes verbales sans rapport avec les modalités sensorielles et en composantes non verbales de représentation, la première de ces composantes étant altérée après les lobectomies temporales gauches.

Deutschsprachige Zusammenfassung:

Die Beeinträchtigung des semantischen Gedächtnisses wurde bei Patienten mit einseitiger vorderer temporaler Lobektomie 1 - 21 Jahre nach Operation untersucht. Die Patienten wurden aufgefordert Strichfigurobjekte oder Objektnamen zu klassifizieren, welche jeweils alle 0,75 sec dargeboten wurden. Patienten mit linkstemporalen Defekten waren unfähig Objekte als belebte oder unbelebte einzuordnen, unabhängig davon, ob die Objekte als Strichfiguren oder durch Namen dargeboten wurden. Eine Objektklassifikation nach dem Gesichtspunkt größer oder kleiner als ein Stuhl waren nicht gestört. Die Patienten wurden außerdem aufgefordert, Objektstrichfiguren, die in gleicher Rate wie vorher gezeigt wurden und mit und ohne Buchstabenkennzeichnung versehen waren, zu benennen. Die links temporal Operierten waren unfähig Objekte die nicht durch Buchstaben gekennzeichnet waren, zu benennen. Patienten mit rechtsseitigen temporalen Defekten zeigten dabei keine Ausfälle. Die Resultate wurden dahingehend interpretiert, daß offenbar das semantische Gedächtnis in die Komponenten verbal-amodal und nichtverbal-bildhaft aufteilbar ist.