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THE SELECTIVE IMPAIRMENT OF SEMANTIC MEMORY

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The selective impairment of semantic memory is described in three patients with diffuse cerebral lesions. These patients, selected on the basis of a failure to recognize or identify common objects (agnosia for objects), were investigated in detail. In particular, their perceptual, language and memory functions were assessed, and the limits and properties of their recognition difficulties explored.

It was found that knowledge of pictorial representations of objects, and of words, was impaired or impoverished, and in both instances knowledge of subordinate categories was more vulnerable than superordinate categories. Evidence is presented that this impairment of semantic memory cannot be accounted for by intellectual impairment, sensory or perceptual deficits, or expressive language disorder. The implications of damage to the semantic memory system for the operation of other cognitive systems, in particular short and long-term memory functions, are considered. Some tentative evidence for the structural basis for a hierarchically organized modality-specific semantic memory system is discussed.

Introduction

The selective impairment of recognition, a failure to identify or indicate the significance of meaningful stimuli that cannot be accounted for in terms of sensory impairment, defective perceptual analysis or language deficit, has been reported in the neurological literature for nearly a century. Agnosic deficits are not restricted to one sense modality; visual agnosia, tactile agnosia and auditory agnosia have all been reported as relatively isolated disabilities (Critchley, 1953; Hécaen, 1972; Vignolo, 1969). A similar kind of deficit is observed for verbal stimuli; single words whether spoken or written may not be comprehended in spite of intact hearing (or vision) and intact perceptual analysis of the verbal input (Vignolo, 1969). Typically the agnosic patient is able to describe, copy or repeat the stimulus item but has no knowledge of its meaning or significance. For example, given objects such as a key, toothbrush or umbrella, an agnosic patient would be unable to demonstrate their use. Similarly a patient agnosic for a word meaning is able to repeat the word and often read or write it accurately but is unable to give an adequate definition of the word or demonstrate its meaning by gesture.

Lissauer as long ago as 1890 proposed a dichotomy for the organization of visual recognition. He differentiated two stages in the organization of visual recognition, the "apperceptive" stage in which an adequate percept is achieved

from sense data, and the "associative" stage in which the percepts are linked with memory images laid down in the brain through other sense modalities and with verbal labels, thus achieving semantic significance or meaning.

Recent experimental data support this distinction between apperceptive (perceptual analysis) and associative (semantic analysis) mechanisms for visual object recognition, each with distinctive anatomical correlates. De Renzi, Scotti and Spinnler (1969) have reported a double dissociation of deficits with right- and left-hemisphere lesions, patients with right-hemisphere lesions being impaired on tasks which stress perceptual analysis (e.g. judgements requiring matching as same or different stimuli), and patients with left-hemisphere lesions being impaired on tasks which stress associative processes (e.g. judgements requiring matching objects to pictorial representation). In a further analytical study of the right hemisphere perceptual deficit Warrington and Taylor (1973) suggested that the deficit reflected a failure of perceptual classification, that mechanism whereby two or more stimulus inputs are allocated to the same class, an adequate Gestalt or percept already having been achieved. An often quoted example is that all A's (*A* **A** *A*) are recognized as A. The critical site for this deficit was found to be the right parietal lobe, and in such a group language functions are intact. It was argued that perceptual classification be differentiated as a separate stage in the recognition process, operating independently of verbal hypothesis and semantic information. In one extreme example of visual agnosia it was observed that perceptual classification was virtually normal although the patient had no knowledge of the meaning or significance of any of the items (Taylor and Warrington, 1971). There are as yet few comparable neuropsychological data pertaining to the organization of recognition stages for meaningful stimuli in the other sense modalities or to the word recognition process, but clearly a similar analysis could be applicable. Available evidence regarding the localization of the lesion responsible for the agnosias favours a left posterior site (Geschwind, 1965; Hécaen, 1972).

Although the evidence for a hierarchical organization of visual recognition is fairly firmly based, a detailed analysis of the "associative" (semantic) stage of recognition has not yet been attempted. Hitherto the agnosias have been regarded as obscure neurological syndromes, no attempt being made to relate them to normal cognitive functions. This study explores the possibility that an agnosia represents the selective impairment of semantic memory. Semantic memory is that system which processes, stores and retrieves information about the meaning of words, concepts and facts (Tulving, 1972). The cardinal property of information stored in semantic memory is that it is a common pool of knowledge not unique to the individual, in contrast to information stored in experiential memory (episodic memory in Tulving's terminology) which is unique to the individual. In most studies of semantic memory the word is the stimulus object, but the concept of semantic memory is equally applicable to the object itself. It appears to be precisely this class of information that the agnosic patient has lost. Thus not only an individual's verbal vocabulary, the lexicon, but also an individual's visual vocabulary, what would correspondingly be termed the "iconocon", are examples of information stored in semantic memory. A "verbal thesaurus"

and a "visual thesaurus" might be more appropriate terms, since by definition a thesaurus stores its contents by semantic grouping or categories as opposed to a lexicon which stores its contents alphabetically, and the former terms will be adopted here.

Three patients having visual object agnosia, a relatively rare neurological syndrome, have been intensively investigated and are reported here. The aims of this study are threefold. First, to establish that agnosic deficits in these three cases represent the selective impairment of semantic memory: the concept of semantic memory would then be strengthened by the existence of a structural basis. Second, the existence of selective deficits permits the inter-relationship of that system with other systems to be examined: in the present case the impairment of semantic memory has implications for the operation of other cognitive systems, e.g. short- and long-term memory. Last, since the impairment of a system may highlight properties of the system otherwise overlooked, the results are considered in relation to the hierarchical organization and modality specificity of semantic memory.

Selection and description of patients

Visual object agnosia, the inability to recognize or identify common objects that cannot be accounted for by sensory impairment or more generalized cognitive deficits, was identified in three patients on routine clinical examination during a three-year period 1970–2. No patient meeting this criterion was excluded.

Neurological assessment

Case 1

A.B. (born 1910) was a high-level civil servant until his early retirement a few months previously. He was admitted to the National Hospital in 1971 for investigations of his deteriorating memory. Neurological examination was entirely normal; in particular, visual fields were full to confrontation and visual acuity (L6/6 R6/6) and hearing were normal. Bilateral carotid angiography was entirely normal; the E.E.G. showed low-voltage slow waves in the left posterior parietal area; and air encephalogram demonstrated a moderate degree of cortical atrophy, the lateral ventricles being moderately dilated, air passing over the cortex bilaterally but the sulci being within normal limits. The discharge diagnosis was cerebral atrophy of unknown cause. He was tested in the psychology department between 1971 and 1974 for short sessions at very irregular intervals; he was somewhat reluctant to be tested although he attended the department voluntarily. During this time there was progressive deterioration in his cognitive functions and his ability to co-operate so that further testing became impracticable.

Case 2

E.M. (born 1914) was a teacher before retiring to become a full-time housewife and hostess to her husband who held a position of some rank. She was an amateur artist and potter of considerable skill. Her memory had been deteriorating for the previous 3 years when she was admitted to the National Hospital in 1972 for investigations. There were no abnormalities on neurological examination, visual fields were full to confrontation and visual acuity (L6/6 R6/6) and hearing were normal. Air encephalogram demonstrated mild cortical atrophy without any localizing features. Arteriography and other neurological investigations were entirely normal. The discharge diagnosis was atrophy of unknown origin. She was tested in the psychology department between 1972 and 1974 for short sessions at irregular intervals and there was only slight deterioration in her mental state during this period.

Case 3

C.R. (born 1910) was an industrial chemist until his early retirement in 1971 due to his failing memory, he himself complaining he had "forgotten" his chemistry. He was admitted to the National Hospital in 1972 for investigation of his deteriorating intellectual capacities. Neurological examination was entirely normal; in particular his visual fields were full to confrontation and visual acuity (L6/6 R6/6) and hearing were normal. Air encephalogram demonstrated a mild degree of cerebral atrophy, without localizing features; a Gamma scan showed an area of increased uptake in the parieto-occipital region of the left hemisphere (which was no longer present two weeks later), and left carotid angiogram indicated vascular disease of the left hemisphere. The discharge diagnosis was cerebral atrophy secondary to arteriosclerosis. He was investigated intensively in the psychology department for one week early in 1973, and subsequently for two test sessions later that year, after which he deteriorated to the extent that testing was no longer practicable.

Psychological assessment

Intelligence test results

A pro-rated verbal and performance IQ together with the individual weighted scores (corrected for age) for seven subtests of the W.A.I.S. for each patient are given in Table I. A score of 10 (s.d. $\pm$ 3) is equivalent to an IQ of 100 (average for the population). All three patients were able to function at least at the average level on some of the subtests; but it is clear that A.B.'s verbal skills were better preserved than his non-verbal skills whilst the converse was the case for E.M., whereas for C.R. there was no difference. The Progressive Matrices, a high-level non-verbal reasoning test, was administered and the percentile score for each patient is given in Table I. A.B. and E.M. were still able to function at a superior level indicating that there was no significant degree of non-specific intellectual deterioration; C.R. obtained an average score indicating at most a mild degree of non-specific intellectual deterioration.

TABLE I

Intelligence tests

	A.B.	E.M.	C.R.
W.A.I.S. scores			
Vocabulary	11	7	7
Similarities	10	5	5
Digit span	19	11	11
Arithmetic	14	11	5
Picture completion	9	10	8
Block design	10	16	10
Picture arrangement	3	12	3
Verbal IQ	122	89	80
Performance IQ..	87	117	89
Progressive Matrices	95%	90%	50%

Language functions

Expressive speech functions were well preserved in all three patients. At the conversational level no dysphasia could be detected in the speech of A.B. and E.M.; both were able to converse fluently using an impoverished vocabulary. C.R. had occasional word-finding difficulty and his syntax was slightly impaired. Comprehension of single words was impaired although all three patients were able to give lucid concise definitions of words within their vocabulary. Similarly comprehension of sentences appeared to be intact within the limits of their vocabulary. Handwriting was preserved in all three patients. A number of more formal tests of language function were administered and the results for each patient are given in Table II. It can be assumed that these three patients who

TABLE II

Language tests

	A.B.	E.M.	C.R.
Token Test (De Renzi)	13/15	15/15	10/15
Reading (Schonell)	89/100	87/100	70/100
Reading (Nelson)	20/30	10/30	N.T.
Spelling (Schonell)	85/100	60/100	65/100
Fluency	15	23	6
Naming	0/12	5/15	5/15
Naming from description	3/12	3/15	1/15

were all highly educated would have scored at a high level (i.e. without error) on these tests premorbidly. On the Token Test (De Renzi and Vignolo, 1962), which uses a limited high-frequency vocabulary to test the comprehension of a syntactically complex message (e.g. if I touch the green square you pick up the blue circle), A.B. and E.M. had virtually no difficulty and C.R. was only mildly impaired. All three patients had significant difficulty naming objects which had been recognized (e.g. for compass—a thing which tells you the direction). On the object-naming test reported here in addition to the errors of recognition, errors of naming were recorded. Naming a word from its description was also impaired; again errors of recognition and errors of naming were recorded. The measure of fluency reported here is the number of words beginning with the letter S, spoken in 2 min—for E.M., the patient with greater verbal than visual difficulty, performance was normal on this task, whereas A.B. and C.R. were impaired. Literacy skills were assessed by Schonell's (1942) graded reading and graded spelling test. A.B. and E.M. had a mild deficit on the reading test and a more pronounced difficulty on the spelling test. C.R. was clearly impaired on both. On the reading test it was observed that relatively high frequency words departing from the standard phonetic rules of English presented most difficulty (e.g. A.B. could read Classification but not Nephew). Nelson (in preparation) has developed a new test of reading skills in which reading by phonetic rules is minimized whereas familiarity with the word form is maximized: on the Nelson reading test A.B. and E.M. demonstrated a clear-cut deficit although they both read with only occasional errors on the Schonell word test.

Visual and perceptual functions

Shape discrimination. On a test of shape discrimination (Taylor and Warrington, 1973) the subject was shown a series of pairs of triangles, one with straight sides and one with curved, the discriminable difference between each member of the pair being graded in difficulty. The mean number correct in pointing to the triangle with straight sides was within the normal range for each patient (see Table III).

TABLE III

Visual and perceptual tests

	A.B.	E.M.	C.R.	Controls Mean score and range ($n = 20$)
Shape discrimination	15/20	20/20	16/20	17·85 (15/20–20/20)
Figure–ground discrimination ..	36/40	36/40	36/40	35·2 (28/40–40/40)
Matching faces	25/28	25/28	21/28	24·4 (22/28–27/28)
Matching objects	17/20	20/20	17/20	19·15 (17/20–20/20)
Unconventional views	12	12	6	19·8 (19/20–20/20)
Conventional views	11	12	9	20·0 (20/20)
Spatial imagery	29/30	12/12	N.T.	N.T.

Figure/ground discrimination. The test stimuli (Warrington and Taylor, 1973) were fragmented letters, either an O or an X, on a fragmented ground, the task difficulty being manipulated by varying the ratio of black to white in the figure in relation to the ratio of black to white in the background. The subject was required to detect the presence or absence of a known stimulus (either an X or an O). The mean number correct for each of the three patients and the normal range are given in Table III. No patient had any deficit.

Faces matching test. The test stimuli were photographs of young men's faces (age range 18–30) taken from five different views. The subject was required to judge whether two photographs were of the same man or a different man. The task difficulty was manipulated by pairing faces taken from different views (e.g. a full face with a profile). The number of items correct for each patient and the normal range are given in Table III. Performance on this task, which clearly demands a capacity for perceptual analysis and the perceptual classification of one category of meaningful complex visual stimuli, is quite intact in A.B. and E.M. Patients with right-hemisphere lesions are impaired on this type of task (De Renzi *et al.*, 1969; Warrington *et al.*, in preparation).

Object matching test. A series of common objects were photographed from two angles, a conventional view and an unconventional view. The subjects were required to judge whether two photographs were of the same or different objects. The mean number correct for the three patients and the normal range are given in Table III. Although many of the objects used in this test were not recognized by the patients (either the conventional or unconventional view), nevertheless, this form of perceptual classification presented little difficulty. This observation is in contrast to patients with right hemisphere lesions who as a group show a reliable deficit on this matching task (Warrington and Taylor, in preparation). The effect of orientation was also assessed by comparing their ability to recognize the conventional and the unconventional view of the object. There was no additional difficulty with the unconventional view photographs (see Table III) although this is an important variable in patients with right hemisphere lesions (for further detail see Warrington and Taylor, 1973). On being shown the conventional view of a table tennis bat having already attempted to identify the unconventional view of it, A.B. remarked that he had already been shown a photograph of that object taken from a different angle and that he had already told me that he had no idea what it was. (This observation highlights the discontinuity between perceptual classification and semantic classification for object recognition).

Imagery. The Flags test (Thurstone and Jeffrey, 1956) was used to obtain a rough measure of the capacity for visual imagery. A.B. and E.M. attempted the first few items of this test; their performance was almost without error and it appeared effortless to them (see Table III).

Comment

There were two major limitations to the investigation of these patients. First, all three were living at home and were only intermittently available for testing. They attended voluntarily and at their own convenience. Second, these three patients all have progressive neurological disease and their mental status was deteriorating during the period they were being investigated. For this reason all the individual experiments reported were completed in one-test sessions (e.g. concrete v. non-concrete, pp. 645–6). Although their overall level of functioning declined, the pattern of disability in each patient remained constant. This consistency of the pattern of impairment in each patient, whatever the degree of impairment, indicates that the interpretation of the present findings can in no way be regarded as a consequence of the progressive nature of the disease.

Experimental investigations

Object and word recognition

These three patients were all the subject of detailed investigation on account of object-recognition difficulties first observed on clinical examination. In order to confirm these observations quantitatively the first 100 test items of the Peabody Picture Vocabulary test were administered. This test requires the subject to match a spoken word to its pictorial representation (four choices given). The 100 words are graded in frequency from AA (clown and digging) to 1 per mil (precipitation and amphibian) and include both concrete and abstract items. The number of items correct for each patient is given in Table IV. Their educational and occu-

TABLE IV

Picture and word recognition tests

	A.B.	E.M.	C.R.
Picture word matching .. .. (Peabody picture vocabulary)	52/100	69/100	70/100
Picture recognition	19/40	37/40	13/40
Word recognition	27/40	26/40	21/40

pational record was such that this task would have presented no difficulty whatever prior to their neurological illness. The 50–70% error rate recorded in all three cases represents a moderately severe deficit. The Peabody Picture Vocabulary test combines a visual and an auditory component and performance on it can be impaired either by object recognition difficulties, or word recognition difficulties or both.

A picture and word recognition test was therefore compiled from Zinkin's (1968) stimulus material. Forty clear line drawings of objects (38 × 38 mm), for the most part of medium frequency, animals, plants and inanimate objects being included, were presented singly to the patient who was required to name them or identify them by description or function. After a short interval the patient was required to define the object name presented auditorially. All test items were well within the visual/verbal vocabulary of an average adult, e.g. the lowest frequency items were a sledge, scales, etc. The number of items correct on the visual and auditory version of the test for each patient are given in Table IV. The pattern of difficulty is of some interest as it is not the same for each patient. A.B. and C.R. were somewhat worse on the visual version of the task than on the auditory version (Sign test, n 12 × 2, $P < 0{\cdot}05$ and n 14 × 3, $P < 0{\cdot}06$ respectively); and conversely E.M. was considerably worse on the auditory than the visual version (Sign test, n 13 × 1, $P < 0{\cdot}01$). The discrepant test scores on the visual and auditory version of the test in these patients indicates that their recognition difficulties cannot be a trivial consequence of impaired expressive speech functions. A.B. could give an adequate definition of an object name but failed to describe the visual representation of the object and the converse was

observed for E.M. It was of interest to note that all three patients gave qualitatively similar responses to items not adequately recognized. They would state it was a "familiar" item or that they had "forgotten" it. All three patients on occasion would describe an item in terms of its superordinate category (e.g. animal) or broad class (e.g. container) but be quite unable to give any more precise or detailed description or definition. This observation was particularly striking on the verbal version of the task.

Agnosia for objects

Selective deficits of recognition of different classes of meaningful visual stimuli are accepted by clinical neurologists. Agnosia for letters and words is relatively frequent, agnosia for colours and faces is less frequent, agnosia for objects is comparatively rare; and the reports of agnosia for a particular class of objects (e.g. parts of the body, or animate objects) are more controversial (Hécaen, 1972). The three patients reported here could identify letters, numbers and colour without difficulty, their visual agnosia being restricted to objects (including visual representations of objects and faces). The severity of deficit in these three patients ranged from mild (E.M.) to moderately severe (A.B.). However, in all three patients some objects were recognized, some partially recognized, others not at all. Though no exact measures of visual frequency are available this was a relevant variable. In addition objects from taxonomic categories comprising many exemplars only differentiated by detail appeared to present especial difficulty. For example these patients could recognize a flower, but not which particular flower; they could differentiate between fruit and vegetables, but had great difficulty in identifying which particular one. Two types of incorrect response were noted. First, the object would be described in terms of a very general category (usually correct) the superordinate class word being used appropriately (e.g. Daffodil—some kind of flower, Hammer—some kind of tool). Second, occasional semantic errors occurred the response being an alternative item from the same category (e.g. donkey–horse; dog–cat).

Appropriate test material for quantitative investigation of the properties of object recognition impairment is not readily available. Two tests were devised to assess the relative knowledge of superordinate and subordinate categories, using techniques devised to minimize an expressive speech component.

Test 1

A forced choice object-recognition test was devised to assess the subjects' knowledge of visual representations of animals and of inanimate objects. Triplets of coloured drawings were assembled and the subject required to point to the test items having a particular property, the distractor items being animals or objects not having the property in question. In the case of animal pictures the subjects' knowledge of superordinate categories (animal/not animal, e.g. spider, tree, leaf; and insect/not insect, e.g. bee, bat, owl) was tested, and for both animals and inanimate objects an attempt was made to test the subjects' knowledge of subordinate categories (attributes and associations of the items). In the animals' pictures test the subject was required to indicate the dangerous animal, the foreign

animal, the largest animal and the animal having a particular colour. Similarly for the inanimate objects the subject was required to indicate the metal object, the heaviest object, the kitchen object and the object used primarily by a man. Thus there were six sets of animal pictures and four sets of inanimate object pictures, each set comprising 10 triplets. Patients with extra-cerebral neurological disease were tested as a control group (no attempt was made to select them on the basis of age or IQ).

The number of items correct (forced choice of three) for each patient on the superordinate and subordinate judgements on the animals test is given in Table V.

TABLE V

Visual recognition by forced choice

	Animals			Objects	
	Animal/ not animal and Bird/ not bird	English/ not English and Dangerous/ not dangerous	Largest/ smallest and Black/ not black	Used in kitchen and Used by a man	Metal/ not metal and Heaviest/ lightest
A.B.	15/20	11/20	8/20	11/20	9/20
E.M.	20/20	17/20	15/20	20/20	15/20
C.R.	16/20	9/20	10/20	13/20	13/20
Controls (Mean score) $n = 25$	19·9	19·8	19·4	19·0	18·5

Performance was relatively good on superordinate judgements; animals could be differentiated from plants, and birds and insects, etc., could be differentiated from each other and from other major animal classes. In contrast ability to differentiate animals on the basis of attributes and associations was very poor. The superordinate/subordinate dichotomy is less easily applied to common objects; however, with object pictures, there was a high error rate for A.B. and C.R. in differentiating objects on the basis of both attributes and associations (Table V). E.M. the patient with the mildest deficit only made errors differentiating objects on the basis of their attributes and not by their associations.

Test 2

A probe technique was used in a further test of different levels of semantic knowledge (category, attribute and associative). The test stimuli comprised 40 clear unambiguous photographs (3 × 4 in) of 20 animals and 20 objects. A Yes/No response was required throughout. First the subject was shown each photograph singly (the animal and object photographs in random order) and asked "Is it an animal?". Then the animal pictures alone were presented singly and the subject asked "Is it a bird?". This procedure was repeated asking the subject first "Is it foreign?" then, "Is it bigger than a cat?". Similarly with the objects, first the subject was asked "Is it used indoors?" then, "Is it made of metal?"

followed by "Is it heavier than a telephone directory?". Finally, recognition of the object name was tested in a forced choice task (e.g. "Is it a picture of a swan or a duck?"). Patients with extra-cerebral nuerological disease were tested as a control group (no attempt was made to select them on the basis of age or IQ).

The mean number of items correct for each of these eight types of probe for each patient is given in Table VI. On the probe "Is it an animal?" the error

TABLE VI

Visual recognition by semantic probe

	Animals + objects	Animals				Objects			
	Animal	Bird	English	Size	Name	Indoors	Metal	Weight	Name
A.B.	37/40	13/20	9/20	11/20	8/20	16/20	18/20	8/20	8/20
E.M.	39/40	19/20	11/20	14/20	13/20	19/20	18/20	12/20	12/20
C.R.	38/40	13/20	8/20	10/20	8/20	14/20	14/20	8/20	10/20
Controls	39·6	19·6	18·4	16	18·6	19·8	19·4	14·8	20
(mean score)	40	20	20	20	20	20	20	20	20
$n = 5$									

rate in all three patients was very low. Performance on the probe "Is it a bird?" to the animal pictures and "Is it found indoors?" to the object pictures, was much worse but still above chance, whereas on one of the associative probes "Is it English?" and on one of the attribute probes "Is it heavier than a telephone directory?" performance drops to chance level. In no case was an animal or an object named. All three patients were at chance level matching a name to the animal or object picture (see Table VI). An auditory version of this test was devised and the findings are reported in the following section.

Agnosia for words

A number of tests were administered to investigate the properties and assess the limits of agnosia for words. The three patients here reported, though selected on the basis of their agnosia for objects, all demonstrated some degree of agnosia for words. The investigation of word agnosia is less hampered than object agnosia by a dearth of appropriate test materials and techniques. As was the case with object recognition difficulties it was observed that the patients were able to report the broad category, giving a superordinate response when attempting to define a word. Therefore the test described above to test levels of semantic knowledge was adapted for auditory presentation.

Test 1

The test stimuli were the 20 animal names and 20 object names of the photographic material used above. The procedure was as described above: each word was spoken individually, the patient responding Yes/No to each set of probe questions in the same order as above. The 20 animal names and 20 object names

were spoken in random order and the patient asked "Is it an animal?". Following the three probe questions for the animal names the three probe questions for the object names were attempted. This test was not paced and was completed at the patients' own speed which was often very slow. They often appeared to give great consideration to the question repeating it (accurately) to themselves.

The mean number of items correct for each of these eight types of probe for each patient is given in Table VII. Although a significant error rate was recorded,

TABLE VII

Auditory recognition by semantic probe

	Animals and objects	Animals				Objects	
	Animals	Bird	English	Size	Metal	Indoors	Weight
A.B.	29/40	15/20	14/20	13/20	11/20	15/20	12/20
E.M.	34/40	13/20	12/20	11/20	11/20	16/20	7/20
C.R.	26/40	9/20	9/20	5/20	12/20	12/20	11/20
Controls	39·8	19·4	18·8	15·2	19·6	19·2	15·8
(mean score)	40	20	20	20	20	20	20
$n = 5$							

performance was for the most part least impaired on the probe "Is it an animal?". Performance was worst on the probes "Is it bigger than a cat?" and "Is it heavier than a telephone directory?", all three patients' scores being close to chance. Intermediate scores, that is a high error rate but significantly above chance (patients A.B. and E.M.), were recorded on the probes "Is it a bird?" and "Is it used indoors?" (see Table VII).

Test 2

All three patients were able to express themselves fluently and with precision within the limits of their vocabulary. It was therefore practicable to investigate the contribution of the variables of frequency and concreteness to the impairment of word knowledge. A common pool of 70 words obtained from the Brown and Ure list (1969) were defined by all three patients. These 70 words were divided into four groups; high and low concrete (concrete rating above or below 5·25) and high and low frequency (A and AA or less than A). The patients' responses were judged correct or incorrect using a very lenient criterion. A definition, however vague and imprecise, given it was appropriate to the concept, was accepted, e.g. pond—"water", cheese—"eats", modest—"ought to be".

The number of words in each category correctly defined for each patient is given in Table VIII. No patient showed any significant difficulty on the high frequency words whether of low or high concreteness rating. Definitions of the low frequency words were poor and it is of interest to note that the concreteness variable operates in opposite directions in two of the patients. A.B. was significantly worse on concrete words than abstract words ($\chi^2 = 28{\cdot}6$, $P < 0{\cdot}001$) whereas the trend for E.M. to be worse on abstract words than concrete words did not approach significance. However, by analysis of the total pool of words (20) to which the responses of A.B. and E.M. did not correspond, it can be shown

TABLE VIII

Word definition test

	High concrete		Low concrete	
	High frequency	Low frequency	High frequency	Low frequency
A.B.	14/15	6/25	10/10	17/20
E.M.	14/15	14/25	10/10	9/20
C.R.	15/15	15/25	9/10	12/20

that the pattern of correct responses to concrete and abstract words is significantly different in the two patients (Fisher Exact Test, $P < 0{\cdot}005$). This different pattern of difficulty observed in these two patients was apparent on many verbal tasks where concreteness ratings were not available. This was particularly striking in A.B.; some examples of his responses to abstract words were as follows:

Supplication	Making a serious request for help.
Arbiter	He is a man who tries to arbitrate.
	Produce a peaceful solution.
Hint	When you've given information.
	What will occur.
Vocation	What one's job is.
Tame	An animal not behaving wildly.
Pact	Friendly agreement.

In contrast the best he could manage for relatively common concrete words was as follows:

Hay	"I've forgotten".
Poster	"No idea".
Needle	"Forgotten".
Acorn	"Don't know".
Cabbage	"Eat it" (no further information on questioning).
Geese	"An animal but I've forgotten precisely".

Test 3

Recognition of written words was assessed by requiring the patients first to discriminate real words from nonsense words, and second, to discriminate sensible sentences from absurd sentences. Ten high-frequency words were typed in a column randomly interspersed with nonsense words of the same length and construction. Eight to 10-word sentences using middle-range frequency words were typed in rows on a single sheet interspersed randomly with absurd sentences of the same length. Absurd sentences were constructed by juxtaposing improbable verbs and nouns, e.g. The woman was wearing a meringue on her head. The patients were required to mark the real word and the sensible sentence respectively. Their performance was impaired on both tasks, discrimination of sensible from

absurd sentences being more difficult than discrimination of real words from nonsense words (Table IX). The patients were all able to read this test material aloud apart from occasional minor errors.

TABLE IX

Recognition of written words

	Real/nonsense words	Sensible/absurd sentences
A.B.	17/20	12/20
E.M.	16/20	16/20
C.R.	N.T.	11/20

Test 4

Comprehension of proverbs—only qualitative data were obtained. A.B., the patient with relative preservation of his vocabulary for abstract words compared with concrete words, was totally unable to understand simple proverbs—for example, he could make no attempt to explain "Too many cooks spoil the broth". He commented, "If I knew what broth was I expect I could explain it". His response to "Strike while the iron is hot" was "I know iron is a metal". Thus he appeared to have as much difficulty with concrete words within an abstract framework as with isolated concrete words, yet he gave every indication that his understanding of abstract concepts was intact at this level. The other two patients were totally at a loss to explain proverbs.

Test 5

Semantic analysis of words was further explored in case E.M. Two samples of words were assembled, 20 which she claimed to have "forgotten" and 20 words which she recognized, being able to give some indication of their meaning (without further probing by the experimenter as to the degree of their precise meaning). The following examples would be accepted as a known word: melon—eat—fruit; crab—animal; sherry—drink. The total pool from which these words were assembled were of similar frequency (49–1) concrete words drawn from superordinate categories with many exemplars.

For each word, alternating between a known word and an unknown word, two tasks of recognition of the superordinate category and two tasks of recognition of the subordinate categories were given, using a forced choice from three. The choices for the superordinate categories were:

(1) Animal, plant or inanimate object.
(2) Mammal, bird, insect; or tree, flower, fruit; or liquid, stone, metal, etc.

The choices for the subordinate categories were:

(1) Green, brown, grey; or wool, metal, stone, etc.
(2) Two, four or six legs; or soft, crisp, juicy, etc.

Apart from the first superordinate choice which was the same for all items the choices were adapted to be appropriate to the item. The number of correct responses for each category choice for the known and unknown words are given in Table X. These findings provide further evidence for hierarchical organization

TABLE X

Auditory recognition of known and unknown words (patient E.M.)

	Known words		Unknown words	
	Superordinate choices	Subordinate choices	Superordinate choices	Subordinate choices
Both correct	19	10	10	4
One of two correct ..	1	9	8	12
Both wrong	0	1	2	4

of semantic memory. Knowledge of superordinate categories is much more intact than knowledge of subordinate categories; with the words classified as "known" there was a minimal error rate for the superordinate category choices and a significantly higher error rate for the subordinate category choices ($\chi^2 = 5{\cdot}08$, $P < 0{\cdot}05$). An increased error rate was obtained on the "unknown" words but the same pattern of difficulty was maintained, there being significantly more errors on the subordinate choices than the superordinate choices ($\chi^2 = 3{\cdot}96$, $P < 0{\cdot}05$).

Auditory agnosia

Recognition of meaningful sounds was assessed using a test devised by Shallice and Warrington (1974). The patients were required to identify 12 sounds, each of 3 s duration, each being repeated once if necessary. Normal subjects are able to identify all 12 sounds. A.B. and C.R. scored 2/12 and 5/12 respectively; however E.M. had no difficulty scoring 12/12. It is of interest to note that E.M. was at least as impaired, and indeed more so, on some tests of word recognition as A.B. and C.R.

Auditory verbal short-term memory

Digit span, one measure of the capacity of verbal short-term memory, was average or above in these three patients (9, 7, 7 digits respectively). Span for three other classes of verbal material (known words, unknown words and nonsense syllables) was investigated in two of the patients (A.B. and E.M.).

Test 1

The patients were required to define common three-letter words in order to compile two groups of words, those known to the patient and those unknown. A pool of 15 known and 15 unknown words was used to test their word span. Strings comprised either five known or five unknown words and the strings were presented auditorially in blocks of five, alternating known and unknown, at a

1-s rate. A total of 50 strings were presented, 25 known and 25 unknown. The individual words used for each patient were not identical because A.B. was more likely to know the abstract words and E.M. the concrete words. The frequency of the unknown words was marginally lower than the known words for each patient. The number of items in the correct order per string for the known and unknown words are given in Table XI. The level of performance on this test was good, both patients frequently being able to repeat all five items correctly from both classes of words. There is a slight difference in favour of the known words which is not significant in either case ($t = <0{\cdot}92$ and $t = <1{\cdot}76$ respectively).

TABLE XI

Span for known words, unknown words, and nonsense syllables

	Test 1		Test 2	
	"Known" words	"Unknown" words	"Unknown" words	Nonsense syllables
A.B.	4·4	4·0	3·8	2·8
E.M.	4·6	4·2	2·9	1·1

Test 2

The same set of unknown words was used to compare span for unknown words and for nonsense syllables, this experiment being done some six months after Experiment I. Forty five-word strings drawn randomly from the pool of 15 unknown words were presented in blocks of 10 alternating with 10 blocks of five-word strings of nonsense syllables similarly compiled from a pool of 15 nonsense syllables. The mean number of items in the correct order for the unknown words and the nonsense syllables for each patient is given in Table XI. Their span for nonsense syllables is significantly worse than their span for unknown words ($t = 2{\cdot}51$, $P < 0{\cdot}05$ and $t = 4{\cdot}87$, $P < 0{\cdot}001$, respectively). Thus they are demonstrating the normal difference between span for words and span for nonsense syllables in spite of the fact that the words had no meaning for them and might be supposed to be similar to nonsense syllables. Neither patient realized that the experimenter was alternating between real words and nonsense syllables, though both commented that all the test material was meaningless. At the end of the experiment E.M. was given the total pool of words and nonsense syllables in random order and required to mark the real words. Her performance was at the chance level, scoring 16/30.

Long-term memory

The first symptom in all three patients was the complaint of poor memory yet the quantitative assessment of their long-term memory functions proved elusive. On two items from the Wechsler Memory Scale (recall of a short story and reproduction of visual designs from immediate memory), performance was impaired in all three patients. Their recognition memory for photographs of contemporary

personalities was remarkably poor, 2/15, 0/15 and 0/15 respectively, a normal score being in the region of 10/15. An attempt to obtain free recall of 10-word lists after a 20-s delay was abandoned as recall was virtually non-existent and the patients found the task distressing. Yet these patients were not at all like amnesic patients with a global amnesia for all on-going events. Unlike an amnesic patient they were all well-orientated in time and place; their conversation was not so repetitive and they were able to refer forwards and backwards to detailed events of importance in their lives. An attempt to compare their long-term memory for known and unknown words was unsuccessful because using a forced choice recognition technique they scored at the chance level with the "known" words. Testing time was not available to obtain word definitions for a further pool of words.

Test 1

A forced choice recognition memory test (described in detail by Warrington, 1974) for 50 words, 50 unfamiliar faces and 50 paintings was administered to A.B. and E.M. The number of correct responses for each patient is given in Table XII together with the scores obtained by a group of 20 normal subjects

TABLE XII

Long-term memory tested by forced choice

	Words	Faces	Paintings
A.B.	23	24	36
E.M.	34	23	44
Normal controls (mean score)	45·2	43·0	40·6
Global amnesics (mean score)	30·5	27·3	27·5

and a small sample of four amnesic subjects. Both patients were as impaired as amnesic patients on the word and faces version of the test, but scored within the normal range on the paintings test. This is of some interest as the two patients reported here were unable to recognize the content of many of the paintings whereas amnesics had no difficulty whatever.

Test 2

Retention tested by different methods of retrieval was investigated in a further attempt to contrast these patients' verbal memory deficit with that of the global amnesic patient, who by definition has no difficulty in understanding the meaning of words. Three 16-words lists were presented at a one per 2-s rate. Retention of eight of the words was tested with no delay interval by cueing the word with the first three letters of the word, and retention of eight of the words was tested by Yes/No recognition, the distractor items being drawn from the same pool of words as the stimulus items (for further details of this paradigm see Warrington and Weiskrantz, 1974). Twenty normal subjects obtained a mean score of 14·8 (s.d. 3·6) on the cued recall test and 19·0 (s.d. 2·8) on the recognition test (true

positives—false positives). A.B. was grossly impaired on both conditions; he was able to produce five items by cued recall which may be just significantly more than could be achieved by guessing, but he was at chance level on the recognition task scoring+4. E.M.'s performance is of more interest as her retention tested by cued recall was very poor, scoring only 1, whereas on the recognition test she scored 9 which, though impaired compared with the normal control group, was significantly above the chance level. Thus she demonstrated the opposite relationship between retention tested by cued recall and by recognition to that found in amnesic subjects, who have been reported as normal on retention tested by cued recall and very impaired on retention. tested by recognition (Warrington and Weiskrantz, 1970, 1974).

Discussion

Object agnosia and word agnosia in three patients with cerebral disease have been studied and an analysis of their recognition difficulties attempted. First, an explanation in terms of generalized intellectual impairment, perceptual deficit or language disorder will be considered and rejected. Second, the hypothesis that a specific impairment of semantic memory is the basis of their recognition difficulties will be advanced. If it is accepted that semantic memory systems are implicated then two further issues merit comment, namely the relationship of semantic memory to other cognitive systems and the properties or characteristics of the organization of semantic memory.

Intellectual function was well preserved in these three patients. A.B. and E.M. were still able to function at the superior level on the Progressive Matrices and C.R., the most impaired patient, at an average level. Their difficulty in recognizing objects and words clearly cannot be attributed to a failure of attention or a more generalized failure of intellectual functions. Of greater importance is the question of their expressive language and perceptual functions. Spoken speech within the limitations imposed by their restricted vocabulary appeared virtually intact and their expressive speech functions were sufficiently intact that words which were recognized were qualitatively well defined. Comprehension for the syntax of language seemed intact in so far as performance on the Token Test, based on the relationship between words within their vocabulary, was relatively well preserved. No articulatory difficulties were observed. The average or above-average digit span can be used as evidence that auditory perception was intact in these patients. The relative preservation of many aspects of language function other than word recognition and nominal functions is well illustrated in A.B., who obtained the remarkably high verbal IQ of 122.

Visual acuity was normal and the visual fields full in all three patients. This latter observation is relevant to the disconnection theory discussed below. Visual discrimination and figure–ground perception have been shown to be intact. More important, perceptual classification, namely the allocation of a particular stimulus configuration to the same perceptual class, appears well preserved. These patients had no greater difficulty in recognizing an unconventional view of an object than a conventional view, and furthermore they were able to judge whether con-

ventional and unconventional view photographs were or were not of the same object with reasonable confidence even when they were unable to identify by name or function either representation. Perceptual classification is impaired in patients with right parietal lesions (Warrington and Taylor, 1973) but was well preserved in a patient with a very severe agnosic defect (Taylor and Warrington, 1971) and in these three patients who are held to have an impairment of recognition at the semantic level. The present findings are further support for the view that perceptual classification and semantic classification are hierarchically organized systems and can be differentially impaired. (These three patients do not contribute to the question of localization of agnosia.)

Neither disordered visual form perception nor impairment of expressive speech functions appear able to account for these patients' agnosia for objects, pictorial representations of objects, and words. There is, therefore, a *prima facie* case for suggesting an impairment of a semantic memory system as the functional basis of their difficulties. Semantic memory itself is a broad term encompassing the storage and retrieval of knowledge of objects, words, facts, concepts, etc., and the relationship between them. These patients are deficient on tasks requiring knowledge of two major classes of semantic information, namely objects and words. There is manifest impoverishment of their verbal thesaurus and of their visual thesaurus. An object or a symbol, in this instance a picture or a word, has semantic properties by reference to the underlying concept (deep structure). Most concepts have both superordinate and subordinate categories, e.g. *dog*—animal and spaniel. But at the limits of semantic knowledge (which will of course depend on an individual's education and experience) a concept is defined by its unique attributes and associations which can be differentiated from other semantically similar concepts, e.g. spaniel and terrier. It has been shown that information pertaining to the concept is deficient. Knowledge of attributes and associations of objects and words is impaired. The findings using probe recognition tasks suggest that the deficit is not merely in the retrieval of semantic information but that the storage systems are damaged.

This paper is intended to be an empirical study, thus consideration of the theoretical problems relating to the nature of a concept and the meaning of meaning will not be attempted except in so far as the data are relevant to current models of semantic memory. For the purpose of the remainder of this discussion it will be assumed that the cardinal deficit of the three patients reported here is in the storage of semantic information. Accepting this formulation the present data are relevant to notions of the organization of semantic memory and these will be considered tentatively. The implications for the operation of other cognitive systems are far reaching and merit discussion whatever model of semantic memory is accepted.

Tulving drew a timely distinction in the organization of long-term memory systems between semantic memory and what he termed episodic memory. In a cogently reasoned argument he rejected the tacitly accepted view that semantic memory was "different in extent but not in kind from other memory domains". The present findings justify his position and offer empirical evidence for the view that semantic memory is a dissociable L.T.M. system not only with its own

properties but also with its own structure. Amnesic patients who are impaired on a wide range of verbal learning tasks are not agnosic for words or objects (Talland, 1965; Warrington and Weiskrantz, 1968); word definition (up to the limits of their education) is normal and no failure of identifying common objects has been reported. It is most unlikely that the preservation of semantic information stems from a relative preservation of remote memory compared with more recent learning. It would be a digression to justify this statement fully; however it is worth noting that memory for very remote events is *not* normally preserved in amnesic patients (Sanders and Warrington, 1971). Conversely the patients reported here are by no means as amnesic as a patient with a severe amnesic syndrome, although their verbal memory is far from normal. This is hardly surprising; verbal memory relies largely on semantic encoding, which could hardly be achieved with a damaged semantic memory system. It proved unpractical to compare retention of words "known" and "unknown" to the patient; however two L.T.M. memory test results are of interest. First, on the forced choice memory test all three patients did relatively well on the "paintings" test, the only stimuli used which could be regarded as multidimensional. This superiority is in contrast to the patterns of difficulty obtained in amnesic patients and normal subjects (Warrington, 1974). It is possible that some aspect of the paintings was meaningful to the agnosic subjects (perhaps the colour), and as they were people of much more than average endowment they were able to score relatively well in spite of their semantic memory handicap. Second, amnesic patients are very impaired on conventional verbal learning tasks compared with certain cued recall tasks on which their performance has been shown to be normal (Warrington and Weiskrantz, 1970, 1974). In contrast the agnosic patients were very impaired on the same cued recall task and, furthermore, one patient, E.M., showed the normal superiority on the recognition task. Thus there is some tentative evidence that the performance of agnosic patients and amnesic patients on memory tasks may be qualitatively different.

Digit span, one measure of short-term memory (primary memory to use the alternative nomenclature), was average or above in these patients. However, since they were not impaired in their use or knowledge of numbers this finding is not so pertinent to the question of the interaction between the short-term memory system and semantic categorization as their performance on word span tasks. In two patients span for unrelated words was within normal limits, but of more interest was the finding that span for "unknown" words was as good as span for "known" words. Thus it would seem that semantic encoding is not a determinate of word span and it follows that the short-term memory system is pre-categorical at least at the semantic level, a position previously widely held (Conrad, 1964; Baddeley, 1966; Shallice and Warrington, 1970) but at present less popular (Shulman, 1970). In contrast their span for "unknown" words was significantly greater than their span for nonsense syllables although the two patients tested were unable to differentiate between these two classes of verbal stimuli. There is thus a paradox: the short-term memory system can differentiate what the long-term semantic memory system has "forgotten". It would appear that short-term memory responds differentially to information previously experienced though no longer

accessible to the semantic memory system, and information not previously experienced. One possible interpretation of these findings is that in the processing of auditory verbal information there is an intermediate post-sensory pre-semantic categorical stage which achieves a word-form. This notion of a word-form which has no meaning or semantic attributes receives some support from the studies of Rommetveit (1968). If this analysis is appropriate, then there is evidence for similarity in the organization of information processing in visual object recognition and word recognition. In the case of visual object recognition it has been argued that form or figure/ground perception is achieved prior to perceptual classification which is in turn prior to semantic classification. In this model, analysis at the level of a word-form without meaning would correspond to perceptual classification without meaning in the visual system.

Although no exact comparison was undertaken, indirect evidence suggests that these patients probably had equal difficulty in understanding the spoken word and the written word. Yet the mechanical aspects of reading were remarkably well preserved; words which were meaningless to the patients could be correctly read and written. The phonetic rules of English appear to be an important factor in determining whether a particular word could be read or not. On the Nelson test (which comprises words not spelt phonetically) their reading skills deteriorated. A dual-route model of word recognition has received strong support from neuropsychological evidence (Marshall and Newcombe, 1973; Shallice and Warrington, 1975). The present observations of these patients' reading skills are also pertinent. The direct graphemic route (in which phonemic analysis is presumed to be bypassed, the visual word form being directly linked with the concept-meaning unit) can hardly be effective when the concept unit itself is damaged. That words which are spelt in a bizarre manner presented difficulty for these patients is consistent with the notion that the direct graphemic route was inoperative. That phonetically spelt words could be read with relatively little difficulty indicates that reading by the phonetic route alone can be quite effective. A more detailed investigation of the reading skills of this type of dyslexic patient could possibly be used to analyse the characteristics and features of phonetic units.

There are two major classes of theories concerning the organization of semantic memory. The hierarchically organized system first proposed by Collins and Quillian (1969, 1970) has been challenged by those favouring an equipotential component elements model (Schaeffer and Wallace, 1970). The present findings clearly support a hierarchically-organized system but suggest one radical departure from the usual formulation. Although the techniques used here are based on error scores rather than the more usual reaction time measure, it seems reasonable to assume that they are alternative measures of the same class of event. On a component element model agnosia would presumably correspond to either a dropping out of concepts or of their elements. There is no evidence for an all or none pattern of response to knowledge of concepts—on the contrary some semantic meaning was often preserved and this was invariably of the general rather than the specific. Moreover, if it were the case that elements rather than the whole concept were damaged, then access to remaining information of the concept would depend upon the degree of overlap with other concepts. According to Schaeffer and

Wallace, reaction time can be accepted as a measure of this overlap, therefore the agnosic patient should retain those relations to which the normal subject responds most rapidly. This appears not to be the case. For example the normal subject would respond faster to "Is a duck a bird?" than "Is a duck an animal?". Yet the agnosic patient finds the latter question easier.

The present evidence for hierarchical organization is the relative preservation of broad category information and the relative vulnerability of specific attribute and specific associative information. Using multi-choice methods and probe techniques there is some evidence from both the visual and auditory modality that for a given concept superordinate information may be accessible when subordinate information is not. To refer to the often-quoted example of the canary, these patients could correctly categorize it as living, animal, and bird (the attributes of these superordinates still being known) but could not reliably classify it as yellow, small, and pet. This leads one to question the precise operation of the hierarchical organization proposed by Collins and Quillian. In their model it is possible to move in either direction from any given word concept, the node in a hierarchy, from the general to the specific or *vice versa*. For a concept at the limits of the hierarchy only movement in one direction can be possible. For example, the semantic categorization of the word "mallard" could be represented as follows: mallard → duck → bird → animal → living. Thus in moving up the hierarchy from the subordinate to the superordinate the full semantic meaning of the concept is attained. Here the converse is proposed; with the concept, "mallard", either the word or the object would first be categorized as living then as an animal then as a bird then as a duck and so on *down* the hierarchy. The semantic categorization could then be represented as follows: mallard → living → animal → bird → duck → species of duck. This model to some extent mirrors the acquisition of concepts in development, blunt broad concepts gradually becoming differentiated. For example, children learn the concept animal (though probably not the word) before being able to differentiate between very familiar animals such as dogs and cats (Clark, 1973).

It has been shown that the correspondence of the deficit for words and for visual objects is far from complete. E.M. was often able to recognize the visual representation of a concept but not the verbal, and A.B. was often able to recognize the verbal but not the visual representation of a concept. If agnosia could be adequately accounted for by a disconnection syndrome, that is a failure of input or a failure of transmission of information to the semantic memory system, then such a visual/auditory discrepancy would present no problem. It is not implausible to suggest that inputs from the visual and auditory modalities take separate routes, one of which might sustain greater damage than the other. Indeed Geschwind (1965) argues, by analogy with the syndrome of dyslexia without dysgraphia, that object agnosia be considered in terms of a "disconnection" syndrome. The present findings, however, are more plausibly interpreted in terms of damage to the semantic memory system itself. The evidence of hierarchical organization demonstrated by partial semantic analysis of concepts is particularly compelling in this regard. Furthermore each patient showed a remarkable degree of internal consistency. Their repertoire of known and unknown words or objects hardly

fluctuated with time or fatigue. On the other hand semantic variables were crucial, e.g. frequency and concreteness. Indeed it will be argued elsewhere that the disconnection syndrome has very different properties from those described here (Shallice and Warrington, in preparation).

If this formulation is appropriate, the implications of the partial double dissociation of visual and verbal semantic memory are far-reaching. It raises the possibility of structurally and presumably functionally partially distinct modality-specific meaning systems. That is, a particular concept, say "canary", would be represented in two semantic memory hierarchies, the one primarily visual and the other primarily verbal. Developmentally this is not an entirely absurd suggestion; the visual world of an infant is well differentiated long before language is acquired. If this speculation holds then it follows that verbal concepts during acquisition are not mapped directly on to previously existing visual concepts. Thus in the adult where dissolution of function can be observed the double dissociation of visual and verbal semantic memory would be explicable.

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References

BADDELEY, A. D. (1966). Short-term memory for word sequences as a function of acoustic semantic and formal similarity. *Quarterly Journal of Experimental Psychology*, **18**, 362–5.

BROWN, W. P. and URE, M. J. (1969). Five rated characteristics of 650 word association stimuli. *British Journal of Psychology*, **60**, 233–49.

CLARK, E. V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In *Cognitive Development and the Acquisition of Language*. New York and London: Academic Press.

COLLINS, A. M. and QUILLIAN, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behaviour*, **8**, 240–7.

COLLINS, A. M. and QUILLIAN, M. R. (1970). Experiments on semantic memory and language comprehension. In GREGG, L. W. (Ed.), *Cognition in Learning and Memory*. New York: John Wiley & Sons Inc.

CONRAD, R. (1964). Acoustic confusion and immediate memory. *British Journal of Psychology*, **55**, 75–84.

CRITCHLEY, M. (1953). *The Parietal Lobes*. London: Edward Arnold.

DE RENZI, E., SCOTTI, G. and SPINNLER, H. (1969). Perceptual and associative disorders of visual recognition: relationship to the site of cerebral lesion. *Neurology*, **19**, 634–42.

DE RENZI, E. and SPINNLER, H. (1966). Facial recognition in brain-damaged patients. *Neurology*, **16**, 145–52.

DE RENZI, E. and VIGNOLO, L. A. (1962). The token test. A sensitive test to detect receptive disturbances in aphasics. *Brain*, **85**, 665–78.

GESCHWIND, N. (1965). Disconnection syndromes in animals and man. Part II, *Brain*, **88**, 585–644.

HÉCAEN, H. (1972). *Introduction à la Neuropsychologie*. Paris: Librairie Larousse.

LISSAUER, H. (1890). Ein Fall von Seelenblindheit nebst einem Beitrag zur Theorie derselben. *Archiv für Psychiatrie und Nervenkrankheiten*, **21**, 222—99.

MARSHALL, J. C. and NEWCOMBE, F. (1973). Patterns of paralexia: a psycholinguistic approach. *Journal of Psycholinguistic Research*, **2**, 175–99.

ROMMETVEIT, R. (1968). *Words, Meanings and Messages.* New York and London: Academic Press.

SANDERS, H. and WARRINGTON, E. K. (1971). Memory for remote events in amnesic patients. *Brain*, **94**, 661–8.

SCHAEFFER, B. and WALLACE, R. (1970). The comparison of word meanings. *Journal of Experimental Psychology*, **86**, 144–52.

SCHONELL, F. J. (1942). *Backwardness in the Basic Subjects.* Edinburgh and London: Oliver & Boyd.

SHALLICE, T. and WARRINGTON, E. K. (1970). Independent functioning of the verbal memory stores: a neuropsychological study. *Quarterly Journal of Experimental Psychology*, **22**, 261–73.

SHALLICE, T. and WARRINGTON, E. K. (1974). The dissociation between short-term retention of meaningful sounds and verbal material. *Neuropsychologia*, **12**, 553–5.

SHALLICE, T. and WARRINGTON, E. K. (1975). Word recognition in a phonemic dyslexic patient. *Quarterly Journal of Experimental Psychology*, 187—99.

SHULMAN, H. G. (1971). Similarity effects in short-term memory. *Journal of Verbal Learning and Verbal Behaviour*, **9**, 499–508.

TALLAND, G. A. (1965). *Deranged Memory.* New York and London: Academic Press.

TAYLOR, A. M. and WARRINGTON, E. K. (1971). Visual agnosia: a single case report. *Cortex*, **7**, 152–61.

TAYLOR, A. M. and WARRINGTON, E. K. (1973). Visual discrimination in patients with localized cerebral lesions. *Cortex*, **9**, 82–93.

THURSTONE, L. and JEFFREY, T. E. (1956). *Flags: a Test of Space Thinking.* Chicago Industrial Relations Center.

TULVING, E. (1972). Episodic and semantic memory. In TULVING, E. and DONALDSON, W. (Eds), *Organization of Memory.* New York and London: Academic Press.

VIGNOLO, L. A. (1969). Auditory agnosia: A review and report of recent evidence. In BENTON, A. L. (Ed.), *Contributions to Clinical Neuropsychology.* Chicago: Aldine Publishing Co.

WARRINGTON, E. K. (1974). Deficient recognition memory in organic amnesia. *Cortex*, **10**, 289–91.

WARRINGTON, E. K. and TAYLOR, A. M. (1973). The contribution of the right parietal lobe to object recognition. *Cortex*, **7**, 152–64.

WARRINGTON, E. K. and WEISKRANTZ, L. (1968). A study of learning and retention in amnesic patients. *Neuropsychologia*, **6**, 283–91.

WARRINGTON, E. K. and WEISKRANTZ, L. (1970). Amnesia: consolidation or retrieval? *Nature (London)*, **228**, 628–30.

WARRINGTON, E. K. and WEISKRANTZ, L. (1974). The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia*, **12**, 419–28.

ZINKIN, S. and BIRTCHNELL, J. (1968). Unilateral electroconvulsive therapy: its effects on memory and its therapeutic efficacy. *British Journal of Psychiatry*, **114**, 973–88.

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