Identification without manipulation: a study of the relations between object use and semantic memory

OLIVIER MOREAUD*, ANNIK CHARNALLET and JACQUES PELLAT

Service Neurologie et Neuropsychologie, Centre Hospitalier Universitaire and Laboratoire de Psychologie Expérimentale, Université Pierre Mendès France, Grenoble, France

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Abstract—The role of semantic knowledge in object utilisation is a matter of debate. It is usually presumed that access to semantic knowledge is a necessary condition for manipulation, but a few reports challenged this view. The existence of a direct, pre-semantic route from vision to action has been proposed. We report the case of a patient with a disorder of object use in everyday life, in the context of probable Alzheimer’s disease. This patient was also impaired when manipulating single objects. He showed a striking dissociation between impairment in object use and preserved capacity to perform symbolic and meaningless gestures. To elucidate the nature of the disorder, and to clarify the relations between semantic knowledge and object use, we systematically assessed his capacity to recognise, name, access semantic knowledge, and use 4 common objects. We found no general semantic impairment for the objects that were not correctly manipulated, and, more importantly, no difference between the semantic knowledge of objects correctly manipulated and objects incorrectly manipulated. These data, although not incompatible with the hypothesis of a direct route for action, are better accommodated by the idea of a distributed semantic memory, where different types of knowledge are represented, as proposed by Allport

Key Words: semantic memory^ apraxia^ Alzheimer’s disease.

Introduction

Semantic memory is conceived as a system where our general knowledge about the world is stored. Information in semantic memory is highly interconnected and organised, relatively permanent, and context independent [37]. As Saffran and Schwartz [33] pointed out, ‘the content in semantic memory is generally considered to include information about objects that is relevant to perceptual identification and action, as well as knowledge that underlies the use of words’. A prevalent view in cognitive neuropsychology is that meaning is permanently represented in semantic memory. However, there is still much debate in regard to the number and the organisation of semantic system or systems. Some authors [3, 40] assume that pictures and words give access to separate semantic systems (the multiple semantics hypothesis), while others propose a unitary view [7, 30]. The existence of agnostic patients with relative preservation (in word comprehension and/or picture identification) of non living versus living things, reflects, for some authors [7], the fact that the organisation of the semantic system is taxonomic; this view is challenged by others [39], who claim that semantic memory could be subdivided in different subsystems specialised in visual-sensorial and functional-associative knowledge.

Most studies devoted to semantic memory do not make any reference to the manipulation and use of objects. When this problem is considered, it is usually not the main point of interest, and the methodology does not allow to draw conclusions about what kind of semantic information about an object is necessary to use this object. Despite these inadequacies, different hypotheses have been proposed: manipulation could be accomplished via a non-semantic route by association between the stored structural descriptions of an object and the learned action routine [30]; manipulation could require ‘access to a conceptual system where the functions and uses of an object are represented’ [24, 32]. Another view [1] maintains that the properties of an object are encoded in a number of ‘attribute domains, encompassing every class of sensory and motor (action-related) attributes pertaining to the particular object concept’; each object con-
cept is represented as a pattern of auto-activation over featural units in different attribute domains that have become ‘auto-associated’. This model suggests that the neural elements devoted to perception and motor organisation are ‘directly involved in the auto-associated activity patterns that represent object-concepts’.

A few reports directly assessed the nature of the relationships between semantic memory and object use. Sirigu et al. [35] described a patient with associative visual agnosia, who could give precise information about manipulation, or manipulate objects, despite severe problems to identify them by vision, touch and sound, and inability to describe their function. The authors postulate that this dissociation is in favour of a direct non-semantic sensorimotor route mediating some degree of object use. However, this route was not sufficient to allow the patient to use objects according to their function, suggesting that access to semantic memory was, at least in part, necessary for correct utilisation. Although the authors do not refer explicitly to it, it seems that their hypothesis of a direct route is akin to Riddoch’s one [30]. More recently, Buxbaum et al. [6] described two patients with degenerative disease: one, DM, in the context of loss of functional and associative knowledge, remained able to use objects and to perform more complex tests of action; the other, HB, exhibited the reverse pattern, i.e. an inability to perform action tasks (although he could use single objects) without any impairment in semantic memory. The data are interpreted as suggesting that ‘semantic memory is neither necessary, nor sufficient to ensure good object utilisation in naturalistic action’. However, the interpretation is limited by at least two facts: first, HB’s impairment of action seems to originate in a trouble of executive functions and planning, and his errors in action are not found in single object use; second, in DM, the semantic knowledge relative to objects that are manipulated is not systematically assessed, and one can not be sure that it is impaired.

We report the case of a patient with a disorder of object use in everyday life, in the context of a degenerative disease. This patient was also impaired when manipulating single objects. Moreover, he showed a striking dissociation between impairment in object use and preserved capacity to perform symbolic and meaningless gestures. To elucidate the nature of the disorder, and to specify the relations between semantic knowledge and object use, we systematically assessed his capacity to recognise, name, access semantic knowledge, and use 15 common objects. The patient was tested without any a priori about the structure of semantic memory. We will show in the discussion that the data fits quite well with Allport’s conception of distributed sub-domains [1].

**Case report**

EJ, a right-handed man (born 1944) began to experience serious difficulties in his professional activity (accountant in a bank) in the course of 1992. These difficulties were the source of frequent conflicts with his co-workers. They were first attributed to depression. Indeed, EJ looked sad, unconfident in himself, and progressively decreased his activities. At that time, he admitted that his memory was not as good as before, and complained of calculation and writing disorders. Things got worse, and EJ could not sustain his work anymore. A treatment with fluoxetine did not alter the evolution. Formal testing (10/95) revealed impaired general intellectual level. EJ scored only 11 in (45 mn) at the Raven’s Progressive Matrices [28]; the digit symbol and similarities subtests of the WAIS-R [41] yielded a score of 1/20. MMSE [14] at that time was 21/30. Verbal digit span was 7 forward and 2 backwards. On Battery 84 [34], a French standardised test of long-term learning, immediate and delayed recall of verbal and visual material was more than 2 standard deviations below the norm. On Wisconsin Card Sorting Test [23], only 3 criteria out of 6 were achieved, with 12 perseverative errors. Trail Making Test [29] part A was completed in 56 s, but part B could not be finished due to deficit of shifting. Spontaneous language was fluent, with at times paraphasias and word-finding difficulties, but pictures, famous faces, and colour naming on confrontation was normal. Formal and semantic category fluency was reduced. Comprehension was only slightly impaired. Dysorthography was evident on spontaneous writing, and spelling and calculation were impossible. EJ exhibited constructional apraxia and an impairment of transitive gestures pantomime. There was no evidence of visuo-perceptual disorder [20].

Personal and familial history, neurological examination, and standard biological tests in serum and CSF, were unremarkable. A cranial MRI showed moderate cortical and subcortical atrophy. A diagnosis of probable Alzheimer’s disease was proposed, according to widely used criteria [22], and a treatment with tacrine was started. No positive effect was seen, and tacrine was discontinued due to inefficacy and serious cholinergic side-effects. EJ soon became unable to perform even simple daily activities, like washing, shaving, or dressing, and could not leave home unaccompanied anymore. His wife noticed that he was totally deficient in the use of objects, even when strongly incited or shown the correct gesture. EJ’s spontaneous speech became less informative, with frequent paraphasias, circumlocutions, and word-finding difficulties, but his comprehension remained relatively preserved, and on a picture naming test, only a slight anomia was noted. He was more and more distractable and less aware of his deficits. Despite this, his behaviour remained very well adapted, and he was very co-operative.

The experiment described below filled in a period of about 3 months, during which EJ’s deficits were stable. MMSE score was 10/30. Performance was just below normal limits on DO80, a French standardised test of naming of line drawings [8]. EJ was able to match black
and white photographs of objects taken under different points of view. On the Pyramids and Palm-trees Test [19], performance was low, according to norms for age and education, both in the visual (31/52) and verbal (36/52) modalities. We reassessed executive functions after the end of the experiment sessions; performance is not reported because most of the tasks were either impossible, or, if performed, out of time-limits. Writing and copying of simple figures were severely impaired.

**Experimental investigations**

We systematically evaluated EJ’s capacities to identify, name, and use a set of 15 common objects (compasses, pencil sharpener, scissors, candle, nail file, camera, stapler, hair drier, corkscrew, telephone, whistle, cheese grater, nail cutter, can opener, and bottle opener). For each of them, we tested, in the following order (all tests were completed for an object, before testing the next object):

- naming
- access to semantic knowledge:
  - spontaneous knowledge of use (‘what is it used for?’)
  - three-choice probe questions (4 questions for each object, assessing knowledge of the precise use, manipulation, and contextual and functional knowledge). For example, for the stapler, questions were:
    - Is it used to cut, separate, or join sheets of paper?
    - To use it, must you lean, pull, or separate a part?
    - Is it used by doctors, pupils or hairdressers?
    - Is it used to do odd jobs, office job, or cooking?
  - matching by identity: matching with an identical but visually-different object, in the presence of a visual distractor (for example, matching a telephone with another type of telephone, in the presence of a pocket calculator).
- matching by function: matching with another object that is used with the target object, in the presence of a semantic distractor (for example, camera, film, and battery).
- pantomime of use, on visual presentation of the object, and on verbal command (for example, ‘show me how you use a stapler’).
- object use.

EJ’s capacity to identify 12 symbolic and 14 transitive gestures (pantomime of object use) from photographs, and to perform 12 symbolic (on verbal command) and 10 meaningless gestures, was also assessed.

Gestures were rated as correct when performed without error. In case of errors, their type was recorded, and the gesture was considered incorrect. The whole performance of the patient was videotaped.

**Results**

The results of the different tasks about objects are described in Table 1. Eight objects were normally manipulated (53%); probe questions were correctly answered for 6 of them (75%, vs 71% for the 7 objects not manipulated). The type of manipulation required was known for 6/8 objects (75%, vs 71%). Matching by function failed for 1 (12.5%, vs 28%), matching by identity for 1 (12.5%, vs 14%). Name was found for 4 (50%, vs 42%). The questions about use were correctly answered for all objects.

When an object was not used, the errors were always of

<table>
<thead>
<tr>
<th>Objects</th>
<th>Object use</th>
<th>Imitation</th>
<th>Pantomime (visual)</th>
<th>Pantomime (verbal)</th>
<th>Name</th>
<th>Knowledge of use</th>
<th>Questions</th>
<th>Matching by identity</th>
<th>Matching by function</th>
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<tbody>
<tr>
<td>Compasses</td>
<td>+</td>
<td>NP</td>
<td>+</td>
<td>–</td>
<td>–</td>
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<td>4/4</td>
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<td>Pencil sharpener</td>
<td>+</td>
<td>NP</td>
<td>–</td>
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<td>+</td>
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<td>4/4</td>
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<td>Scissors</td>
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<td>NP</td>
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<tr>
<td>Hair drier</td>
<td>+</td>
<td>NP</td>
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<td>Telephone</td>
<td>+</td>
<td>NP</td>
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<td>Whistle</td>
<td>+</td>
<td>NP</td>
<td>–</td>
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<td>Cheese grater</td>
<td>+</td>
<td>NP</td>
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<td>Can opener</td>
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<td>Candle</td>
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<td>Nail file</td>
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<td>4/4</td>
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<td>Stapler</td>
<td>–</td>
<td>–</td>
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<td>Corkscrew</td>
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<td>Nail cutter</td>
<td>–</td>
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<td>+</td>
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<td>3/4</td>
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<td>NP</td>
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<td>Bottle opener</td>
<td>–</td>
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<td>–</td>
<td>+</td>
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<tr>
<td><strong>Total</strong></td>
<td>8/15</td>
<td>2/7</td>
<td>3/15</td>
<td>4/15</td>
<td>7/15</td>
<td>9/15</td>
<td>100% for 11/15</td>
<td>13/15</td>
<td>11/14</td>
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+ = Correct; – = Incorrect; NP = Not performed.
the same type: no response, perplexity, prolonged visual inspection of the object, manipulation of parts of the object without global use. Only one perseveration was noted. Even when the object was manipulated, the correct performance was reached after several hesitations, and at no times was immediate. When pantomiming, errors were of the same kind, with absence of response being more frequent; there was neither body part as object, nor spatial or timing errors [17]. Imitation improved performance in only 2/7 cases (28%). At some rare instances, EJ showed normal but fugitive performance, usually at the very moment he saw an object, although this performance could never be reproduced afterwards, and although EJ never showed any automatic-voluntary dissociation and did not have any fluctuation of his performance from a session to the other. It may be important to note here that EJ was asked to use 4 of the objects (telephone, hair-drier, corkscrew, and whistle) at two different sessions (separated by a period of approximately 6 weeks), and that he showed similar performance. Unfortunately, deterioration of his cognitive status prevented us to retest his performance for all objects.

Table 2 shows the comparisons of semantic knowledge for objects correctly used and objects for which manipulation failed. There is no significant difference between objects correctly and incorrectly manipulated. These results suggest that semantic knowledge (including verbally expressed knowledge of object use) and capacity to use an object are independent.

The performance in object use contrasts with almost perfect performance for symbolic gestures (10/12; 83%) and gestures without signification (9/10; 90%). These gestures were immediately performed, without any hesitation. Identification was correct for 11/12 symbolic (92%) and 11/14 transitive (78%) gestures.


discussion

EJ suffers from a severe impairment in the use of objects, in the context of a degenerative disease. This impairment contrasts with almost normal performance for symbolic and meaningless gestures. EJ has no global semantic impairment for the objects tested, and access to semantic knowledge is comparable for the objects correctly and incorrectly manipulated. We will first discuss the nature of the disease producing this disorder; then we will discuss the results of the experimental study, with an attempt to specify the relationships that could exist between semantic knowledge and utilisation of an object. We will try to see the implications for models and functional anatomy of semantic memory and we will propose a tentative hypothesis to account for the preservation of symbolic and meaningless gestures.

Nature of the disease

EJ suffers from a slowly progressive disease, taking its course in several years. This, in conjunction with the normality of ancillary procedures, is strongly in favour of a degenerative process, with presenile onset.

The early severe impairment of executive functions in EJ could suggest a diagnosis of frontal lobe dementia (FLD). However, severe behavioural abnormalities predominate in FLD, and usually reveal the disease; praxis and visuo-spatial functions remain normal until the end [26, 36]. Cortico-basal degeneration [31] and diffuse Lewy body disease [21] are easily ruled out, based on the nature of cognitive and praxis impairment, and the absence of extrapyramidal signs.

The most plausible hypothesis then seems to be Alzheimer’s disease (AD): insidious onset with depressive symptoms and change in personality, and early mnestic impairment, are the rule. The secondary emergence of an impairment of language, praxis, visuo-spatial and visuo-constructive functions, and semantic memory (assessed by the PPT), is also very suggestive of AD [20]. What seems at first glance more surprising is the nature of the gesture disorder in EJ. There are not much studies of praxis in AD, and most of them do not test real use of object. Since De Ajuriaguerra’s pioneering work [9, 10], the conception of a progressive disintegration of praxis in AD is widely accepted, and no study has fundamentally

<table>
<thead>
<tr>
<th>Manipulation +</th>
<th>Manipulation −</th>
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<tr>
<td>Spontaneous knowledge of use</td>
<td>6/8</td>
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<tr>
<td>Probe questions</td>
<td>29/32</td>
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<td>Matching by identity</td>
<td>7/8</td>
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<td>Matching by function</td>
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challenged this view. Constructional apraxia appears first, followed by disturbance of symbolic gestures and difficulty to pantomime transitive gestures; utilisation of objects is only lately impaired. The errors that are observed are frequently spatial or temporal errors, or body-part as objects, and then suggest ideomotor apraxia [27]. No such errors were observed in EJ, and object use was more impaired than symbolic gestures. However, the rare studies that specifically assessed object use in AD show that the errors are typically content errors, i.e. no responses or irrelevant movements [24], with perplexity and indecision [4]. These errors are those we observed in EJ, so that we may consider that EJ’s disorder of gesture is not incompatible with a diagnosis of AD.

Nature of the deficit and implications for the structure of semantic memory

EJ presents an isolated impairment of the utilisation of objects. This impairment cannot be explained by perceptual abnormalities, nor by poor comprehension. A disorder of execution is very implausible: symbolic and meaningless gestures are almost perfectly performed, and we did not observe spatial and timing errors. The errors are rather those encountered in ideational or conceptual apraxia. The definition of ideational apraxia (IA) is far from consensual, but it is usually considered to result in a difficulty to perform complex sequential gestures. De Renzi and Lucchelli [11] propose that, in fact, for several reasons, IA may be provoked by any gesture where an action must be evoked, even it is more easily elicited in complex actions requiring multiple objects: complex actions place a heavy load on working memory and attentional resources, they give rise to more frequent errors, and it is easier to discriminate between conceptual and executive errors. IA is generally interpreted as a result of semantic memory impairment. However, no reference is made to models of semantic memory, and correlation with other aspects of semantic knowledge is hardly, if ever, made. Barbieri and De Renzi [2] propose that IA is ‘a form of semantic amnesia, due to the defective activation of the memories of actions’. Ochipa et al. [25] define IA as ‘a loss of conceptual knowledge related to tool use’. These authors describe a patient with IA who had lost the knowledge of tool function; although he could name and point out to objects he could not use, he was not able to identify them by function and describe their function. They consider that IA is the consequence of an impairment of a conceptual system where representations of function and use of objects are stored [24].

The nature of the representations in this system is not clear, although it seems that they can be accessed by different modalities (visual, tactile, or verbal). It is also not clear if these conceptual praxis system may be fractionated from a general conceptual system [18].

EJ’s performance in the utilisation of objects suggests the presence of IA. However, the results of our experimental testing are difficult to accommodate with a uniform damage of the semantic system: EJ does not suffer from a general semantic impairment, since he is able to name, identify, and answer semantic questions about objects he can not use. More interestingly, he does not make any error on questions assessing knowledge of use, and he spontaneously gives the function of three objects he can not manipulate. There is also no correlation between the ability to manipulate and the verbal knowledge about manipulation. This pattern of performance is for us compatible with the idea of a distributed semantic memory, where different types of knowledge are represented, as proposed by Allport [1]. Such a model would also explain why other types of gestures are preserved, and could be reconciled with anatomical data. Indeed, when we learn to use objects during our cognitive development, strong connections are established between sensorial (visual and tactile) domains, and action-based knowledge. We could presume that EJ’s connections between sensorial and motor domains are disrupted, preventing correct utilisation of an object presented in a visual and/or tactile modality. EJ’s action-knowledge does not seem to be completely cancelled, as EJ can recognise transitive gestures, and sometimes perform correctly a gesture, but very fleetingly and without being conscious of it, just as if he implicitly gained access to it.

Pantomimic on verbal modality is impossible, because it is probably necessary to access a representation of sensorial features, stored in sensorial domains, before miming; furthermore, it is well known that pantomime is difficult and not ecological [27]. Conversely, symbolic gestures are well performed, because they are learned by direct association between verbal knowledge and action, and do not call to sensory properties. The preservation of meaningless gestures may reflect the fact that EJ does not suffer from a deficit of execution, or that meaningless gestures are particular types of gestures, requiring general knowledge about the body schema, and which preservation or impairment may be independent of preservation or impairment of meaningful gestures [16]. What is not clear to us is why EJ is not much improved by imitation in the actual use of objects. Perhaps this reflects the fact that EJ’s deficit is so important that it contaminates the performance and prevents correct imitation.

Our results are not totally incompatible with the existence of a direct route from vision to action [30]. However, we must presume in EJ that this route is interrupted, since he can not manipulate despite intact stored structural descriptions, and that the route from semantic system to action is disrupted too. The existence of two such lesions in the context of a degenerative disease may be plausible, but this is not a very economic way to accommodate the data, that can be more easily explained by Allport’s model [1]. This model may also account for the performance of patients FB [35] and DM [6]. Moreover, FB constitutes a double dissociation with EJ, since FB can manipulate an object, even if he does not
access to semantic knowledge about it. This suggests that a correct identification of an object is not a guarantee of a correct manipulation, and vice-versa.

Anatomical considerations

The exact anatomical loci implicated in semantic memory are still to be known, but data are available, based on lesions of patients suffering from semantic memory disorders, and on results of functional imaging studies. Taken together, these data suggest that semantic memory is distributed in multiple cortical regions, including lateral temporal cortex and presumably prefrontal cortex, preferentially in the left hemisphere. Recently, Decety et al. [12] designed a PET study where transitive and meaningless gestures were observed, with the aim, either to identify them, or to imitate them. The results are that the observation of transitive gestures in order to imitate activates regions implicated in planning and motor control (dorsolateral prefrontal cortex, and anterior supplementary motor area (SMA), preferentially on the left) and in object recognition (left inferior frontal and left middle temporal gyrus). EJ’s capacity to identify objects was normal for objects he could not use, and we can assume that his ventral occipito-temporal pathway is functional. SMA is presumably intact since EJ has no execution problems. What could be impaired are the pathways linking the regions implicated in visual (and tactile) knowledge, and regions implicated in motor planning, particularly the left DLPF. We do not intend to identify left DLPF as the place where semantic for action is represented, but it is probably an important region for planification of actions that have a semantic content. This is in agreement with involvement of the left DLPF in tasks that implies access to semantic representations [5, 13, 15, 38, 42], and with the fact that Decety et al. [12] found no activation of this region when meaningless gestures were to be imitated.

Conclusion

EJ presents a severe deficit of the manipulation of objects. His access to semantic knowledge about objects seems well preserved, and is not different for objects correctly and incorrectly manipulated. The data from our study and others in the literature, suggest a relative independence between semantic knowledge and manipulation. They are in agreement with the idea of a distributed semantic memory, where different types of knowledge are represented, as proposed by Allport [1].

References


