Semantic memory in object use

Maria Caterina Silveri*, Nicoletta Ciccarelli

Memory Clinic, Centre for Medicine of the Ageing, Catholic University, Largo Agostino Gemelli 8, 00168 Rome, Italy

A R T I C L E   I N F O

Article history:
Received 16 December 2008
Received in revised form 11 March 2009
Accepted 20 May 2009
Available online 29 May 2009

Keywords:
Semantic dementia
Herpes simplex encephalitis
Ideational apraxia
Motor memory

A B S T R A C T

We studied five patients with semantic memory disorders, four with semantic dementia and one with herpes simplex virus encephalitis, to investigate the involvement of semantic conceptual knowledge in object use. Comparisons between patients who had semantic deficits of different severity, as well as the follow-up, showed that the ability to use objects was largely preserved when the deficit was mild but progressively decayed as the deficit became more severe. Naming was generally more impaired than object use. Production tasks (pantomime execution and actual object use) and comprehension tasks (pantomime recognition and action recognition) as well as functional knowledge about objects were impaired when the semantic deficit was severe. Semantic and unrelated errors were produced during object use, but actions were always fluent and patients performed normally on a novel tools task in which the semantic demand was minimal. Patients with severe semantic deficits scored borderline on ideational apraxia tasks. Our data indicate that functional semantic knowledge is crucial for using objects in a conventional way and suggest that non-semantic factors, mainly non-declarative components of memory, might compensate to some extent for semantic disorders and guarantee some residual ability to use very common objects independently of semantic knowledge.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

There are reports in the literature of patients with preserved ability to use objects in spite of impaired object recognition (Buxbaum, Schwartz, & Carew, 1997; Hodges, Spatt, & Patterson, 1999; Hodges, Bozeat, Lambon Ralph, Patterson, & Spatt, 2000; Lauro-Grotto, Piccini, & Shallice, 1997; Negri, Lunardelli, Gigli, & Rumiati, 2007; Sirigu, Duhamel, & Poncet, 1991). Single patients presenting the opposite pattern, that is, inability to use objects whose conceptual knowledge is preserved, have also been reported (Hodges et al., 1999; Ochipa, Rothi, & Heilman, 1989; Rumiati, Zanini, Vorano, & Shallice, 2001; Silveri & Ciccarelli, 2007) and there is also some evidence from group studies (Buxbaum & Saffran, 2002; Cubelli, Marchetti, Boscolo, & Della Sala, 2000; Rosci, Chiesa, Laiacona, & Capitani, 2003).

Different explanations of this “double dissociation” have been provided. According to the original hypothesis, object semantics and action semantics represent dissociable aspects of meaning (McCarthy & Warrington, 1985). This hypothesis was to some extent reformulated by Lauro-Grotto et al. (1997) to account for a patient in which information accessed from visually presented items was able to trigger complex action procedures, but who failed to perform even simple verbal tasks on the same items. They assumed that within the hypothesis of a multimodal semantic system (McCarthy & Warrington, 1988), in which verbal semantic and visual semantic are considered dissociable components of meaning, action semantic has a privileged access from visual semantic. The authors did not, however, consider action semantic as a specific component of the visual semantic system.

In patients with semantic deficits due to semantic dementia (Snowden, Goulding, & Neary, 1989), a high correlation was found between the degree of impairment to both verbal and visual non-action aspects of semantic knowledge and the ability to demonstrate how to use objects (Hodges et al., 2000). These results led the authors to conclude that there is no evidence to postulate a separate action component of the semantic system and that an object may be correctly used by relying on residual conceptual semantic knowledge, supplemented to some degree by a combination of non-semantic factors, such as visual affordance and mechanical problem solving.

The relationship between conceptual knowledge about objects and the ability to use objects has also been discussed by authors who started from the concept of ideational apraxia, a disorder of skilled movements that cannot be attributed to motor deficits or mental deterioration (Heilman & Rothi, 1993). Buxbaum et al. (1997) assumed that at least residual semantic knowledge is necessary for the correct use of objects. In particular, they claimed that object manipulation should require interaction between functional/associational semantic knowledge and non-semantic information, such as sensorimotor elements directly recruited from

* Corresponding author.
E-mail address: silveri@rm.unicatt.it (M.C. Silveri).
perception (affordance). According to this view, physical affordance that supports object use from sensorimotor input derived from the physical characteristics of objects is not sufficient to elicit a correct action plan because it does not account for the purposes of conventional action.

More recently, Negri, Lunardelli, et al. (2007) described two patients (one with semantic dementia and the other with Alzheimer's disease) whose knowledge about objects and ability to use objects correctly declined independently. The authors interpreted this pattern as evidence that semantic conceptual knowledge is not necessarily involved in object use but that object use might be guaranteed by a motor memory independent from, but interacting with, semantic knowledge and modularly represented in the brain.

To summarize, the extent to which semantic memory is involved in object use is still unclear. To contribute toward clarifying this issue we investigated object knowledge and object use in patients affected by pathologies that typically produce semantic memory disorders, semantic dementia and herpes simplex encephalitis.

2. Methods

2.1. Participants

Four patients with semantic dementia (SD) and one patient who had recovered from herpes simplex encephalitis (HSE) were given a test battery to investigate object knowledge and object use.

2.1.1. SD patients

All patients (GG, CB, CL and RP) presented a typical history of semantic disorder, that is, progressive loss of the meanings of words and objects on both production and comprehension tasks, with relatively good preservation of episodic memory, visuo-spatial and “high-level” abilities, and everyday activities. Phonological and grammatical aspects of language were also preserved. All subjects underwent an MRI-scan (Fig. 1) and a functional study (SPECT) that confirmed asymmetric (> in the left) bitemporal damage. RP had a mild disorder (mostly anomia), whereas the other patients had semantic deficits that ranged from severe (GG) to moderate (CB and CL). CB and CL were administered the experimental battery twice, at the beginning of the study and after an interval of approximately 2 years.

2.1.2. HSE patient

OC was a 50-year-old woman who was sent from the Department of Infectious Diseases of Catholic University to the Rehabilitation Unit of the same hospital. She had received a diagnosis of HSE two months earlier, had been treated with antiviral therapy (acyclovir), and had experienced a partial remission of symptoms. When she was admitted to the Rehabilitation Unit, OC presented severe episodic and semantic memory deficits. The MRI showed bilateral involvement of the deep temporal structures primarily in the right hemisphere (Fig. 1).

Fifteen normal subjects (10 females and 5 males; mean age = 68.13 (7.93) and mean education = 9.60 (4.25)) were selected from the patients’ spouses or from the subjects attending a fitness program at the Centre for the Medicine of the Ageing. Patients and controls were matched for age (p > 0.1) and education (p > 0.1).

All patients and controls gave their formal consent to participate in the study. Patients demographic data are reported in Table 1.

2.2. General neuropsychological examination

All patients were administered a neuropsychological test battery that included memory tasks (immediate and delayed free recall of 15 words, forced choice of 15 words, recall of the Rey-Osterrieth complex figure, verbal and spatial span), verbal and semantic fluency, non-verbal problem solving (Raven’s Coloured Matrices), and visuo-spatial exploration (line barrages). Patients were also administered the MMSE, as a general measure of mental deterioration, and four subsets of Warrington and James’s (1991) VOSP (Visual Object and Space Perception Battery; Shape detection screening test, Incomplete letters, Number location and Dot counting). Face perception was evaluated by the Benton Facial Recognition test (Short version; 1968). Several subsets of the BADA (Miceli, Laudanna, Burani, & Capasso, 1994) and the Token test were also given to explore the linguistic function.

2.3. Semantic assessment

Patients underwent a detailed examination of pre-categorical visual processing and stored information using subsets taken from the Birmingham Object Recognition Battery (BOR; Riddoch & Humphreys, 1993). Patients were also administered the Naming test (40 living and 40 non-living items), the Intercategorial and Intracategorial Comprehension task (Laiacona, Barbarotto, Trivelli, & Capitani, 1993), the Face Familiarity task and the Face Recognition task (De Renzi, Faglioni, Grossi, & Nichelli, 1991).

2.4. Apraxia assessment

Ideational and ideomotor apraxia were evaluated using the tasks proposed by De Renzi and Lucchelli (1988). The Movement Imitation test (MIT) comprises 24 gestures, half symbolic and half nonsymbolic. The Multiple Object Test (MOT; a slight
modified version was given) assumes that the ideational disorder may be better identified by tasks requiring the use of more than one object at a time. This task requires performing gesture sequences using different objects (e.g., to open and then close a padlock with the key). Three gesture sequences are requested (total score = 13).

### 2.5. Action Program

In this test the subject is faced with a practical task that requires developing a plan of action to solve a problem (Wilson, Alderman, Burgess, Emslie, & Evans, 1996). This task allows investigating the ability to infer function from the physical features of tools; it also requires planning multi-step actions. In any case, normal performance on this task indicates normal ability to infer function from structure.

### 2.6. Exploring object knowledge and object use

We applied a slightly modified version of a battery devised to investigate object use in patients with ideational apraxia, which was described in detail in a previous study (Silveri & Ciccarelli, 2007). The battery includes recognition and production tasks comprised of sixteen commonly used manipulable objects.

#### 2.6.1. First set: Object Naming, Pantomime execution, Object use

The subject is requested to name objects (Object Naming), presented one at a time, and then to demonstrate how the object should be used, without any manipulation (Pantomime execution). Then, the examiner gives the object to the patient and asks him to actually use it (Object use). The patient receives no feedback from the examiner about the correctness of his/her responses on the various tasks. The tasks are given in the sequence in which they are described above.

Subjects’ performances were videotaped and then evaluated by two independent raters.

A score of one was assigned only if both raters scored the performance as correct. Object naming was scored as correct when the correct noun or a synonym (e.g., cellulare/telefonino—CELLULAR PHONE/LITTLE PHONE) was produced. Most errors produced were anomas and semantic paraphasias.

#### 2.6.2. Second set: Recognition of correct use, Pantomime recognition, Action recognition

Three tasks were devised to investigate patients’ ability to recognize object use. The first task (Recognition of correct use) is a forced-choice task exploring functional aspects of semantic knowledge about objects. For each of the 16 objects three types of actions were generated, for a total of 48 items, each represented in a color picture: (1) action representing the correct use; (2) action representing a semantically related action; (3) action representing incorrect use due to incorrect hand or object position. Items are given one by one. The patient is requested to say whether the object is or is not used correctly. The pictures are presented on a video display in fixed random order. Hits and false alarms are computed and converted into accuracy scores ranging from 50 (random) to 100. In the second task the examiner pantomimes the use of the object and the patient is requested to name the object whose use the examiner is pantomiming or to name the action the examiner is pantomiming (Pantomime recognition). In the third task the patient is requested to name the action the examiner is performing with the object (Action recognition-naming). Answers such as “you are using the pen” in the place of “writing” are not accepted.

### 3. Results

#### 3.1. General neuropsychological examination

Table 2 summarizes the results. All SD patients presented with the typical pattern of semantic memory deficit, with anomas, word comprehension deficits and reduced categorical word fluency. Episodic memory was relatively preserved also in patient GG who had a 9-year history of disease. Short-term memory,
visual–perceptual tasks, and planning and reasoning were largely preserved in RP, whereas in GG and CL they were moderately impaired. OC (HSE) demonstrated a mild deficit in the semantic memory tasks and the episodic memory tasks as well as in reasoning and planning. Sentence comprehension was preserved in all patients. GG and CB scored below the cutoff in letter fluency. No major deficit was detected in visuo-perceptual tasks in either patient. Only CB and CL obtained pathological scores in Benton’s facial recognition test (Benton & Van Allen, 1968).

3.2. Semantic assessment

Patients obtained normal scores on most tasks evaluating pre-categorical visual processing and access to stored information (Riddoch & Humphreys, 1993) and pathological scores on most verbal semantic tasks (Table 3).

3.3. Apraxia and Action Program (Table 4)

All patients performed normally on tasks exploring ideomotor apraxia (Movement Imitation task); CB, RP and OC also obtained normal scores on the ideational apraxia task (Multiple Object test, De Renzi & Lucchelli, 1988), but GG and CL scored borderline. On the Action Program (from the BADS, Wilson et al., 1996) all patients performed at ceiling.

3.3.1. Comment

Disease duration was not homogenous and severity of the semantic deficit was comparatively different: RC and OC had a mild disorder, whereas GG, CB and CL had semantic deficits that ranged from moderate to severe. No patient presented signs of ideomotor apraxia. Only GG and CL scored borderline on tasks formally exploring ideational apraxia (MOT, De Renzi & Lucchelli, 1988). All semantic dementia patients (even those with severe dementia) performed normally on the Action Program test (Wilson et al., 1996). These results indicate that even when patients suffered from a severe semantic deficit they were able to extract the information necessary to organize correct object manipulation from the physical characteristics of the novel objects, a task in which semantic demand is minimal; nevertheless, some very mild disorders emerged when recognition of manipulable objects was necessary to perform a complex sequence of actions, such as in the MOT (De Renzi & Lucchelli, 1988).

3.4. Object knowledge and object use

3.4.1. Object naming, Pantomime execution, Object use

Controls performed at ceiling. All patients performed worse than controls in Object naming and Pantomime execution. GG, CB and CL were also pathological in Object use (Table 5). All patients scored better in pantomiming than in object naming task (naming vs. pantomiming: 37/80 vs. 58/80; Fisher Exact Test, two-tailed, \( p < 0.001 \)). When they had the possibility of manipulating the object their performance improved further, and although the difference was not significant (58/80 vs. 66/80), it was better than their pantomiming performance. However, it is worth noting that although patients CB, RP and OC reached the ceiling when requested to manipulate objects, GG and CL, who presented more severe semantic deficits than the other patients, received little (or no) help from object manipulation. GG, in particular, was not helped by object manipulation; in fact, he was unable to manipulate (correctly use) any of the seven objects whose use he was unable to pantomime.

Consistency between Naming and Object use was found in GG (consistent vs. inconsistent responses: 11/16 vs. 5/16; Fisher Exact Test (one-tailed) \( p < 0.0378 \)). In all other patients the analysis was prevented by ceiling or floor effects. The consistency effect was, however, confirmed on the total number of responses produced by the five patients (consistent vs. inconsistent responses: 38/80 vs. 14/80; Fisher Exact Test (two-tailed) \( p < 0.0001 \)).

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Patients’ performance in pre-categorical visual processing and in semantic tasks (adjusted scores; pathological scores in bold).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GG</td>
</tr>
<tr>
<td>BORB</td>
<td></td>
</tr>
<tr>
<td>Object decision</td>
<td>18</td>
</tr>
<tr>
<td>Foreshortened match</td>
<td>21</td>
</tr>
<tr>
<td>Minimal feature</td>
<td>22</td>
</tr>
<tr>
<td>Item-match</td>
<td>22</td>
</tr>
<tr>
<td>Association match</td>
<td>20</td>
</tr>
<tr>
<td>Naming test</td>
<td>17</td>
</tr>
<tr>
<td>Inter- and intracategorical lexical comprehension task</td>
<td>100</td>
</tr>
<tr>
<td>Categorical word fluency</td>
<td>0.22</td>
</tr>
<tr>
<td>Face familiarity</td>
<td>4.02</td>
</tr>
<tr>
<td>Face Recognition</td>
<td>7.1</td>
</tr>
</tbody>
</table>

* Errors.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Patients performance in tasks exploring ideomotor and ideational apraxia (De Renzi &amp; Lucchelli, 1988) and in Action Program (Wilson et al., 1996; pathological scores in bold).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement Imitation Task</td>
<td>Multiple Object task</td>
</tr>
<tr>
<td>(MIT; ideomotor apraxia)</td>
<td>(MOT; ideational apraxia)</td>
</tr>
<tr>
<td>Cut-off = 51</td>
<td>Cut-off = 13</td>
</tr>
<tr>
<td>GG</td>
<td>CB</td>
</tr>
<tr>
<td>67</td>
<td>12</td>
</tr>
<tr>
<td>68</td>
<td>13</td>
</tr>
<tr>
<td>59</td>
<td>12</td>
</tr>
<tr>
<td>70</td>
<td>13</td>
</tr>
<tr>
<td>64</td>
<td>13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Performance of patients and controls in Object naming, Pantomime execution and Object use.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object naming</td>
<td>Pantomime execution</td>
</tr>
<tr>
<td>(N = 16)</td>
<td>(N = 16)</td>
</tr>
<tr>
<td>GG</td>
<td>4</td>
</tr>
<tr>
<td>CB</td>
<td>8</td>
</tr>
<tr>
<td>CL</td>
<td>1</td>
</tr>
<tr>
<td>RP</td>
<td>13</td>
</tr>
<tr>
<td>OC</td>
<td>12</td>
</tr>
<tr>
<td>Controls</td>
<td>Mean</td>
</tr>
<tr>
<td>SD</td>
<td>0.72</td>
</tr>
</tbody>
</table>
In the regression analysis naming predicted the ability to use objects (by-item analysis: $\beta = 0.50; p = 0.047$; by-subject analysis: $\beta = 0.90; p = 0.033$). A significant correlation emerged between Object use and two semantic tasks: the “non-living” subset (but not the “living” subset) of the Naming task (Laiacona et al., 1993; $r = 0.919; p < 0.0315$) and the Lexical Comprehension task (Laiacona et al., 1993; $r = 0.9731; p = 0.006$). No significant correlation emerged between Object use and Categorical fluency.

3.5. Qualitative analysis of errors in Object use

A qualitative analysis of errors was performed on the pool of errors produced by GG and CL in Object use (no error was produced by the other three patients). Two raters were instructed to classify the error as “semantic” if the object was used as if it were a semantic related object, “unrelated” if a meaningful action could be identified, even if it was not related to the object, and “generic” if no recognizable action was produced. Inter-rater consistency was very high. In a pool of 14 errors, four were classified as “semantic” by both raters (e.g., pipe used as a hammer), and four as meaningless by the first rater and five by the second rater (e.g., an object moved from one part of the table to another).

3.5.1. Comment

Results clearly demonstrate that only patients with mild semantic impairments were able to use objects correctly. Patients with more severe semantic deficits were unable to mime use and did not receive any real facilitation from manipulation. The consistency between object naming and object use observed in GG and in the overall patients’ performance, as well as the results of the regression analysis, indicate that there is a relationship between knowledge of an object (as proven by correct naming) and the ability to use it. It is worth noting in this respect that in Laiacona et al.’s naming test (1993) only naming of non-living items was significantly correlated with Object use, in agreement with the hypothesis that knowledge about “how to use” an object is a critical feature in the conceptual knowledge of non-living items (Warrington & Shallice, 1984).

Also, the correlation that emerged between object use and some semantic tasks such as naming and lexical comprehension (Laiacona et al., 1993), which were not specifically devised to explore semantic knowledge about the items of the experimental battery, indirectly suggests that the ability to use objects is to some extent dependent on the integrity of the semantic domain.

Patients produced semantic or unrelated errors as well as very general, but correct, actions with the objects. This pattern confirms the non-appractic nature of the errors. Pantomiming and object use were both systematically better than object naming. These results are in agreement with previous reports evaluating the contribution of affordance (vision to motor translation) to object use, compared to object naming which can be exclusively driven by the activation of semantic representation (Coccia, Bartolini, Luzzi, Provinciali, & Lambon Ralph, 2004). Object use was even better than pantomiming in patients with mild semantic disorders. This is plausible as patients might also have been supported by sensory information. However, GG and to some extent CL, whose semantic deficit was severe, were not facilitated by the possibility of manipulating the object, suggesting that non-semantic factors may not appreciably compensate for a severe loss of knowledge about the object (see also comments in the follow-up).

3.5.2. Recognition of object use, Pantomime recognition, Action recognition

All but one patient (RP) scored worse than controls in Recognition of object use. GG, CB and CL were also impaired in Pantomime recognition and Action recognition. Two patients (GG and CL) scored better in Action recognition (naming) than in Pantomime recognition. The other three patients, CB, RP and OC, obtained the opposite score pattern (lower scores in Action recognition than in Pantomime recognition (Table 6). No consistency was found between the two tasks in either patient (RP and OC were at ceiling). Recognition of object use predicted the ability to use objects (by-item analysis; $\beta = 0.576; p = 0.019$). In GG consistent responses were observed between Recognition of object use and ability to use the object (Object use; consistent vs. inconsistent responses: 12 vs. 4; Fisher Exact Test (two-tailed) < 0.012).

3.5.3. Comment

Recognition of object use was impaired in patients with semantic disorders and was related to ability to use the object. Results indicate that a specific component of semantic knowledge, that is, knowledge about function (how to use), was impaired. Pantomime recognition and action recognition were also pathological. Thus, not only the “motor” tasks involved in manipulating objects or pantomiming were impaired, but also those involved in recognizing the action. This observation supports the hypothesis that the same processes might mediate both production of actions and recognition of actions and manipulable objects (see Negri, Rumiati, et al., 2007 for discussion). Nevertheless, the patients’ behavior was not homogeneous. Those with mild semantic disorders scored better in Action recognition than in Pantomime recognition (showing the same trend as controls), whereas those with severe semantic disorders showed the opposite pattern, that is, they scored better in Pantomime recognition than in Action recognition. In addition, there was no consistency between the two tasks in either patient. Indeed, lexical factors might have contributed to making Action naming more difficult than Pantomime recognition (only the correct verb was accepted as indicating correct recognition of the action). If this were true, however, lexical factors would have had similar effects across all patients, not only those with more severe semantic disorders. Lack of consistency also tends to minimize the contribution of lexical impairment and suggests that action naming and pantomime recognition are independent processes (Cubelli et al., 2000; Negri, Rumiati, et al., 2007). Note also that in patients with severe semantic disorders an object that cannot be processed because its semantic-conceptual representation is degraded might interfere negatively with recognition of the action produced by its manipulation.

Table 6

<table>
<thead>
<tr>
<th>Recognition of object use (N=48)</th>
<th>Pantomime recognition (N=16)</th>
<th>Action recognition (Naming; N=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GG</td>
<td>93</td>
<td>4</td>
</tr>
<tr>
<td>CB</td>
<td>95</td>
<td>11</td>
</tr>
<tr>
<td>CL</td>
<td>76</td>
<td>3</td>
</tr>
<tr>
<td>RP</td>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>OC</td>
<td>96</td>
<td>16</td>
</tr>
<tr>
<td>Controls</td>
<td>Mean</td>
<td>98.9</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.23</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>97–100</td>
</tr>
</tbody>
</table>
3.6. Competence in everyday activities

When asked whether CL had any specific difficulty in using common objects, his son reported that the patient was no longer able to use a hair dryer or to distinguish a soup plate from a dinner plate when setting the table; furthermore, he was unable to shop at the supermarket because, in his own words, he “could not distinguish between different types of food”. However, he was still able to use money correctly and to drive a car for long distances without any help. CB had difficulty in choosing the appropriate clothes and shoes for the weather. GG was the most impaired patient in everyday activities. He had been an expert car mechanic but had to give up working at the onset of the disease because he confused the various tools. Some anecdotes were reported by his wife: When asked to clean his shoes, CG painted them with silver paint; on another occasion, he pruned the fruit trees in his garden as if they were rose bushes.

3.6.1. Comment

The general claim that SD patients are competent in everyday activities (Bozeat et al., 2002; Lauro-Grotto et al., 1997; Schwartz & Chawluk, 1990; Snowden, Griffiths, & Neary, 1994) should be reformulated: SD patients are competent in everyday activities when their semantic deficit is not severe. Although contextual factors, familiarity or affordance (Bozeat et al., 2002; Hodges et al., 2000) might contribute to enabling patients to use objects in their own context, our observations indicate that as semantic deficits become more severe patients become progressively unable to deal even with objects they were quite familiar with before the disease onset.

3.7. Follow-up (CB and GG)

CB was given the battery for Object knowledge and Object use approximately 24 months after the first administration. Object naming was abolished (0/16). Nevertheless, the patient was still able to pantomime correctly the use of 9 out of 16 objects. The possibility of manipulating the object did not improve the patient’s performance. In fact, he was unable to manipulate correctly any of the seven items whose use he had failed to pantomime. The patient recognized only four pantomimes performed by the examiner. CB was still able to recognize (to name) four actions performed by the examiner with the objects, but his performance was not consistent with Pantomime recognition. Recognition of the correct use of the object (forced choice) was close to random (58).

GG was dramatically impaired at the follow up (20 months after the first examination). He was able to name only one item; he correctly recognized (named) only two actions. Confabulations and inability to collaborate prevented any further observations. In general, the patient moved the object or simply picked it up and held it in his hands without making any attempt to use it. Although he was able to perform some ordinary tasks, such as going to buy the newspaper, he needed help to perform other simple tasks at home, such as washing or dressing himself.

3.7.1. Comment

The follow-up confirmed what had already been suggested by the comparison between the patients at different disease stages. Naming progressively decayed in both patients and the ability to use objects decayed comparatively, as did performance on all other tasks of the experimental battery. At the follow up, when his semantic impairment had become more severe, CB obtained no facilitation from object manipulation compared to pantomiming, thus showing the same pattern observed in GG at the first examination. Pantomiming was confirmed to be more preserved than naming. These observations concur in suggesting that when the semantic deficit is severe non-semantic factors do not provide sensible compensation and patients have marked difficulty in using even common objects. CB showed no consistency between Pantomime recognition and Action recognition (naming), supporting, as already mentioned, the hypothesis that the two processes are independent (Cubelli et al., 2000; Negri, Rumiati, et al., 2007).

4. General discussion

Patients who present selective disorders of semantic memory offer a unique opportunity to explore the role of semantic knowledge in object use.

Our data show that there is a significant relationship between the severity of the semantic deficit and the inability to use objects, as well as a significant consistency between object knowledge and object use.

These observations suggest that for a conventional use semantic knowledge about the object is crucial. In other words, only semantic knowledge, principally knowledge of functional aspects (how the object must be used) can allow using an object in a way that cannot be elicited by its structural characteristics.

Comparison between patients with mild and severe semantic deficit accounts for some reports about subjects who, in spite of degradation of semantic knowledge, preserve some ability to use objects and show competence in everyday living activities (Bozeat et al., 2002; Lauro-Grotto et al., 1997; Schwartz & Chawluk, 1990; Snowden et al., 1994). According to our findings, this is largely true when the semantic deficit is mild; when the semantic deficit is severe patients can be unable to deal even with objects they were quite familiar.

At the same time performance in using objects or in everyday activities never was at the floor, suggesting that patients were supported by non-semantic abilities.

The production of semantic errors (for example using the paint brush as if it were a shaving brush) as well as some behaviors associated with everyday activities (pruning fruit trees as if they were rose bushes, but action of pruning itself fluent) confirm that it is not the programming and execution of motor schema that is impaired, but selection of motor schema in relation to the semantic conceptual meaning carried out by that object that should drive its use towards a specific conventional purpose. The performance of patients with severe semantic impairments did not improve when they were allowed to manipulate rather than pantomime the use of the object; furthermore, they produced some errors classified as generic; for example, they moved the object from one part of the table to another or simply picked it up and held it in their hands. All these observations concur in suggesting that although non-semantic factors are still operating and able to trigger fluent actions, they cannot evoke that conventional action with that object because of the lack of specification that can only be provided by semantic knowledge.

The integrity of non-semantic factors is confirmed by patients’ ability to perform normally on the Action Program (Wilson et al., 1996) in which action can be largely derived from perceptual properties, such as affordance, and the contribution of problem-solving abilities.

The contribution of affordance, that is, sensorimotor information derived from the physical characteristics of the object (Gibson, 1977), is considered by some authors to account for the preserved ability to use objects shown by patients with semantic disorders (Buxbaum, Schwartz, & Montgomery, 1998; Hodges et al., 2000). According to other authors (Negri, Lunardelli, et al., 2007) affordance is not sufficient to explain the behavior of patients with semantic deficit whose residual ability to use objects goes beyond the possibility of deriving information from physical attributes.
Based on a reviewed notion of affordances that emphasizes dispositional properties of the subject’s nervous system as a result of evolutionary as well as of lifetime individual adaptation (Ellis & Tucker, 2000), and supported by functional studies (Grezes, Tucker, Armony, Ellis, & Passingham, 2003), these authors assume that affordance may not be computed on-line, but represents a stored action–object association. Thus, they conclude for the existence of a stored “motor knowledge” that finds theoretical support in the action selection model proposed by Norman and Shallice (1980).

The hypothesis of a stored motor knowledge is also in line with previous reports showing that in particular experimental conditions, both normal and brain damaged subjects may rely upon a visuo–motor direct route when asked to imitate meaningful actions (Cubelli, Bartolo, Nichelli, & Della Sala, 2006; Tessari & Rumiati, 2004).

We suggest that the proposed concept of motor knowledge should to some extent be ascribed to the domain of procedural memory. Thus, we agree with Negri et al. (2007a) and conclude that explicit (semantic) and implicit (procedural–motor) memory represent separate forms of knowledge that interact, thus enabling appropriate object use. Further, we suggest that procedural knowledge might account for residual ability to use objects also in the presence of a severe semantic deficit, as has been occasionally reported (Negri, Lunardelli, et al., 2007; Sirigu et al., 1991) and in some respects was also evident in our subjects (performance was at floor only in GC at the follow up, and all patients, GC included, preserved some competence in everyday activities).

In conclusion, object use requires semantic knowledge belonging to the domain of explicit memory, supported by implicit knowledge. The nature of the semantic knowledge implicated in object use should be better specified. The so called “functional” knowledge, formally investigated by means of verbal/visual tasks on “how the object must be used”, should be considered a component of semantic memory (Gainotti, Silveri, Daniele, & Giustolisi, 1995) and distinct from the actual ability to use objects (“preparing to action the world is not the same as preparing to describe or answer question about it”; Buxbaum et al., 1998, p. 248; see also Negri, Rumiati, et al., 2007). Recently, some attempts have been made to distinguish “function” from “action” in functional studies (Boronat et al., 2005; Canessa et al., 2008). However, this distinction is not always sufficiently clear in neuropsychological reports (Magniè, Ferreira, Giusiano, & Poncet, 1999; Schwartz, Marin, & Saffran, 1979; but see also Sirigu et al., 1991). Our patients (mostly when their semantic deficit was severe) performed pathologically if requested to say whether the object represented in a picture was or was not used correctly. This result confirms that the functional aspects of semantic knowledge were impaired and that the deficit regarding explicit knowledge about objects was so extensive in some of the patients that it did not allow for sensible compensation by (preserved) implicit knowledge.

Our patients scored normally on tasks of motor apraxia; patients with severe semantic deficit were borderline on tasks of ideational apraxia. This latter result was to be expected because in order to perform the ideational apraxia task the patients had to use objects whose meaning could have been somewhat degraded. According to De Renzi and Lucchelli (1988), ideational apraxia is an autonomous syndrome pertaining to the area of semantic memory that concerns the way objects must be used. If we consider “the way objects must be used” as a functional feature of object conceptual knowledge, we might also explain why patients with semantic disorders, in particular SD patients, can be apraxic. If the functional aspect of meaning is degraded objects cannot be used correctly, whether in a testing situation or in spontaneous behavior (De Renzi & Lucchelli, 1988; Poeck, 1983), which is what we demonstrated in patients with severe semantic deficits.

Our conclusion is that in order to use objects correctly, functional conceptual knowledge about objects, must be largely preserved. Non-declarative forms of knowledge can support object use and thus compensate for partial loss of semantic knowledge and also guarantee some residual ability to use very common objects independently of semantic knowledge. Some issues are still open and need to be considered in future neuropsychological studies, for example: the relationship between implicit/procedural memory and concepts such as affordance or context; the differential contribution of stored object–action association and on-line elaboration of perceptual information to object related actions; whether what we know as “non-verbal semantic” within a multimodal model of semantic memory (Warrington & McCarthy, 1987) might include non-declarative/procedural components (for example, for allowing “privileged access to action” (Lauro-Grotto et al., 1997); to what extent and in which conditions procedural-motor memory could operate independently of semantic knowledge and when, instead, semantic knowledge becomes essential for the correct use of the objects.

A final consideration is based on clinical/neuropathological evidence. Patients with disproportionate disorders of object knowledge compared to object use suffer from pathologies that typically involve the temporal lobes and produce semantic disorders, such as semantic dementia (Buxbaum et al., 1997; Hodges et al., 1999, 2000; Lauro-Grotto et al., 1997; Negri, Lunardelli, et al., 2007), Alzheimer’s disease (Negri, Lunardelli, et al., 2007) or herpes simplex encephalitis (Sirigu et al., 1991). Clinical data in our patients are in line with these reports. The opposite pattern, disproportionate impairment for object use compared to object knowledge, has been mainly described in apraxic patients with lesions of either a vascular (Ochiai et al., 1989; Rumiati et al., 2001) or degenerative nature, such as corticobasal degeneration (CBD; Hodges et al., 1999; Silveri & Ciccarelli, 2007) involving the frontotoparietal areas and, in CBD, also extending to the basal ganglia. This empirical evidence about lesion site supports the hypothesis that object knowledge and object use respectively belong to different functional domains, the former to the semantic domain, and the latter to the motor (although at a high level) domain, subtended by distinct neural substrates, temporal vs. frontotoparietal/subcortical. The functional interaction between the two neural systems (Frey, 2007; Goldenberg, 2009; Tranel, Kemmerer, Adolphs, Damasio, & Damasio, 2003) is necessary to guarantee objects conventional use in ecological contexts. This observation is incongruent with any account of the “dissociation” between object knowledge and object use based exclusively on models of semantic memory (even multimodal models, Lauro-Grotto et al., 1997; see also Allport, 1985) and, instead, emphasizes the role of non-declarative forms of memory supported by neural substrates organized in brain regions other than the temporal lobes.

References


