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Semantic memory in object use

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ABSTRACT

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.

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

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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 Rehabilitative 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 (BORB; 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

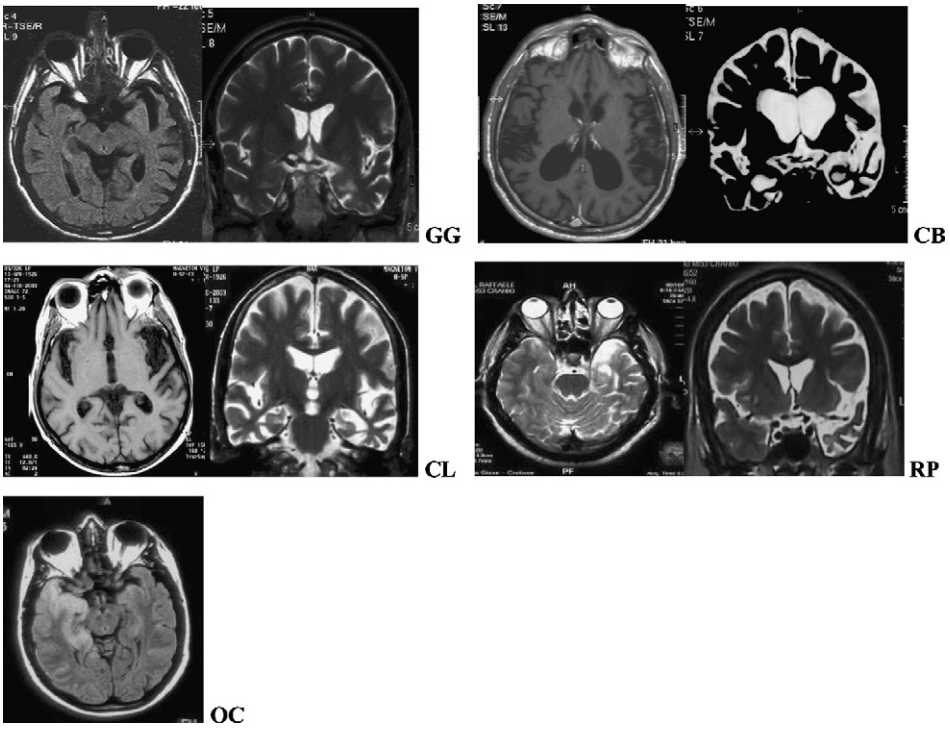

Fig. 1. MRI scan. Semantic dementia patients (GG, CB, CL, RP): brain atrophy mainly involving the left hemisphere. Herpes simplex virus encephalitis (OC): bilateral deep temporal lesion.