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The role of sensory-motor information in object recognition: Evidence from category-specific visual agnosia ☆

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Abstract

The role of sensory-motor representations in object recognition was investigated in experiments involving AD, a patient with mild visual agnosia who was impaired in the recognition of visually presented living as compared to non-living entities. AD named visually presented items for which sensory-motor information was available significantly more reliably than items for which such information was not available; this was true when all items were non-living. Naming of objects from their associated sound was normal. These data suggest that both information about object form computed in the ventral visual system as well as sensory-motor information specifying the manner of manipulation contribute to object recognition.

Keywords: Semantics; Visual agnosia; Motor knowledge

1. Introduction

Warrington and Shallice (1984) reported four patients who were more accurate naming and, in two cases, defining non-living as compared to living entities. Although the impairment with living entities was considered by some to be artifactual, reflecting differences between living and non-living entities with respect to variables such as familiarity and visual complexity (Funnell & De Mornay Davies, 1996; Funnell & Sheridan, 1992; Gaffan & Heywood, 1993; Stewart, Parkin, & Hunkin, 1992), several lines of evidence argue strongly against this possibility. First, these factors were carefully controlled in a number of studies in which patients demonstrated deficits related to semantic category (Gainotti & Silveri, 1996; Kurbat & Farah, 1998; Sartori, Job, Miozzo, & Zago, 1993; see Capitani, Laiacona, Mahon, & Caramazza, 2003 for a comprehensive review). Second, and perhaps most convincingly, patients who exhibited the opposite pattern of performance—that is, worse performance naming non-living as compared to living entities have also been reported (Hillis & Carramazza, 1991; Tippett, Glosser, & Farah, 1996; Warrington & McCarthy, 1983, 1987). This double dissociation makes an account invoking differential difficulty in tasks involving the two categories unlikely.

Three general types of hypotheses regarding the organization of semantics have been proposed to explain category-specific deficits. Perhaps the most influential account, a version of which was first articulated by Warrington and colleagues (Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984), proposes that information about an object is distributed in different brain regions reflecting the properties of the object or concept that are most relevant to the individual's experience with that object or concept. On this account selective impairment in knowledge of animals is attributed to the fact that visual perceptual features are central to the definition of most animals, fruits, and vegetables whereas a

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selective impairment in knowledge of non-living objects reflects the fact that sensory-motor information, including the manner in which the non-living object is manipulated, constitutes the most important knowledge for that entity. Variants of this account have been proposed by a number of investigators (Allport, 1985; Martin, Ungerleider, & Haxby, 2000; Saffran & Schwartz, 1994; Simmons & Barsalou, 2003).

An alternative account of category-specific deficits attributes the impairment to the fact that evolutionary pressures have selected for specialized, dissociable neural systems that are dedicated to the processing of different categories of objects. Caramazza and Shelton (1998), for example, have argued that knowledge of animals, fruits, vegetables, conspecifics and, perhaps, tools is so fundamental to survival that specialized mechanisms for representing information about these categories have evolved. On this account, category-specific deficits are attributed to the disruption of the mechanisms for processing one or more categories.

A third account of semantic knowledge proposes that information is stored in a single amodal store (Carramazza, Hillis, Rapp, & Romani, 1990; Rogers et al., 2004; Tyler & Moss, 2001). On the "conceptual structure account" (Devlin et al., 2002; Tyler & Moss, 2001), for example, the susceptibility of a semantic representation to damage is a function of the strengths of the correlations between the attributes that define an entity. According to this theory, category-specific deficits for living things are attributed to the fact that these entities share more features and have fewer distinctive features than non-living things. Mild damage to the system is likely to cause a loss of knowledge of living things because there are fewer distinctive or specific features to support identification of a specific object. More recently, Rogers et al. (2004) presented a parallel distributed processing model of semantics in which semantic representations emerge from the procedures that map between verbal descriptions of objects and their visual representation. After training on inputs and outputs derived from attribute-norming experiments, the investigators "lesioned" connections in the network. They found that the lesioned model reproduced many of the patterns of performance exhibited by patients with one type of impairment of semantic memory—that is, "semantic dementia" (Hodges, Patterson, Oxbury, & Funnell, 1992).

Finally, it should be noted that the three accounts discussed above are not mutually exclusive; Simmons and Barsalou (2003), for example, have recently provided an account, the Conceptual Topography Theory, that incorporates key elements of the three accounts described above (see also Humphreys & Riddoch, 2003).

We report a patient with a high-level visual recognition deficit (AD) whose performance speaks to the possible role of sensory-motor representations in object recognition. AD is impaired in naming living as compared to non-living items when these items are presented visually. He performs normally, however, when asked to name items from both categories on the basis of their characteristic sounds. His naming of non-living objects is predicted in part by the extent to which an object's form predicts its mode of manipulation; objects for which the form predicted mode of manipulation were named more reliably than objects rated lower on this dimension. Thus, items such as pliers that have an element that may be suitable for grasping or a baby carriage that has an element suitable for grasping in conjunction with wheels that may suggest mobility were named more accurately than a chain or an ashtray; the latter provide few visual cues regarding the manner in which they would be used. Finally, AD names actions for which sensory-motor information is available (e.g., "to hammer") more reliably than actions for which such knowledge is not available (e.g., "to bloom"). These data suggest that naming an object entails access to perceptual information and that sensory-motor knowledge derived at least in part from an object's form may be decisive in the naming of non-living objects for some subjects.

2. Case report

AD was a 50 year-old, right-handed sales representative with a college education who developed deficits in visual recognition after cardiac surgery complicated by hypotension. Initially, he exhibited substantial difficulty recognizing people on the basis of their facial appearance and had moderate difficulty recognizing objects and words. He was unable to recognize his own house and complained of difficulty reading text. At the time of subsequent assessments (10–30 months after his operation), he continued to complain of significant visual recognition problems as well as a poor memory. He recognized members of his immediate family and close friends by sight but continued to be unable to recognize most friends and acquaintances except by voice. He also noted that he was impaired in recognizing animals; his wife reported, for example, that he referred to squirrels as pigs and deer as chickens.

Neurological examination was normal except for the high-level visual deficits described below. Limb and buccofacial praxis were normal. Visual fields, ocular motility, color discrimination, and visual acuity were normal. CT of the brain revealed a small area of hypodensity in the right occipito-temporal junction inferiorly which was thought to represent a stroke. Given the presumed etiology of his neurologic deficit (hypotension), it is possible that the CT scan does not reveal the full extent of neuronal injury. In light of the facts that the patient exhibited both verbal and non-verbal memory deficits as well as