



## Research report

# When concepts lose their color: A case of object-color knowledge impairment

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## ABSTRACT

Color is important in our daily interactions with objects, and plays a role in both low- and high-level visual processing. Previous neuropsychological studies have shown that color perception and object-color knowledge can doubly dissociate, and that both can dissociate from processing of object form. We present a case study of an individual who displayed an impairment for knowledge of the typical colors of objects, with preserved color perception and color naming. Our case also presented with a pattern of, if anything, worse performance for naming living items compared to non-living things. The findings of the experimental investigation are evaluated in light of two theories of conceptual organization in the brain: the Sensory/Functional Theory and the Domain-Specific Hypothesis. The dissociations observed in this case compel a model in which sensory/motor modality and semantic domain jointly constrain the organization of object knowledge.

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## 1. Introduction

Conceptual knowledge consists of stored information about objects, ideas, and events. Knowing that an elephant is gray, has a trunk, and can be found in Africa is an example of conceptual knowledge. One issue currently debated in the field is the degree to which concept representations are distributed over modality-specific systems, or represented in

an amodal or modality-independent format. Another issue that is currently debated is whether or not conceptual knowledge is organized by semantic category. Here we explore the intersection of these two theoretical issues in the context of an individual who exhibited a loss of object-color knowledge across multiple semantic categories.

Neuropsychological studies of brain damaged patients and functional MRI studies can jointly constrain theories of how concepts are structured in the brain. For instance, patients

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with naming impairments for animals or for plant life tend to have lesions to the temporal lobe, while patients with disproportionate impairments for artifacts tend to have lesions to parietal–frontal regions (Capitani, Laiacona, Mahon, & Caramazza, 2003; Damasio, Tranel, Grabowski, Adolphs, & Damasio, 2004; Gainotti, 2005)—although notable exceptions exist (e.g., Caramazza & Shelton, 1998). Furthermore, areas on the lateral surface of the temporal lobe process object motion (e.g., posterior middle temporal gyrus and the superior temporal sulcus; Beauchamp, Lee, Haxby, & Martin, 2002; Kourtzi & Kanwisher, 2000). Additionally, there are separate pathways in extra-striate cortex for processing form (e.g., lateral occipital cortex) as opposed to other surface properties such as texture and color (e.g., fusiform gyrus; e.g., Cant & Goodale, 2007; Grill-Spector, Kourtzi, & Kanwisher, 2001; see also Cant, Large, McCall, & Goodale, 2008 for behavioral evidence for the independence of form, texture, and color).

Unlike features such as texture, size, and form, color is unique in that it is perceived only through the visual modality. Furthermore, color has been shown to facilitate recognition of natural objects, compared to incorrectly colored or gray-scaled images (Humphrey, Goodale, Jakobsen, & Servos, 1994; for a review, see Tanaka, Weiskopf, & Williams, 2001). Recognition of natural scenes is faster for colored as opposed to gray-scaled images (Gegenfurtner & Rieger, 2000). Cant and Goodale (2007) suggested that compared to other surface properties such as texture, object color is analyzed early in visual processing. Others have examined the role of color in higher-level visual areas such as the lingual and fusiform gyrus (for review, see Simmons et al., 2007).

An important question is whether retrieving object-color knowledge activates the same regions responsible for early color processing. Using positron emission tomography (PET), an early study by Martin, Haxby, Lalonde, Wiggs, and Ungerleider (1995) found that generation of the typical colors associated with objects, when the objects are presented as achromatic line drawings and written words, led to selective activation of a region of the ventral temporal lobe, slightly anterior to the area involved in color perception. However, cortical regions that mediate color perception were not independently defined in that study. Also using PET, Chao and Martin (1999) had subjects passively view colored and gray-scale Mondrian displays, name colored and achromatic objects, and generate colors associated with the achromatic objects. They found that the location of regions activated during color perception (lingual and fusiform gyri) and object-color knowledge retrieval did not directly overlap. Specifically, regions associated with color retrieval were 2 cm lateral to the occipital activations associated with color perception, and were highly similar to the regions involved in simple naming of achromatic objects. This led the authors to conclude that retrieving information about an object's color does not require reactivation of the same areas that mediate color perception. Simmons et al. (2007) used functional magnetic resonance imaging (fMRI) to show overlap in the neural substrate for perceiving color and knowing an object's typical color. They found that a region of the left fusiform gyrus was highly activated for both a color perception task and a color retrieval task that used only linguistic stimuli. This study differed from Chao and Martin (1999) in that all their stimuli were linguistic

(i.e., verbal names of objects presented on the screen). The authors interpreted the overlap of regions involved in color perception and color retrieval as evidence that conceptual knowledge is grounded in modality-specific subsystems, supporting simulation theories. In addition, they concluded that the posterior lingual gyrus is more active for passive color sensation while the anterior ventral fusiform gyrus involves more active processing of color information for the purpose of extracting meaning (Simmons et al., 2007).

Damage to early visual processing regions can impair the ability to perceive and know about color. Achromatopsia, an impairment for color perception, typically results from lesions to posterior occipital fusiform and lingual gyri (Bouvier & Engel, 2006). Color agnosia is an impairment for knowing an object's prototypical color, due to lesions in ventral temporal cortex (for a review see Simmons et al., 2007). The lesions that lead to color agnosia tend to be slightly more anterior in the ventral visual pathway than the lesions that produce achromatopsia. When selective, these two deficits represent a double dissociation between color perception and color knowledge. Isolated achromatopsia shows that it is possible to have intact color knowledge with impaired color perception (e.g., see Shuren, Brott, Schefft, & Houston, 1996), while isolated color agnosia shows that it is possible to have intact color perception with impaired object-color knowledge (e.g., Miceli et al., 2001; Luzzatti and Davidoff, 1994).

Perhaps not surprisingly, cases of impaired knowledge of object color in the context of otherwise spared conceptual knowledge are rare. It is not uncommon to find cases of semantic impairment in which object-color knowledge is impaired along with other stored semantic properties of a category, such as knowledge of an object's function, shape, and texture (e.g., case P.C.O.: Miceli et al., 2001; see Capitani et al., 2003 for review). Similarly, in cases of semantic dementia, color perception, or the ability to discriminate and categorize colors, is frequently impaired along with object-color knowledge, leading to a general color deficit (Rogers, Patterson, & Graham, 2007). However, selective dissociations have been observed. For instance, case R.S. had impairments for retrieving semantic information about fruits and vegetables, but intact object-color knowledge (in the visual modality) for fruits and vegetables (Samson & Pillon, 2003). Cases G.G. and A.V. (Luzzatti & Davidoff, 1994) had intact color perception and impaired object-color knowledge. However, those two cases also had a mild visual form agnosia. The clearest case to date, I.O.C., was reported by Miceli et al. (2001). I.O.C. exhibited color agnosia with normal color perception. Critically, I.O.C. was unimpaired for knowledge of objects' form and function, which at the time made I.O.C. the first (and to our knowledge, only) case on record with a truly selective semantic deficit for object-color knowledge.

Here we report a case (AC) that has a strikingly similar pattern as case I.O.C. (Miceli et al., 2001) as a consequence of a stroke damaging a significant portion of his left temporal and occipital lobes. AC exhibited a semantic impairment for object-color knowledge with spared color perception and spared knowledge of form; in addition, AC's conceptual knowledge of objects was generally spared for both the living and the non-living categories. However, a naming deficit was present for animals, fruit and vegetables, and musical

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