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Heterogeneity is a Fact of Category-Specific Semantic Deficits. So? Comments on Rosazza, Imbornone, Zorzi, Farina, Chiavari, and Cappa (2003)

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Abstract

The Sensory/Functional Theory, until recently the received explanation of category-specific semantic deficits, has been shown to be at variance with various facts that have emerged about the nature of these deficits. In this context, Rosazza, Imbornone, Zorzi, Farina, Chiavari, and Cappa (2003: The Heterogeneity of Category-Specific Semantic Disorders: Evidence from a New Case. *Neurocase*, 9, 189–202.) report the case study of a patient, MA, with a purported category-specific semantic deficit for living things compared to nonliving things, and an associated modality-specific impairment that differentially affected visual/perceptual compared to functional/associative knowledge. While acknowledging that the Sensory/Functional Theory cannot account for the existence of category-specific semantic deficits, Rosazza and colleagues (2003) contend that ''...the presence of a more severe loss of specific visual rather than functional knowledge could support an interpretation according to the Sensory/Functional Theory'' [sic] (p. 200). Our comments are divided into two parts. First, we point out that there is an asymmetry between evidence and theory: if there is clear evidence that ''disconfirms'' a given theory, evidence that is consistent with the theory cannot be argued to support the theory. Second, we argue that the performance profile of MA could potentially be relevant to other interpretations of category-specific deficits but that theoretical interpretations of the performance profile of patient MA are undermined by a lack of methodological rigor, as well as the generally weak data associated with the case.

Introduction

The phenomenon of category-specific semantic deficits places important constraints on theories of the organization of conceptual knowledge in the human brain. The criterion for evaluating a given theoretical framework is whether it can account for relevant variation in the performance profiles of different patients. Perhaps the theoretical issue that has received the most attention in recent work is whether the Sensory/Functional Theory, until recently the received view, can account for the currently known facts of category-specific semantic deficits. The Sensory/Functional Theory assumes that category-specific semantic deficits result from damage to modalities or types of information upon which successful recognition/identification of items from the impaired categories differentially depends (e.g., Warrington and McCarthy, 1983; Martin *et al.*, 2000; Borgo and Shallice, 2001; Humphreys and Forde, 2001; Cree and McRae, 2003; Crutch and Warrington, 2003). Specifically, the ability to recognize/identify living things is assumed to differentially depend on the visual/perceptual semantic subsystem, while the ability to recognize/identify nonliving things is assumed to differentially depend on the functional/associative semantic subsystem. The Sensory/Functional Theory generates two predictions. First, because all living things depend on information internal to the same (visual/perceptual) semantic system, a dissociation should not be observed within living things. Second, because category-specific semantic deficits are assumed to be caused by damage to a modality or type of knowledge upon which recognition/identification of items from the impaired category differentially depends, the prediction is made that there will be a necessary association between an impairment for a given category of objects and a given modality or type of knowledge (but see Crutch and Warrington, 2003 for discussion). Both predictions have been shown to be at variance with various facts about the nature of category-specific semantic deficits.

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For example, patient EW (Caramazza and Shelton, 1998) was disproportionately impaired for living animate things, but was within or near the normal range for fruit/vegetables and nonliving things. This patient was also equivalently impaired for visual/perceptual and functional/associative knowledge of living animate things, but was in the normal range for both types of knowledge for non-animals. These patterns of impairment, selective impairment to either fruit/vegetables (e.g., MD: Hart *et al.*, 1985; JJ: Hillis and Caramazza, 1991; TU: Farah and Wallace, 1992; FAV: Crutch and Warrington, 2003; RS: Samson and Pillon, 2003) or living animate things (KR: Hart and Gordon, 1992; EW: Caramazza and Shelton, 1998), and equivalent impairments to visual/perceptual and functional/associative knowledge (FM: Laiacona *et al.*, 1993; SB: Sheridan and Humphreys, 1993; EA: Barbarotto *et al.*, 1996; Laiacona *et al.*, 1997; EW: Caramazza and Shelton, 1998; CN98: Gaillard *et al.*, 1998; Jennifer: Samson *et al.*, 1998; PL: Laiacona and Capitani, 2001), indicate that the Sensory/Functional Theory cannot account for the existence of category-specific semantic deficits (e.g., Caramazza and Shelton, 1998; Tyler and Moss, 2001; Cree and McRae, 2003; Rosazza *et al.*, 2003; Samson and Pillon, 2003; for review see Capitani *et al.*, 2003).

In this context, one issue that arises concerns the theoretical import of the performance profiles of patients that are not problematic for the Sensory/Functional Theory. For instance, consider what would follow from a patient who presented with an impairment for all living things compared to nonliving things, and who was also disproportionately impaired for visual/perceptual compared to functional/associative knowledge. Would such data support the Sensory/Functional Theory as an account of *some* observations of category-specific impairment? Would it matter if the patient in question were tested with the same procedures, or even the same materials, as were used to investigate a patient who provided clear evidence against the Sensory/Functional Theory? The answer to these questions is *no*. This is because there is an asymmetry in the relevance of various patterns of deficit to an evaluation of the Sensory/Functional Theory. As argued above, the Sensory/Functional Theory cannot account for the existence of category-specific semantic deficits. Thus, in the context of a patient such as that hypothetically outlined above, one would be compelled to explore how an alternative theoretical account of the existence of category-specific semantic deficits might explain the performance profile of such a patient.

In this state of the art, Cappa and colleagues (Rosazza *et al.*, 2003) report a new case, patient MA, who was tested with the same tasks (but different materials) as were used to investigate patient EW. The authors claim that patient MA presented with an impairment for all living things compared to nonliving things, and was also disproportionately impaired for visual/perceptual compared to functional/associative knowledge. Setting aside for discussion (but see below) methodological problems with the reported data, we can ask the following question: If this pattern of performance is not relevant to an evaluation of the Sensory/Functional Theory, then of what theoretical import is the case?

The Domain-Specific Hypothesis

An alternative account of category-specific semantic deficits is the Domain-Specific Hypothesis (Caramazza and Shelton, 1998). This hypothesis assumes that evolutionary pressures have resulted in Domain-Specific neural circuits dedicated to processing, conceptually and perceptually, different categories of objects; plausible categories are restricted to animals, plants, conspecifics, and possibly tools. The basic predictions that derive from this hypothesis are consistent with the principal facts of category-specific semantic deficits: the grain of category-specific deficits is as fine as these evolutionarily plausible domains, and category-specific semantic deficits do not necessarily present with disproportionate deficits for a type or modality of knowledge.

One way in which a theory of the organization of conceptual knowledge might be further specified would be to demonstrate that object domain is not the *only* constraint on the organization of conceptual knowledge. For instance, if there were to be a patient who presented with associated category- and modality-specific impairments, such a performance profile could be interpreted as indicating that information is organized within domains according to modality or type of knowledge. Such a performance profile has been reported for patient Michelangelo (Sartori and Job, 1988; Sartori, Job, and Coltheart, 1993; Sartori, Miozzo, and Job, 1993, 1994; Mauri *et al.*, 1994; Sartori, Coltheart, Miozzo, and Job, 1994; see also patient Giulietta: Sartori, Job, Miozzo, Zago, and Marchiori, 1993; Sartori, Miozzo, and Job, 1994). Patient Michelangelo presented with an impairment for living things compared to nonliving things, and a disproportionate deficit for visual/perceptual compared to functional/associative knowledge of living things, but not of nonliving things (but see Capitani *et al.*, 2003 for critical discussion). This interaction between a modality-specific and a category-specific impairment may be taken to indicate that conceptual knowledge is organized by modality within domains. In fact, the observation that visual/perceptual knowledge was worse than functional/associative knowledge, but *only for the impaired categories*, is problematic for a theory that assumes that modality-specific semantic systems are not functionally organized by object domain.

However, Cappa and colleagues criticize the Domain-Specific Hypothesis on the grounds that it "... does not account for a number of cases of category-specific impairments restricted to living things in which perceptual information was specifically lost ..." (p. 190).[1] In support of this contention, Cappa and colleagues cite five patients, Michelangelo (Sartori and Job, 1988), LA (Silveri and Gainotti, 1988), Giulietta (Sartori *et al.*, 1993), Felicia (De Renzi and Lucchelli, 1994), and NV (Basso *et al.*, 1988). With the exception of Michelangelo and Giulietta, all of these case studies have been shown to have improperly controlled for relevant

stimulus variables (Caramazza and Shelton, 1998; see also Capitani *et al.*, 2003 for re-analysis of the published data). In other words, the performance profiles of patients LA, NV, and Felicia are not relevant to the theoretical issue of whether information is organized by modality within object domains. For instance, the integrity of visual/perceptual versus functional/associative knowledge in patient LA was investigated with a naming to definition task that stressed either perceptual or functional attributes of the target concepts (Silveri and Gainotti, 1988; Gainotti and Silveri, 1996). However, in the first examination, the target concepts used in the definition to naming task were not equated for difficulty (see Silveri and Gainotti, 1988; Exp.'s C and D) while in the second examination, the perceptual definitions were more difficult than the functional definitions (see Gainotti and Silveri, 1996 and control performance). In the case study of patient NV (Basso *et al.*, 1988) controls were not examined and perceptual probe questions were only administered for animal stimuli.

Anyway, independently of the above methodological problems, the performance profile of such patients (e.g., Michelangelo) would not be problematic for a Domain-Specific account of category-specific semantic deficits. The reason why was clearly stated in Caramazza and Shelton's original paper (1998; pp. 20–21):

> However, it is important to stress here that the appeal to evolutionary pressures as a possible causal basis for the categorical organization of knowledge in the brain is not necessarily incompatible with the cognitive principles that characterize the OUCH and SFT proposals. Indeed, it is quite likely that both domain-specific and domain-general learning principles are involved in the organization of conceptual and linguistic knowledge in the brain. The domain-specific principles have a very narrow range of applicability and serve only to explain why it might be the case that knowledge of animals and of plant life is represented in distinct neural circuits. This account is silent on the larger issue of how conceptual knowledge *within* the broad categories of living and nonliving things is organized. And it could very well turn out that domain-general principles such as those invoked under OUCH (or SFT, although no empirical support has been found for this account) provide the basis for the organization of conceptual knowledge *within* the distinct categories of animals, plant life, and artifacts.

It is important to make a distinction between theories and the assumptions of which they are composed. The Sensory/Functional Theory and the Domain-Specific Hypothesis are mutually contrary as hypotheses about the causes of category-specific semantic deficits. However, the individual assumptions that comprise each theory are not necessarily mutually contrary as hypotheses about the organization of information. Thus, while the Sensory/Functional Theory can be rejected as a viable account of category-specific semantic deficits, the assumption that one constraint on the organization of conceptual knowledge is modality or type of information remains a viable theoretical hypothesis (for discussion see Caramazza and Mahon, 2003). The data from patients Michelangelo, Giulietta, and (possibly) MA (but see below) could be taken to indicate a framework in which information is organized within domains by knowledge type. Evidence that converges on such a framework may be provided by recent work in functional neuroimaging (for recent reviews see Joseph, 2001; Martin and Chao, 2001; Bookheimer, 2002; Thompson-Schill, 2002; for discussion of functional neuroimaging data in relation to the Domain-Specific Hypothesis, see Mahon and Caramazza, 2003).

A second criticism raised by Cappa and colleagues against the Domain-Specific Hypothesis is that it "... assumes and predicts a strong correlation between [the] cerebral substrates that have been damaged and the impaired domains of knowledge" (p. 199). This criticism is also misplaced. The claim made by the Domain-Specific Hypothesis is that there are functionally dissociable neural circuits dedicated to processing, conceptually and perceptually, different categories of objects. It remains to be determined whether such neural circuits spatially overlap or are separated in the cortex. Part of the resolution of this issue will include a corroborated theory of the relationship between the category-specific patterns of activation observed in functional neuroimaging and the consequences of focal lesions to the observed activated neural regions. However, the resolution of this issue is independent of whether the Domain-Specific Hypothesis can account for the facts of category-specific semantic deficits. The reason why is that the facts of category-specific semantic deficits that distinguish between extant theories concern the patterns of cognitive deficits observed in patients.

A third criticism raised by Cappa and colleagues against the Domain-Specific Hypothesis is that category-specific semantic deficits have been observed for categories more fine grained than would be predicted by this hypothesis. This is a correct characterization of the Domain-Specific Hypothesis: its range of applicability extends only to the categories of "living animate," "plants," "conspecifics," and possibly "tools" (for discussion of this latter category, see Hauser, 1997; Laiacona and Capitani, 2001). For instance, Cappa and colleagues cite the performance of patient JP who was impaired for fruit, vegetables, birds and musical instruments. The authors note that "[i]t is difficult to understand how the neural system specialize for animals is preserved in [the] presence of an impairment of the category of birds" [sic] (p. 199). However, an elegant series of analyses by Cree and McRae (2003) demonstrate that different subcategories of items (e.g., birds, weapons, etc.) systematically differ along a number of relevant stimulus dimensions. For instance, in their corpus of object concepts, Cree and McRae found that birds, compared to mammals, were on average less familiar, less frequent, and more visually complex. A recent and nearly exhaustive review of the category-specific literature (Capitani *et al.*, 2003) did not find support for reliable fractionations of

deficits within the domains of living animate, fruit/vegetables, and nonliving things.[2]

Should MA be counted in the ledger of facts?

To this point, we have been discussing the arguments developed by Cappa and colleagues on the basis of patient MA as if the data from this patient should be counted in the ledger of facts of category-specific semantic deficits. It is not obvious, however, that this is the case. The project of Cappa and colleagues was to use the same procedures as were used to investigate patient EW to investigate a new case of category-specific semantic deficit for living things.[3]

In picture naming, MA was more impaired for living animate things (Time I: 42%, Time II: 56%) and fruit/vegetables (Time I: 38%, Time II: 38%) than for nonliving things (Time I: 64%, Time II: 71%), with no difference between living animate and fruit/vegetables. The authors also report a qualitative difference in the types of information provided by the patient in response to living and nonliving stimuli; specifically, the authors note that ''detailed semantic information'' was provided for nonliving things that were not named, and give as an example: ''bomb: you fire it at enemies, you kill a lot of people'' (p. 194). But how is this ''detailed''? From this definition, one might infer that the patient was looking at a picture of a bullet, or a gun, a rocket propelled grenade, a missile, a cannon, or a giant ball of flaming wax. More problematic is the fact that the *quantitative* effect of living versus nonliving in picture naming was primarily carried by the patient's performance on flowers (1/14 correct; 7%) and birds (6/22 correct; 27%), two categories that are not familiar at the species level to many people.

Another problematic aspect of MA's (purported) category-specific picture-naming impairment concerns the factor visual complexity: while the authors statistically controlled for frequency, familiarity, typicality, and age of acquisition, the factor visual complexity was ignored. It has been shown (Stewart *et al.*, 1992; Gaffan and Heywood, 1993; Cree and McRae, 2003) that images of living things tend to be more visually complex than images of nonliving things. (One can compare the case study of patient EW, in which the category effect was present over items controlled jointly for familiarity and visual complexity (EW: animals = 41% (7/17); non-animals = 94% (16/17); control range: animals (16–17); non-animals: (16–17)).

On a task in which patient MA was required to judge whether an animal was a food animal or not (according to the patient's respective culture), the patient was impaired. However, control data are not reported on the food/non-food animal task, and so there is no way to evaluate the patient's (culturally contingent) judgments. Furthermore, on a number of tasks, patient MA did not show *any* differences between living and nonliving things. For instance, no difference between living and nonliving things was observed in a category-fluency task. In fact, for some categories there was a trend in the opposite direction (e.g., MA: animals: 14; clothing: 5; control range: animals: 24–27; clothing: 22–30). The authors argue that the lack of a category effect ''. . . is probably due to the coexistence of a frontal deficit with a semantic deficit'' (194). However, as the authors also note, MA's performance was not ''defective'' for phoneme fluency (p. 193), which suggests that a 'general' frontal deficit cannot account for the ''lack'' of a category effect.

Two other tasks in which patient MA did not show effects of semantic category were object decision (animals 13/17 versus non-animals 14/15)[4] and size judgments (indicate which of two objects is larger). MA also did not show a category effect on a task requiring the patient to choose the correct part (e.g., head, handle) that corresponded to a given (i.e., headless, handle-less) animal or object. The performance of patient MA on this latter task can be contrasted with the performance of patient EW, who performed at chance for animal stimuli (60%) but in the normal range for artifact stimuli (97%) (control performance: animals 100%; artifacts 97%; Caramazza and Shelton, 1998). The fact that patient MA did not present with a category-specific impairment on tasks for which other patients (e.g., patient EW) have presented category-specific impairments would not in itself be problematic, *given* that other aspects of MA's profile of impairment clearly indicate that the patient had a category-specific impairment. However, as has already been argued for picture naming, and as will be shown below for other tasks, it is not at all clear that the patient does have a category-specific impairment. Furthermore, given that the ''aim'' of Cappa and colleagues' project was to ''replicate'' the methodology used to investigate patient EW, it is important to highlight the many ways in which patients EW and MA differ.

Two central attribute tests were administered to investigate the integrity of visual/perceptual versus functional/associative knowledge. On one test, a category effect was observed, such that MA was more impaired for living things (both living animate and living inanimate) than nonliving things, but no significant difference was obtained between visual/perceptual and functional/associative questions. The second central attribute test was designed to probe general and specific information about object concepts. On this test, collapsing across general and specific attribute questions, there was a significant difference between living animate things and non-animals, but not between living things in general (living animate and living inanimate) and nonliving things. There was also no significant difference between visual/perceptual and functional/associative knowledge. When looking at only those questions concerning specific attributes, again, the only reliable semantic category effect was between living animate and non-animals (nonliving things and living inanimate). However, for questions concerning specific attributes, there was a significant difference between visual/perceptual and functional/associative attributes. This means that it has not (yet) been demonstrated that the living – nonliving and the visual/perceptual – functional/associative dissociations can both be obtained over the same materials. This is important, since Cappa and colleagues present their arguments as following from the (purported) association

of two types of impairment: (1) a category-specific impairment that affected *all* living things compared to nonliving things; and (2) a disproportionate impairment for visual/perceptual compared to functional/associative knowledge.

On the methodological side (and as in the picture-naming task discussed above) both central attribute tests emphasized categories of living things that are not familiar to many people at the species level. For instance, the first attribute test contained 15 different birds while the second attribute test contained 16 different birds. Similarly, the second attribute test queried semantic information about 14 different exemplars from the category ''insects.'' (N.B. The authors report a *control* range on the category fluency task for ''insects'' of 8–11.) This methodological criticism could be addressed by reporting control means and ranges for the various conditions in the semantic attribute tests: however, it was only reported that ''[c]ontrol subjects did not show any significant differences'' (e.g., p. 197).

Given the wide range of methodological problems and generally weak data associated with the case study of patient MA, this case should not be counted in the ledger of facts of category-specific semantic deficits. In fact, it is not even clear that the patient *has* a category-specific semantic deficit. This conclusion would seem to be at odds with the 'motivation' for Cappa and colleagues' project: to ''replicate'' the procedures used by Caramazza and Shelton (1998). The decision to ''replicate'' the procedures used by Caramazza and Shelton led Cappa and colleagues to make questionable decisions, for instance, contrasting the performance of patient MA on animals versus non-animals. This contrast was appropriate for case EW, since that patient performed in or near the normal range for both fruit/vegetables and nonliving things. The procedures used to study a given case are constrained by two factors: (1) the theoretical hypotheses that are under investigation, and (2) the nature of the case under investigation.

Conclusion

The criterion for evaluating theories of the causes of category-specific semantic deficits is whether they can account for the relevant facts. If a given theoretical proposal cannot account for the variation in performance profiles across well studied patients with category-specific semantic deficits, then the theory can be rejected as a viable account of the causes of category-specific semantic deficits. There is growing consensus, even among Sensory/Functional theorists (e.g., Cree and McRae, 2003; Rosazza *et al.*, 2003), that the Sensory/Functional Theory cannot account for the existence of category-specific semantic deficits. Observations of patients that show associations of impairment that *would have been* predicted on the Sensory/Functional Theory, *if only the theory were not falsified*, are not relevant to the Sensory/Functional Theory. This is a logical consequence of the asymmetry of evidence and theory.

In this regard, not every observation is worth reporting: Observations are worth reporting that are theoretically useful. The patient reported by Cappa and colleagues is not useful for evaluating the Sensory/Functional Theory, but is potentially informative of further constraints that may be placed on a domain-specific interpretation of category-specific semantic deficits. However, observations can be theoretically relevant only if they are methodologically well studied and carefully reported.

The substantive goal of theoretical work on category-specific semantic deficits is to use the variation that characterizes the phenomenon to inform the assumptions that might be made by a theory of the causes of category-specific semantic deficits, and by extension, the organization of the normally functioning conceptual system. The field of category-specific semantic deficits is at a point where progress will be made only when proponents of various theoretical persuasions acknowledge the weight of the empirical evidence. This includes the practice of not citing papers that have been shown to be methodologically inadequate. There have been recent attempts to critically review the literature (e.g., Capitani *et al.*, 2003), but the responsibility is ultimately that of the authors to critically evaluate the extant facts with what is currently known in the field.

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Notes

[1]Cappa and colleagues also criticize the Domain-Specific Hypothesis on the grounds that it predicts equivalent deficits for visual/perceptual and functional/associative knowledge. This amounts to the same criticism as that under discussion in the text.

[2]Rosazza and colleagues also point out that the categories ''body parts'' and ''musical instruments'' can dissociate from ''living'' and ''nonliving'' things, respectively (for discussion of how ''body parts'' and ''musical instruments'' pattern with ''living'' and ''nonliving'' things, see Barbarotto *et al.*, 2001; concerning the category ''body-parts,'' see Shelton *et al.*, 1998; see also Cree and McRae, 2003 for analysis and discussion of relevant stimulus factors).

[3]Rosazza and colleagues (2003) write: ''The aim of this study is to replicate the methodology used by Caramazza and Shelton (1998) to another case of category specific semantic impairment in order assess, first, whether their result could be generalized to our case, and second, whether there is theory, either reductionist or non-reductionist, that could explain the different patterns of category-specific deficit shown in the literature, included ours'' [sic] (p. 190).

[4]There was a tendency to reject existing animals as unreal. This tendency may be explained by the presence of more unreal animals than real animals in the test (11 vs. 6). MA was also tested on test 10 of the BORB, an object/non-object test.

However, the way in which the authors report the results obscures whether there was an effect, and if so, what the effect was. For instance: ''Moreover in order to analyze the difference in MA's performance between animals and objects, we combined the 32 pictures we created with BORB stimuli, since BORB items have fewer object pictures than animal pictures. Results have shown that the difference is significant ($X^2 = 6.828$, $p < 0.009$) and that the patient tends to reject real animals. Since items were unbalanced to animals' advantage, we also performed a logistic regression analysis: it confirmed the previous results, namely a defective performance with animals (Wald $= 6.123$, $p < 0.013$)'' [sic] (p. 195). What is not clear from this description is *which* difference was significant, the difference between animals and non-animals, or the tendency to reject real animals as unreal? How did the authors carry out the logistic regression analysis?

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