



Minding the facts: a comment on Thompson-Schill et al.'s “A neural basis for category and modality specificity of semantic knowledge”

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Abstract

In this comment on a recent paper by Thompson-Schill et al. (1999) I argue that the authors failed to consider important empirical facts that are at variance with their favored theory of the causes of semantic category-specific deficits. I also argue that the predictions they make about fusiform gyrus activation on the basis of the interactive modality-specific hypothesis of semantic organization do not obviously follow from that model. I point out that simulations are needed in order to derive predictions from the model. Finally, I argue that the fMRI results they obtained are not obviously relevant to our understanding of the causes of semantic category-specific deficits. © 2000 Elsevier Science Ltd. All rights reserved.

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1. Introduction

In a recent issue of *Neuropsychologia*, Thompson-Schill et al. [22] (1999) report having carried out a test of a “... model of how damage to interactive, modality-specific neural regions might give rise to [semantic] categorical impairments”. These are impairments in which certain semantic categories are disproportionately impaired relative to other categories. The most frequently investigated categorical distinction is that between living and non-living things, but other category-specific deficits have been reported (see [2,8] for brief reviews). Thompson-Schill et al. used functional MRI to determine whether the left fusiform gyrus responds differentially during retrieval of visual and non-visual knowledge about living and non-living things. They found increased fusiform activity, relative

to a baseline, for visual and non-visual knowledge of living things; they also found increased fusiform activity for visual knowledge of non-living things but *not* for non-visual properties. These results were interpreted as providing support for the interactive, modality-specific account of semantic category-specific deficits proposed by Farah and McClelland [7]. However, I will argue that there is a substantial body of data that is highly problematic for Thompson-Schill et al.'s modality-specific account of category-specific deficits. I will further argue that it is not at all obvious that the predictions they derive from Farah and McClelland's computational version of the modality-specific hypothesis follow from that model. Finally, I will argue that the fMRI results reported could as easily be interpreted to reflect imagery processes involved in solving difficult semantic judgment tasks of the sort used in their study, and they may have nothing to say about the causes of category-specific semantic deficits or the organization of the semantic system.

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2. The modality-specific hypothesis and category-specific deficits: what are the ‘facts’

The *interactive*, modality-specific hypothesis is a variant of the sensory/functional theory of semantic organization, which was originally proposed by Warrington and Shallice [25] to account for the existence of semantic category-specific deficits.¹ In a seminal paper, Warrington and Shallice described four brain-damaged patients who named living things far worse than non-living things. They argued that a possible basis for their patients’ disproportionate difficulty in naming (and recognizing) living things was because they had sustained damage to the visual component of the semantic system. Warrington and McCarthy [23,24] further argued that the disproportionate difficulty observed in some patients in naming non-living things reflects damage to the functional/associative component of the semantic system. The sensory/functional theory makes two crucial assumptions about the organization of the semantic system and the structure of semantic categories. One assumption is that the semantic system is organized into modality-specific components, of which the most important are the visual and the functional/associative components. The other assumption is that visual and non-visual properties are differentially important in determining the meaning of living and non-living things: visual properties are more important for living things and non-visual properties are more important for non-living things. Given these assumptions, we would expect that damage to visual semantics would result in disproportionate difficulty for living things, while damage to functional/associative semantics would result in disproportionate difficulty for non-living things.

Farah and McClelland [7] implemented a computational version of Warrington, Shallice, and McCarthy’s sensory/functional theory. The model consists of three sets of units: semantic, visual (picture inputs or outputs) and verbal (word inputs or outputs) units. The semantic units were further subdivided into

visual and functional units, with bi-directional connections among units both within and between components. Two crucial representational assumptions were implemented in the model: (1) There were many more visual than functional units (a ratio of 3:1); and (2) the ratio of visual to functional features for living and non-living things was set at 16.1:2.1 and 9.4:6.7, respectively. When the visual semantic component of the model was ‘lesioned’, the model produced far worse performance in naming living than non-living things. Conversely, when the functional semantic component of the model was lesioned, the model performed worse in naming non-living than living things. Thus, as expected, category-like naming deficits can be obtained by damaging a semantic system that is not organized categorically.²

Farah and McClelland also tested their model’s performance in ‘answering’ questions about visual and functional properties of living and non-living things. This test was carried out in order to determine whether lesioning the visual component of the semantic system would result in impaired access to both visual *and* functional information about living things, as had been found for patients with category-specific impairments. As expected, the simulations clearly showed that lesions to the visual component resulted in impaired access to both visual and functional properties of living *and* non-living things, and that the extent of difficulty in retrieving functional properties of living things was greater than for non-living things. The basis for this result was attributed to a property of the parallel distributed processing (PDP) principles that characterize their computational model. The principle in question involves the fact that in such models the units in each semantic component interact with the units in other components so that the activation integrity of the semantic representation in one component depends on the activation integrity in other components. Extensive damage to one component adversely affects the activation integrity of units in other components, resulting in the observed behavior of the model.

The simulation experiments carried out by Farah and McClelland also showed, however, that the model’s difficulty in accessing visual properties of living things was greater than its difficulties in accessing functional knowledge. The authors put it thus: “Although damage to visual semantic memory impairs retrieval of functional knowledge of living things, it affects functional knowledge of living things less than visual knowledge ... This pattern is consistent with the behavior of the patients reviewed earlier, whose impairments in knowledge of living things tend to be more obvious in the visual than in the functional domain” (p. 348). The simulation results that led to this conclusion are shown in Fig. 1, which shows the

¹ Another empirical fact cited in support of the sensory/functional theory is the performance of so-called optic aphasics who present with difficulties only in naming stimuli in the visual modality ([14] but see [3,9], and [18] for critical assessments of the role of such evidence in informing theories of semantics).

² Several variants of the basic model were tested and various lesioning experiments were carried out. In almost all cases, selective damage to either the visual or the functional semantic component resulted in category-like deficits. Note, however, that this is a very weak test of the sensory/functional theory. It is hardly surprising that category-like deficits would result from damage to a component that is disproportionately necessary for the representation of a concept.

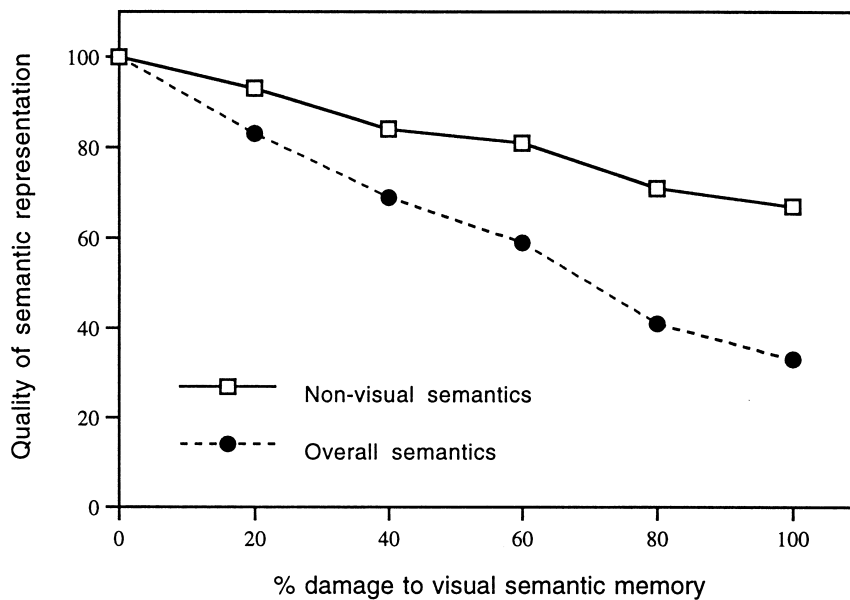


Fig. 1. Performance of Farah and McClelland's basic model as measured by the dot product of the correct and the obtained overall and functional-only semantic patterns for living things, following different amounts of damage to visual semantic units. This figure was obtained by collating parts of Figs. 7 and 12 from Farah and McClelland [7].

model's performance in accessing visual and functional knowledge of living things.³ It can be readily seen that performance in accessing visual semantic knowledge is more severely impaired than performance in accessing functional semantic knowledge. This result was considered to be consistent with the performance of patients with category-specific deficits for living things.

In short then, Farah and McClelland's model shows three important behaviors when it is lesioned. First, selective damage to the visual semantic component results in disproportionate difficulty in naming living things. Second, such damage results in difficulties in accessing *both* visual and functional knowledge of the items in this category, as well as items in the category of non-living things. And, third, it results in greater difficulty in accessing visual than functional semantic knowledge about living things (see Fig. 1). Farah and McClelland argued that these three features of the model's behavior are consistent with the performance of patients with semantic category-specific deficits and,

therefore, that the simulation results provide support for the sensory/functional theory of semantic organization. They further claimed that their results support a particular variant of this theory — an interactive version based on parallel distributed processing (PDP) principles, which Thompson et al. refer to as the interactive, modality-specific hypothesis (IMSH).

The sensory/functional theory of category-specific deficits and the specific variant proposed by Farah and McClelland have been criticized on both empirical and theoretical grounds [4]. Of special relevance here is the fact that a central prediction of the IMSH has been shown to be wrong. The hypothesis predicts that patients with category-specific deficits for living things should perform worse in accessing visual than functional knowledge in this category (see Fig. 1). This prediction has not held up. In a number of tightly designed studies, it has been shown that patients with category-specific deficits for living things are *equally* impaired in accessing visual and functional knowledge of living things [4,11–13,17,19]. Furthermore, the studies that originally seemed to show that patients with category-specific deficits for living things had greater difficulty in accessing visual than functional knowledge [1,6,21] have been criticized on methodological grounds [4]. Thus, there is no convincing evidence for a central prediction of the IMSH and, in fact, there are grounds for thinking that the prediction is discon-

³ This figure was obtained by combining the results of Figs. 7 and 12, following Farah and McClelland's instruction that the contrast between access to visual and functional properties can be seen "... by comparing Figs. 7–11, which show the dot products of the obtained and correct pattern over all of semantics after visual semantic damage, to Figs. 12 and 13, which show the dot products for functional semantics in particular" (p. 368).

firmed by the performance of an increasingly large number of well-studied patients.⁴

Thompson-Schill et al., in motivating the fMRI study they designed to test the IMSH, point out that this hypothesis has been implemented in a computational model [7] and they go on to assert that "... [it] is consistent with neuropsychological data ..." (p. 672). The only studies cited are those that could be considered to be unproblematic for their theory — Farah et al. [6], Mehta et al. [16], Silveri and Gainotti [21], and Warrington and Shallice [25]. They do not cite the more numerous, more recent, and better-controlled studies that are clearly inconsistent with their hypothesis [4,11–13,17,19]. In fact, they fail to even acknowledge that there is an issue here.⁵ Thus, when they note that patients with category-specific deficits are impaired in accessing both visual and non-visual knowledge of living things they cite five studies: Caramazza and Shelton [4], Farah et al. [6], Mehta et al. [16], Silveri and Gainotti [21], and Warrington and Shallice [25]. However, these studies report drastically different results, with clearly different implications for the IMSH. The study by Caramazza and Shelton reports that their patient performed *equally* poorly in accessing visual and non-visual semantic knowledge of animals (the patient performed perfectly in naming fruits and vegetables and in accessing visual and non-visual semantic knowledge about these items!). By contrast the studies by Farah et al. and Silveri and Gainotti report that their patients performed worse in accessing visual than non-visual knowledge about living things (but these studies have been criticized on methodological grounds [4]). And the study by Mehta et al., if anything, found worse performance for non-

visual than visual knowledge of living things.⁶ Finally, Warrington and Shallice did not explicitly test their patients' ability to retrieve visual and non-visual semantic properties of living things, and therefore this study is irrelevant to the issues under consideration here. It appears, then, that Thompson-Schill et al.'s hypothesis is not motivated by the published facts.

3. The modality-specific hypothesis: fMRI predictions

Thompson-Schill et al. derive the following two fMRI predictions from the IMSH:

There are two critical predictions of the interactive modality-specific hypothesis which can be tested ... activity should be present in the left fusiform gyrus during retrieval of non-visual information about living things. This is a straightforward prediction of the claim that visual knowledge is obligatory during the retrieval of any information about living things. Second, activity in the left fusiform gyrus should be greater during retrieval of visual information relative to non-visual information for non-living things. This prediction is based on the assumed (and empirically-demonstrated Farah & McClelland [7]) differences in the proportion of visual knowledge in the representations of living and non-living things (p. 672).⁷

Thompson-Schill et al. found that for living things comparable levels of activation were obtained regardless of whether the task required access to visual or non-visual properties. By contrast, for non-living things greater activation was found when answering questions about visual than non-visual properties. These results were interpreted as consistent with predictions derived from the IMSH. However, it is not at all clear that the predictions derived by Thompson-Schill et al. follow from Farah and McClelland's model. Nor is it clear that the results are consistent with those predictions even if they were to follow from the model.

From our discussion of Farah and McClelland's model thus far, we can infer that there should be activation of visual semantic units even when the task only requires answering questions about non-visual properties of living or non-living things. This prediction follows from the interactivity assumption in the model. That is, activation of either the visual or functional properties of an object will result in the activation of that object's properties in the other network. This means that independently of whether we are asking questions about the visual or the functional attributes of an object, all the semantic attributes of the object will be activated. As a consequence, the model

⁴ There are several other criticisms of the interactive, modality-specific hypothesis proposed by Farah and McClelland. For example, one criticism is that the theory cannot account for the patterns of dissociations within the category of living things — the fact that the category of animals can be damaged independently of other living things (and vice versa). Furthermore, the empirical basis for the claim that living things have many more visual properties than functional/associative properties has been shown to be inadequate [4].

⁵ More generally, the authors ignore a broad range of alternative hypotheses about the possible causes for semantic category-specific deficits (e.g., [4,5,17]). Instead they discuss only their theory in any detail.

⁶ Thompson-Schill et al. fail to mention that aspects of the results reported by Mehta et al. are inconsistent with the IMSH. Contrary to the predictions made by this hypothesis, patient MS performed within the normal range in answering queries about visual and non-visual properties of non-living things. However, as noted above, the IMSH predicts impaired performance also for the category of non-living things (see Figs. 3–5, 7–10, 12 and 13 in Farah and McClelland's original study).

⁷ The 'empirically-demonstrated' differences the authors refer to have not been replicated in more tightly controlled studies (see [4]).

predicts *equal* visual activation whether we are querying visual or functional attributes of an object. The model further predicts that there should be greater visual activation for the living than for the non-living thing category since, by hypothesis, the former category has relatively many more visual than functional attributes. The results reported by Thompson-Schill et al. are inconsistent with the set of predictions derived here. The authors found equal visual activation for living things but greater visual activation for non-living things.

The first set of predictions we derived from the IMSH is clearly different from the predictions derived by Thompson-Schill et al. They claim that the IMSH predicts that visual activation should be greater when answering queries about visual than non-visual information of non-living things. In order to derive this prediction from the IMSH one would have to make the additional (perhaps not implausible) assumption that having subjects focus attention on a specific type of attribute (say, visual) modulates the activation of those attributes relative to other types of attributes. With this additional assumption, we would expect that probing visual properties of non-living things should result in greater visual activation than when probing functional properties of the same category. However, we would also then expect that there should be greater visual activation when answering queries about visual than non-visual attributes of living things. This set of predictions, too, is inconsistent with the results reported by Thompson-Schill et al. Now the mismatch occurs for the category of living things: the theory predicts greater visual activation for both living and non-living things when querying visual as compared to functional attributes but the results show greater visual activation only for the non-living category.

The two sets of predictions discussed here were derived without the benefit of a simulation. They were derived in the style used by Thompson-Schill et al., in their paper. However, it is notoriously difficult to attempt to make predictions from complex interactive model without the benefit of simulations. Therefore it is not impossible that the predictions derived here do not correspond to those we would get by running simulations with IMSH. Thus, we may have to withhold judgment on whether the results reported by Thompson-Schill et al. provide evidence *against* the IMSH. At the very least, however, and contrary to Thomson-Schill et al.'s claims, the results reported by these authors do not provide support for the IMSH.

Leaving aside the fact that the fMRI predictions derived by Thomson-Schill et al. do not obviously follow from the model they wanted to test, there is the question of whether their claim about the role of the fusiform gyrus in explaining category-specific deficits makes sense in light of what we know

about these deficits. Let us suppose for the sake of argument that Thompson-Schill et al.'s predictions from the IMSH were correct and that the fMRI results are consistent with their predictions. What could we conclude from such an outcome? The authors argue that the results indicate that the fusiform gyrus plays a central role in the representation of visual semantic knowledge. However, this conclusion is not consistent with the fact that many or even most of the patients who present with category-specific *semantic* deficits for living things do not have damage to the fusiform gyrus. This fact is important because its recognition invites us to consider alternative explanations for the results obtained by Thompson-Schill et al.

The task used by Thompson-Schill et al. involved difficult perceptual/conceptual judgments, which may have implicated imagery processes. This is most likely to be the case for the visual questions in the task. To answer questions such as "Are both front and back ends of a submarine approximately the same width?" or "Does a parrot have a curved beak?" it may be necessary to generate a visual image of the objects and properties being queried. And it may also be the case that visual imagery was involved in answering non-visual questions (such as "Are pandas found in China?" or "Can headphones play stereo music?") although only in an ancillary and non-essential way. That is, subjects may have generated images of the objects queried (pandas and headphones) even though these images played no direct role in answering the questions. If such were the case, the fMRI results obtained by Thompson-Schill et al. would reflect the functioning of imagery processes rather than access to semantic representations. And, in fact, the authors provide evidence that at least for one of their subjects, for whom they have data on both the semantic judgment task and an imagery task, the same cortical regions are involved in semantic judgment and visual imagery tasks. However, they do not consider the possibility that the visual processes they have studied may involve retrieval of visual-structural representations and not visual-semantic representations (e.g., [3,10,20]). This last possibility is made the more probable when we consider the fact (cited above) that in many cases category-specific semantic deficits for living things are not associated with lesions to the fusiform gyrus. Furthermore, these patients do not typically present with generalized imagery processing difficulties (e.g., [4]) as might be expected if access to visual information were generally damaged.

4. Conclusion

In this commentary on a recent paper by Thomp-

son-Schill et al. [22] I have argued that the authors defend a theory of the causes of semantic category-specific deficits that is at variance with well-established empirical facts. No attempt is made by the authors to deal with these recalcitrant facts. I have also argued (1) that the predictions they make about fusiform gyrus activation on the basis of the IMSH do not obviously follow from this model or are wrong, (2) that simulations are needed to derive predictions from the model, and (3) that the results may actually be inconsistent with the IMSH. Finally, I also argued that the fMRI results they obtained are not obviously relevant to our understanding of the causes of semantic category-specific deficits.

There is a growing body of detailed and sophisticated research on category-specific semantic deficits (see [4,8] for reviews). There is also a growing literature on neuroimaging studies that addresses the organization of conceptual knowledge in the brain [15]. The value of experimental research is greatly enhanced when its results are embedded in a rich network of other constraining facts. All relevant facts must be considered in developing or testing theories of cognitive functioning. We are then much more likely to converge on a reasonable theory of the organization of conceptual knowledge in the brain.

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References

- [1] Basso A, Capitani E, Laiacona M. Progressive language impairment without dementia: a case with isolated category specific semantic defect. *Journal of Neurology, Neurosurgery, and Psychiatry* 1988;51:1201–7.
- [2] Caramazza A. The interpretation of semantic category-specific deficits: what do they reveal about the organization of conceptual knowledge in the brain? *Neurocase* 1998;4:265–72.
- [3] Caramazza A, Hillis AE, Rapp BC, Romani C. The multiple semantics hypothesis: multiple confusions? *Cognitive Neuropsychology* 1990;7:161–89.
- [4] Caramazza A, Shelton JR. Domain-specific knowledge systems in the brain: the animate-inanimate distinction. *Journal of Cognitive Neuroscience* 1998;10:1–34.
- [5] Devlin JT, Gonnerman LM, Andersen ES, Seidenberg MS. Category-specific semantic deficits in focal and widespread brain damage: a computational account. *Journal of Cognitive Neuroscience* 1998;10:77–94.
- [6] Farah MJ, Hammond KM, Mehta Z, Ratcliff G. Category-specificity and modality-specificity in semantic memory. *Neuropsychologia* 1989;27:193–200.
- [7] Farah MJ, McClelland JL. A computational model of semantic memory impairment: modality specificity and emergent category specificity. *Journal of Experimental Psychology: General* 1991;120:339–57.
- [8] Forde EME, Humphreys GW. Category-specific recognition impairments: a review of important case studies and influential theories. *Aphasiology* 1999;13:169–93.
- [9] Hillis AE, Caramazza A. Cognitive and neural mechanisms underlying visual and semantic processing: implications from “optic aphasia”. *Journal of Cognitive Neuroscience* 1995;7:457–78.
- [10] Humphreys GW, Riddoch MJ, Quinlan PT. Cascade processes in picture identification. *Cognitive Neuropsychology* 1988;5:67–103.
- [11] Laiacona M, Barbarotto R, Capitani E. Perceptual and associative knowledge in category specific impairment of semantic memory: a study of two cases. *Cortex* 1993;29:727–40.
- [12] Laiacona M, Capitani E, Barbarotto R. Semantic category dissociations: a longitudinal study of two cases. *Cortex* 1997;33:441–61.
- [13] Lambon-Ralph MA, Howard D, Nightingale G, Ellis AW. Are living and non-living category-specific deficits causally linked to impaired perceptual or associative knowledge? Evidence from a category-specific double dissociation. *Neurocase* 1998;4:311–38.
- [14] Lhermitte F, Beauvois M-F. A visual-speech disconnection syndrome. Report of a case with optic aphasia, agnosia alexia and color agnosia. *Brain* 1973;96:695–714.
- [15] Martin A, Ungerleider LG, Haxby JV. Category-specificity and the brain: the sensory-motor model of semantic representations of objects, Gazzaniga MS, *The cognitive neurosciences*, 2nd ed., Cambridge: MIT Press, 2000.
- [16] Mehta Z, Newcombe F, DeHaan E. Selective loss of imagery in a case of visual agnosia. *Neuropsychologia* 1992;30:645–55.
- [17] Moss HE, Tyler LK, Durrant-Peatfield M, Bunn EM. Two eyes of a see-through: Impaired and intact semantic knowledge in a case of selective deficit for living things. *Neurocase* 1998;4:291–310.
- [18] Riddoch MJ, Humphreys GW, Coltheart M, Funnell E. Semantic systems or system? Neuropsychological evidence re-examined. *Cognitive Neuropsychology* 1988;5:3–25.
- [19] Samson D, Pillon A, De Wilde V. Impaired knowledge of visual and non-visual attributes in a patient with a semantic impairment for living entities: A case of a true category-specific deficit. *Neurocase* 1998;4:273–90.
- [20] Seymour PHK. *Human visual cognition*. London: Collier MacMillan, 1979.
- [21] Silveri MC, Gainotti G. Interaction between vision and language in category-specific impairment. *Cognitive Neuropsychology* 1988;5:677–709.
- [22] Thompson-Schill SL, Aguirre GK, D’Esposito M, Farah MJ. A neural basis for category and modality specificity of semantic knowledge. *Neuropsychologia* 1999;37:671–6.
- [23] Warrington EK, McCarthy R. Category specific access dysphasia. *Brain* 1983;106:859–78.
- [24] Warrington EK, McCarthy R. Categories of knowledge: further fractionations and an attempted integration. *Brain* 1987;110:1273–96.
- [25] Warrington EK, Shallice T. Category specific semantic impairments. *Brain* 1984;107:829–54.