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## The limits of a localized account of conceptual knowledge

Reply to Kiefer and Spitzer

Kiefer and Spitzer take issue with our review paper on both empirical and theoretical grounds<sup>1,2</sup>. We address their comments on each of these points in turn.

### Empirical data

Kiefer and Spitzer argue that our claims for a unified distributed conceptual system are based on a null result and therefore cannot be interpreted as evidence supporting our theoretical account of conceptual knowledge. We do not agree with this view. First, the neuroimaging data that we cite in support of our claims are *not* simply null results. In a series of five studies we have demonstrated robust, significant areas of activation for conceptual representation and processing throughout the frontal and temporal lobes, compared with baseline conditions. It is in this context that we interpret the absence of distinct regional activations for specific semantic domains/categories as evidence for a unified conceptual system. Moreover, not only have we replicated this effect across a number of PET and fMRI studies, we have also reported detailed power analyses, which confirm that our experiments were powerful enough to reveal category/domain effects had they been present in the data<sup>3–5</sup>. This absence of category-specific activation has also been obtained in other studies where stimuli are appropriately matched<sup>6</sup>.

Kiefer and Spitzer point out that 'quite a few' fMRI and PET studies have reported differential activations for semantic categories/domains. This comment suggests a misunderstanding of our point, as we did not dispute this fact. Our point was, and remains, that the *locus* of these category-specific activations is not consistent. Areas of activation found for a certain category in one study often do not show up in other studies, as we catalogued in Table 1 of our review<sup>2</sup>. Nor do the results of functional imaging studies always concur with lesion-deficit data. To take one example, Martin, Chao and colleagues argue that the ventral stream for object processing is partitioned according to category, with tools being processed in more medial areas of the fusiform gyrus and animals in more lateral regions<sup>7,8</sup>. However, this does not concur with lesion data showing that patients with herpes simplex encephalitis, whose brain damage centres on medial temporal regions, typically show category-specific deficits for animals rather than tools, whereas semantic dementia patients, who have more lateral damage, are claimed not to have any category-specific deficits

Kiefer and Spitzer are right to point out that we did not consider data from ERP studies in our review of the literature concerning neuroanatomical bases of conceptual knowledge. In general, ERP paradigms are more sensitive for probing important issues concerning temporal rather than spatial distribution, and thus are not the most appropriate methodology for asking questions about differences in localization.

To recap, our claim is not that there is no neuroimaging evidence at all for category-specific activations. Rather, there is no strong evidence that specific neuroanatomical regions are reliably and consistently activated for a given category or type of conceptual knowledge.

### Theoretical issues

As Kiefer and Spitzer conclude, there is much overlap between their theoretical account and ours. They talk of multiple semantic maps, with degrees of activation varying across maps rather than being all or none. The difference between our account and theirs is that they claim that these semantic maps are localizable to specific regions of the brain. By contrast, within our unified distributed system, we suggest that semantic space might be 'lumpy', such that certain parts of the network emerge as being

more or less involved in the processing of attributes that are highly correlated, or concepts that share many properties. Therefore, the key difference between these accounts is whether the semantic maps (or 'lumps' in the network) for a given category or type of attribute can be consistently located in a specific area of the brain.

We contend that the available neuroimaging data is more consistent with a unified distributed system than with localizable multiple maps. Our distributed model explicitly predicts that although conceptual processing might produce differential activations by category, these will be:

- (1) variable rather than consistent in their localization;
- (2) differences in degree of activation rather than all-or-none selective activations;
- (3) less reliable than differences in activation due to varying task demands;
- (4) small in relation to the much greater *commonality* of activation for all kinds of conceptual knowledge.

This set of predictions seems to us to give an accurate description of the current body of neuroimaging results. As we originally stated, the neuroimaging data suggest important limits to a localized account. However, only further empirical data will determine whether this is correct.

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