The role of similarity structure in category specific deficits in Alzheimer's disease

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A number of studies have reported differential patterns of deficit for naming natural kinds concepts such as ducks and apples and artifact concepts such as cars and shovels in patients with Alzheimer’s disease (AD) (e.g., Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997; Silveri, Daniele, Giustolis, & Gainotti, 1991; Whatmough et al., 2003). Gonnerman and colleagues (1997) proposed that category specific deficits in AD arise because of differences in the structure of natural kind and artifact categories, namely that natural kind concepts tend to share multiple overlapping semantic features (e.g., most animals that have wings also have a bill). These intercorrelated features help maintain relatively higher naming performance initially, since features that are no longer directly connected to a concept may be activated through collateral support. However, as damage progresses a relatively sudden drop in naming ability occurs once insufficient numbers of intercorrelated features are available in a given category.

In contrast, most artifact categories contain concepts with few intercorrelated features, resulting in a greater vulnerability to difficulties in naming ability for individual artifact concepts, but no sudden drop in naming proficiency for the domain.

Concepts can be thought of as occupying a hyperdimensional semantic space with dimensions based on semantic features. Certain tasks such as picture naming require participants to compute a relatively precise meaning in order to distinguish the concept from other similar items. Other tasks, such as the board sorting task described below (cf. Bonilla & Johnson, 1995), simply require participants to determine whether one concept is closer to a second concept or a third one in semantic space. This second type of task can be accomplished with a less fine-grained reading of the semantic space, but will be greatly affected by the similarity structure of the category.

Although category specific deficits have been reported for picture naming, tasks dependent upon semantic similarity structure may reveal systematically different patterns of impairment. Whereas natural kinds concepts receive some protection from damage by being embedded in categories with rich similarity structures, since the semantic space is dense, once features in these concepts are damaged (even those that are not intercorrelated) the similarity structure will be distorted. Artifact concepts, on the other hand, belong to categories with impoverished similarity structures, and thus maintain relatively stable similarity relationships with comparable damage.

Methods

To determine whether AD patients show category specific deficits in board sorting tasks, participants were asked to place 12 chips with concept labels written on them on a 10 × 10 square grid. Participants were instructed to put the chips close to one another if the concepts were more similar and farther apart if the concepts were less similar. We also used a picture naming task as a measure of semantic impairment. Both tasks used 144 items from 12 different categories (e.g., domestic animals, tools).

Fifteen patients with mild to moderate AD and 49 healthy normal control (NC) participants (25 college students and 24 healthy elderly) participated. For the picture naming task, the percent of correctly named pictures was calculated. For the board sorting task, distances between pairs of chips were calculated. A composite board for NC participants was created by averaging all the distances for a given pair of concepts across all NCs who completed that board and repeating this process for each pair of concepts in a given category. Correlations were calculated between the AD board distances and the corresponding NC composite board distances, and these correlations served as the dependent measure. Since we were interested in differences between natural kind and artifact categories, we collapsed all the data for a particular subject within a domain.

Results

We found a weaker correlation between the distances for AD patients and the NC group for natural kinds compared to artifacts (paired t test, t (14) = -2.86, p < .01). This suggests that, as predicted, damage distorted the similarity structure of natural kinds categories more than artifact categories. Additionally, to determine the relationship between deficits in similarity structure and the degree of semantic impairment, we compared the r values from the correlations derived above with each AD patient’s picture naming score. For natural kinds, the degree to which AD board distances were similar to NC distances was highly correlated with the patient’s degree of semantic
impairment, as measured by picture naming. Thus, the worse a patient
performed on picture naming, the more distorted the similarity
structure of their categories was ($r = .62, p < .02$). This was not true for
artifact categories ($r = .3, n.s.$).

Discussion

These results suggest that the similarity structure of a category is
the basis for category-specific deficits in tasks where relative similarity
is crucial. Additionally, these results, considered with those from pic­
ture naming tasks, indicate that the particular similarity structure that
is beneficial for picture naming tasks is in fact detrimental for tasks
such as board sorting.

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