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Structure Versus Processing Deficits in Alzheimer's Disease, a Matter of Degree: A Comment on Storms et al. (2003)

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G. Storms, T. Dirikx, J. Saerens, S. Verstraeten, and P. P. De Deyn (2003) argued that multidimensional scaling studies are ill-suited for investigating semantic deficits in individuals diagnosed with dementia of the Alzheimer type (DAT) because such individuals show great inter- and intraindividual variability in their proximity judgments. Discussed in this commentary are (a) the possible role of attentional set in producing inconsistent performance across trials, (b) the implications of attentional factors on the structure versus process debate, and (c) the inevitable semantic degradation following severe progression of the disease. A framework is presented for considering nonlinear performance differences as a function of attentional demands of the task, vulnerability of the semantic representation, and progression of the disease.

Storms, Dirikx, Saerens, Verstraeten, and De Deyn (2003) investigated the claim that multidimensional scaling (MDS) solutions derived from a triadic comparison task provide a valid measure of structural degradation of semantic memory in patients suffering from dementia of the Alzheimer type (DAT). Consistent with an earlier study by Chan, Butters, Salmon, and McGuire (1993), Storms et al. found that patients with DAT yielded different proximity data from normal control individuals, suggesting qualitatively distinct semantic networks between the two groups. However, Storms et al. argue that interindividual variability among people with DAT renders the resulting solution uninterpretable and that lack of consistency across time among DAT individuals refutes an explanation that their deficient performance is caused by degraded semantic storage.

In general, Storms et al.'s (2003) article makes a very useful contribution to the literature. In fact, the issues they raise point to broader areas of concern in any study of group differences in cognition. Here, we will focus on two of the important implications raised by Storms et al.: the problem of inter- and intraindividual variability and whether one can distinguish between structural and processing explanations of task performance.

Inter- and Intraindividual Variability

The first issue raised by Storms et al. (2003) concerns the problem that variability across participants prohibits collapsing across individual data to obtain an average estimate of performance, because the obtained average is unrepresentative of the sample. This is a general problem in all studies, but particularly in aging and DAT studies, as there is evidence that variability across individuals increases in both healthy aging and dementia (see Hultsch, MacDonald, Hunter, Levy-Bencheton, & Strauss, 2000). However, this problem is further exacerbated in studies using MDS because of the assumption that the individual proximities within a sample of related items explicitly reflects the relative spatial closeness between such items in semantic memory. Storms et al. argue that obtaining a multidimensional solution that graphically depicts a group's semantic representation is unwarranted if the solution is derived from error-prone data. Moreover, they argue that even the individual differences scaling (INDSCAL) analysis used by Chan et al. (1993), which incorporates individual differences in the weighting of relevant dimensions, can render uninterpretable solutions, because this analysis still assumes that all participants use the same underlying dimensions to make their decisions.

Although this issue of individual variability poses problems for Chan et al.'s (1993) attempts to interpret the solutions derived from patients with DAT, it does not undermine one of their most important points: that the primary dimensions used by normal control participants to sort and compare animal stimuli are not used as heavily and consistently by individuals with DAT. In addition, Chan, Butters, and Salmon (1997) demonstrated that such deviation from the proximities of control individuals increased along with increasing progression of the disease. This is an important point, regardless of whether such deviations arise because of deficits in semantic storage, difficulties in retrieval access, or failures in general attention.

One possibility for such variable responding in DAT in this task is that it is primarily due to the transient nature of the triadic comparison itself. As noted by Ober and Shenaut (1999), the triadic comparisons task requires the flexible use of contextually appropriate dimensions. Evidence indicates that normal control participants tend to use the same dimen-

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sions in this task in decreasing order of importance (e.g., domesticity, size, and predation, respectively). However, such structure is missing in the proximities from individuals with DAT. This difference could arise, for instance, if control participants use an ordered algorithm for imposing structure such as use of the rule "first use domesticity to separate, if all 3 domestic or all 3 wild, then use size, etc." In this way, impaired performance on this task could reflect an inability to engage the structural rules used by control participants and should increase both the inter- and intraindividual variability in DAT, especially when the presentation order is randomized on every trial, as is done in the Storms et al. (2003) study. (Indeed, without a corresponding reliability estimate from healthy control participants, even the assumption that individuals with DAT had relatively low intraindividual consistency is unwarranted.). With this issue in mind, if one truly wishes to demonstrate semantic degradation in DAT, a possible improvement in the method would be to first demonstrate which feature dimensions control participants use to sort the stimuli (e.g., domesticity, size, predation) and then test whether individuals with DAT can use those same dimensions under explicit instructions (e.g., "pick the two animals that are *domestic/largest/meat eaters*?"). Accurate responding on this task would provide evidence for intact semantic representations. Consistent with the possibility that such deficits are task-dependent, when Chan et al. (1993) asked their patients to sort their stimuli across these dimensions, the patients were about 93% accurate in sorting according to domesticity and 95% accurate in sorting according to size. Similarly, Ober and Shenaut (1999) found no difference between control and DAT individuals' solutions using a flags-board method, in which patients are asked simply to group similar items together. Taken together, these studies suggest that individuals with DAT are capable of using such dimensions as domesticity and size when they are explicitly told and therefore argue against the explanation that deviant performance in MDS reflects purely storage deficits.[1]

Another, related, explanation for the large variability in performance of patients with DAT is that such variability reflects lapses of attention. For example, Braver et al. (2001) suggested that the maintenance of context is a critical component of attention, with context defined as internally represented task-relevant information such as a task goal, a particular intended action, a prior stimulus, or instructions. Similarly, several other researchers have argued that attention involves the maintenance of a highly tuned set of goals across time (Balota & Faust, 2001; Balota, Paul, & Spieler, 1999; Engle, Tuholski, Laughlin, & Conway, 1999; Lyons, Kellas, & Martin, 1995; Shallice & Burgess, 1996). For example, in the simple Stroop task, even healthy young individuals will sometimes output the word code instead of the appropriate color code in the incongruent condition (e.g., Spieler, Balota, & Faust, 1996). Although it is possible that these intrusion errors may reflect simple stochastic events, we believe that it is more likely that these are states of decreased maintenance of the appropriate attentional set. Because temporal fluctuations in the maintenance of the appropriate attentional set is likely to increase across both aging and DAT, one should not be surprised that DAT individuals perform so differently both compared with each other and across time in a task involving multiple potential semantic dimensions.

Distinguishing Process From Structure

The second important issue raised by Storms et al. (2003) concerns the difficulty in demonstrating that performance on a task reflects the underlying semantic structure, rather than cognitive processes making use of that structure. Support for the latter argument (that DAT deficits reflect conscious retrieval, rather than degraded structure) stems from findings that patients with DAT often perform normally on implicit semantic memory tasks (e.g., priming tasks) when the strategic retrieval components are minimized (Shenaut & Ober, 1996). As pointed out by Storms et al., such dissociations between explicit and implicit retrieval suggest that semantic representations in DAT remain relatively intact, with deficits localized only in the deliberate retrieval and/or use of these representations.

Unfortunately, the broadened conceptualization of attention discussed previously (as including the regulation and maintenance of goal-oriented or contextual information) blurs any distinction between structure and process. Even when using implicit nonsemantic tasks that minimize retrieval demands, one cannot be sure whether impaired performance is due to degraded structure or to disruptions in attentional set. For instance, in a cross-modal priming study using a simple word-naming pronunciation task, Balota, Watson, Duchek, and Ferraro (1999) found no priming for the low dominant meaning of an ambiguous word in individuals with DAT, yet equal priming for both high and low dominant meanings in young adults and healthy older adults. Balota, Watson, et al. (1999) argued that their findings were equally consistent with (a) a structure explanation in which relatively infrequent exposure to low dominance interpretations of homographs makes them especially sensitive to semantic degradation or (b) an attentional explanation in which individuals with DAT have breakdowns in an attentional control mechanism that uses context to inhibit the more dominant, yet inappropriate, interpretation of a homograph.

A related point concerns the inferences one can (or cannot) make from inconsistent performance. Although consistent disruptions in performance for certain stimuli across tasks and across time still argue for a storage deficit, the lack of such consistency cannot be taken as evidence that such structures are still intact. Attentional set difficulties are just as likely (indeed probably more likely) after breakdowns in semantic structure. Thus, contrary to Storms et al. (2003), inconsistent performance in the same task over time (and/or

[1] Chan et al. (1993) did notice deficits in participants ability to sort according to predation, with accuracy dropping to 85% in this condition. However, this dimension was the hardest for the control participants as well, and the focus of Chan et al. (1993) was on decreased use of the domesticity dimension in DAT during the triadic comparison task, rather than predation.

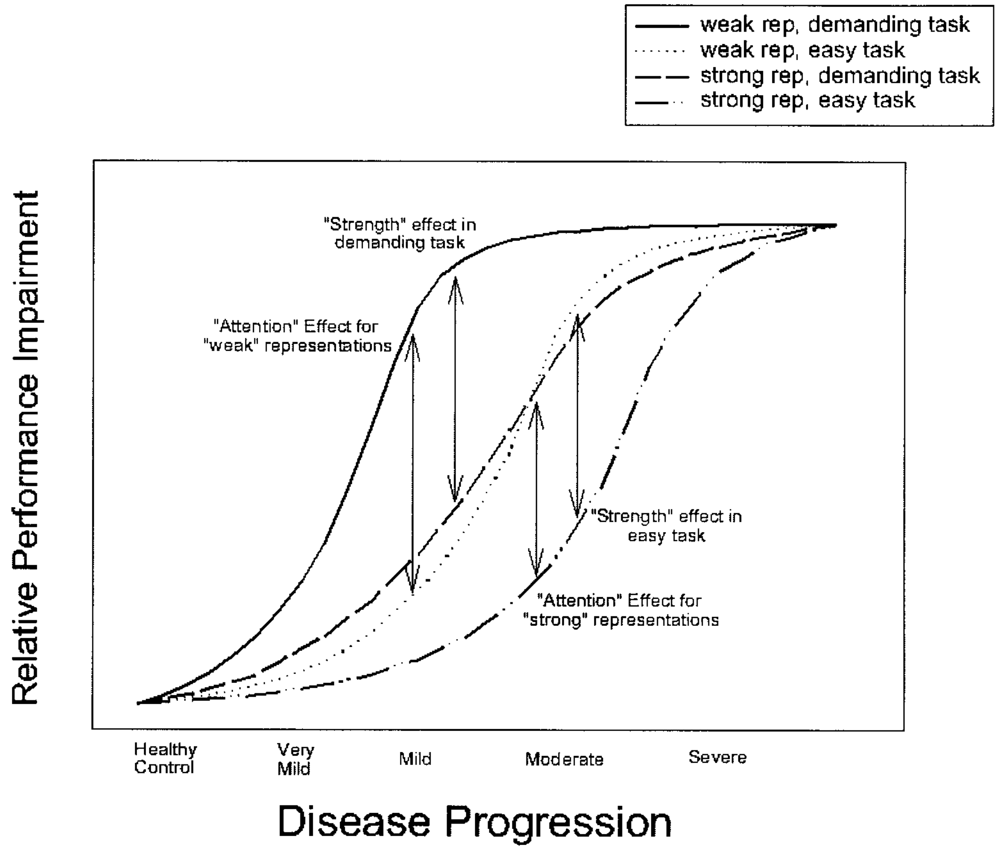

Figure 1. Effect of attentional demands and strength of representations on relative task performance in dementia of the Alzheimer type, as a function of disease progression. rep = representation.

across individuals) does not aid in distinguishing between process and structure. Rather, to make this inference, one must obtain DAT performance comparable with that of normal control individuals under some conditions.

The difficulty in showing degradation using performance measures stands in stark contrast to the considerable neuropathological evidence showing severe and diffuse cortical degeneration in the more advanced stages of DAT. In fact, unless one assumes a complete separation of mind from body, one would surely expect some structural semantic degradation in at least moderate-to-severe stages of DAT. Consistent with this proposal, although they were unable to distinguish between attentional control and semantic degradation accounts, Balota, Watson, et al. (1999) suggested that both factors likely contributed to their findings. Moreover, Gonnerman, Anderson, Devlin, Kempler, and Seidenberg (1997) found that patients with mild DAT performed slightly worse at naming artifacts, whereas moderate DAT patients were worse at naming biological items. They suggested that intercorrelations among biological (perceptual) features allow resistance to mild damage, but produce drastic impairment following moderate-to-severe damage. Thus the course of the disease may play a crucial role in determining the extent to which semantic deficits are caused by degraded structure versus deficits in retrieval and/or attention.

The inclusion of disease severity adds yet another level of complexity to examining semantic deficits in DAT. As such, the effect on performance of factors such as attentional demands of the task, structural degradation, and strength of the original representation may depend on the disease progression. Weak representations, or representations without a strong degree of structural support (such as subordinate interpretations, low frequency words, and low dominant category exemplars), would be most vulnerable to structural degradation and therefore would show deficits early in the course of the disease. As the disease progresses or attentional demands of the task increase, even performance on strong representations would likely show deficits.

Figure 1 displays an attempt to capture these relationships. As shown, individuals with early stage DAT should perform at relatively normal levels on tasks demanding little attention and testing relatively strong representations. However, performance breakdowns increase, even for high-strength representations, following additional disease progression and/or under increased attentional load. Although the precise functions underlying each of the four lines in Figure 1 is uncertain, it is predicted that (a) effects of attentional demands will surface earlier than the effects of strength of representations, because of relatively intact representations during the early course of the disease; (b) patients with moderate-to-severe DAT will show large impairments for all stimuli regardless of attentional demands; and (c) the stage of mild-to-moderate DAT represents the center of the logistic functions revealing the largest effects of both attention and strength. It should be clear from Figure 1 that effects of attentional or strength manipulations will differ depending on the cross section of DAT progression (e.g., very mild, mild, moderate, or severe) one chooses to study. Because of the likely nonlinear function, it would seem especially critical to test at least three levels of disease severity.

In sum, although the triadic comparison task does seem to distinguish individuals with DAT from healthy control individuals, we agree with Storms et al. (2003) that the cause of such differences is unclear. Moreover, we suggest that differences between DAT and normal control individuals in the maintenance of context and task goals likely contributes to greater variability in any measure of performance and that this difference further blurs the (already subtle) distinction between structure and process. Finally, we acknowledge that at some point, structural degradation in DAT is inevitable, as progression through the disease is accompanied by massive and diffuse neural degeneration. Hence, it is important to consider performance in DAT as a reflection of the interactive influence of (a) strength of representation, (b) degree of dementia, and (c) attentional demands of the task. We hope that future studies can aid in identifying the nonlinear function by including more than two levels of each of these three factors.

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