

## CHAPTER 4

# Attention in dementia of the Alzheimer's type

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### Introduction

Attention is central to all cognitive activities. Even under conditions, which encourage non-attentional, more automatic processes within a given domain, attention must still be oriented to that general domain (see Neumann, 1984, for a discussion). In this light, we suggest that there are no attention-free tasks. In the present chapter we will review the evidence concerning aspects of standard attentional paradigms such as visual cueing, visual search, Stroop, dichotic listening, and vigilance tasks, among many others, in a population that exhibits widespread cognitive deficits, i.e., individuals diagnosed with dementia of the Alzheimer's type (DAT). A major goal of the present paper is to extend the relevance of attentional systems beyond standard attentional paradigms to the domains of language and memory processing. We believe that it is time to reorient the field to consider the importance of attentional mechanisms in the wide variety of cognitive deficits exhibited in this population.

In their 1993 review of studies of attention in DAT, Parasuraman and Haxby noted the paucity of detailed studies of attentional function. They listed 33 studies, categorized in three major areas: selective attention (17 studies), divided attention (10 studies), and sustained attention (6 studies). Over the past few years the situation has changed substantially

with a significant amount of research on attention in DAT being published. In this research, there have been significant DAT-related declines in more specific measures of attentional functioning, and theoretical extensions have been proposed to underlie impairments in other domains such as language comprehension (e.g., Balota and Ducheck, 1991; Faust, Balota, Ducheck et al., 1997), memory performance (Balota, Cortese, Ducheck et al., 1999), driving performance (e.g., Ducheck, Hunt, Ball et al., 1997), and performance of everyday tasks (e.g., Perry and Hodges, 1999). What is emerging in the literature is a picture of attentional deficits in DAT that are most evident when a situation (a) requires control over the processing of goal-irrelevant information, (b) requires cognitive control over highly active, but inappropriate responses, and (c) when a situation requires dividing attention for concurrent processing.

Before turning to this literature, one might ask 'why study attention in DAT?' There are several answers to this question. First, attentional processes are fundamental cognitive functions and studying the relationship between the neuropathological and attentional changes in individuals with DAT should provide useful information regarding the neural substrates of attentional processes. Second, evidence is accumulating suggesting that attention is impaired relatively early on in the progression of DAT and a proper understanding of DAT-related changes in cognition will most likely involve an understanding of DAT-related changes in attention. Third, there are important applied questions that attention research may help address. For example, research on driving

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in individuals with DAT has focused on how attentional impairments might affect driving ability (e.g., Duchek, Hunt, Ball et al., 1998; Parasuraman and Nestor, 1991). It is also the case that understanding attentional deficits in DAT may have implications for quality of life issues such as designing memory training programs in DAT (e.g., Camp and McKittrick, 1991). Fourth, there is an interesting parallel between the attentional deficits observed in DAT and those that have been suggested to occur in healthy aging (e.g., Hasher and Zacks, 1988). Many of the neuropathological signatures of DAT also occur, albeit in decreased prevalence, in healthy older adults (see Morris, Storandt, McKeel et al., 1996). There is also an increasing incidence of DAT in the population as it ages from less than 1% at age 65 to 7–8% at age 85 (Bachman, Wolf, Linn et al., 1993; Hebert, Scherr, Beckett et al., 1995), such that many individuals who appear healthy at age 65 are likely to develop the clinical symptoms 20 years later. Finally, because of the increased incidence of AD across age groups, it is quite possible that some of the age deficits in a cohort of healthy older adults will involve individuals who are showing very mild disease-related deficits that have yet to surpass the clinical diagnosis. Thus, the study of attention in DAT individuals may provide valuable information regarding cognitive changes in healthy older adults.

Of course, a methodological concern always arises when one examines the literature on a group of individuals with widespread cognitive deficits. Specifically, is it the case that these individuals will simply be worse on any task that places considerable demand on the processing system? As we will see, this simple notion can indeed accommodate for *some* of the results reviewed below. However, there are a number of empirical findings which cannot be accommodated by this argument, and in fact there are instances in which DAT individuals actually benefit, compared to control individuals, from having an attentional deficit (e.g., homograph disambiguation and negative priming). We will try to highlight these patterns within this review, and also highlight those attentional deficits which appear to be disproportionate based on simple difficulty accounts (see Faust, Balota, Spieler and Ferraro, 1999, for a detailed discussion of procedures that can be used to compare groups with varying levels of overall cognitive performance).

The present chapter is organized in the following manner. First, we will begin with a brief overview of the salient cognitive changes that occur in DAT. We will then turn to a brief review of the neuropathological changes in AD (highlighting the attentional subsystems of the brain), and then discuss attentional function in terms of three commonly accepted functional areas of sustained, divided, and selective attention (e.g., Parasuraman and Haxby, 1993). We will review the DAT and attention literature in the context of traditional attentional tasks and of tasks requiring processing of linguistic stimuli for both comprehension and memory. We will close with a discussion of cognitive control deficits as they relate to the representation of task goals (e.g., Balota et al., 1999).

### **Cognitive decline in dementia of the Alzheimer type**

Before describing the attentional breakdowns in Alzheimer's Disease (AD), we should first describe the general cognitive decline that occurs in this population. Alzheimer's disease is the most common dementing illness (e.g., von Strauss, Vitanen, De Ronchi et al., 1999) comprising up to 70–80% of dementia diagnoses in many studies. The earliest stages of DAT typically present with a memory impairment as the predominant or only impairment detectable by batteries of neuropsychological tests (Albert, 1996; Grady, Haxby, Horwitz et al., 1988; Welsh, Butters, Hughes et al., 1992). This is not surprising given that the criteria for clinical diagnosis of DAT include the requirement of a progressively worsening memory impairment in the absence of other possible causes (McKhann, Drachman, Folstein et al., 1984). Recent evidence from prospective studies (e.g., Howieson, Dame, Camicioli et al., 1997; Linn, Wolf, Bachman et al., 1995; Rubin et al., 1998) also suggests that memory impairments are the best predictors of eventual AD in preclinical populations, which is consistent with recent neurobiological evidence that the lesions associated with AD first appear in the medial temporal lobes (e.g., De Lacoste and White, 1993; Delacourte, David, Sergeant et al., 1999; Nagy, Hindley, Braak et al., 1999).

While it has been recognized for some time that the progression of DAT involves declines in attention as well as memory (e.g., Vitaliano, Breen, Albert et

al., 1984; Vitaliano, Russo, Breen et al., 1986), the predominant view in the neuropsychological literature has been that attention is often the second area of cognition affected in DAT following initial memory impairment (Grady et al., 1988; Haxby, Grady, Koss et al., 1988; Lafleche and Albert, 1995; Reid, Broe, Creasey et al., 1996). This view has been challenged by some researchers who have found evidence for deficits in attentional control in conjunction with impaired memory in very early DAT (e.g., Albert, 1996; Balota et al., 1999; Fabrigoule, Rouch, Taberly et al., 1998). One reason for this state of affairs is that the standard neuropsychological batteries used have been optimized to detect impaired performance amongst broad categories of cognitive function such as memory, language, attention, and visuospatial abilities. Such tests are less appropriate for examining specific aspects of attentional functioning, and indeed, most of the standard neuropsychological measures of attention were designed prior to many of the advancements in attentional theory of the past 20–30 years (e.g., Pashler, 1998; Styles, 1997). In fact, it has been suggested that a major weakness in the literature on cognitive changes in DAT is a paucity of studies using newer, more sensitive tests of attention (e.g., Parasuraman and Greenwood, 1998; Parasuraman and Haxby, 1993). A second reason that early attentional declines may not be detected in studies of DAT is that the role of attentional processes in theoretical treatments of memory (e.g., Awh and Jonides, 1998; Cowan, 1995), and in the analysis of specific memory tasks (e.g., Simone and Baylis, 1997a), has not been fully realized in the DAT literature. For example, as discussed further below, studies of priming (i.e., the facilitation of word identification performance when a target word is preceded by a semantically related word compared to an unrelated word) often find DAT-related changes in performance when the task involves controlled attentional processes (e.g., Balota and Ducheck, 1991; Hartman, 1991; Ober and Shenaut, 1995), whereas studies of automatic priming effects have mainly failed to find DAT-related changes (e.g., Balota and Ducheck, 1991; see Ober and Shenaut, 1995, for a review). Thus, one can find quite different prime influences on the retrieval of information from semantic memory simply by varying the attentional demands of the task. Third, as discussed below, we

will argue that there is a considerable attentional demand in memory performance. In this light, the breakdown in memory performance found in DAT individuals may in fact have an attentional breakdown as an underlying causal factor. Finally, it is noteworthy that there is considerable overlap between attentional models of cognitive control (e.g., Norman and Shallice, 1986; Posner and DiGirolamo, 1998) and what is often called executive control in the short-term or working memory literature (e.g., Baddeley, 1998; Morris, 1996a). Thus, the same pattern of results could be viewed as a working memory deficit or an attentional control deficit depending upon one's theoretical predisposition.

### Types of attention

Given that our ancestors were not the strongest, biggest, meanest, or fastest, it is most likely a good thing that we can attend to the world as well as we do. However, it is because attention is so intimately tied with our ability to consciously experience the world, and because it is so intimately tied to other domains of cognition (e.g., Cowan, 1995), that it has proved difficult to define. While no fully satisfying single classification scheme for the varieties of attention has yet emerged, one common approach is to begin an overview of attentional function by noting three broad types of functions (e.g., Parasuraman, 1998): (a) selective attention, (b) sustained attention, and (c) divided attention.

*Selective attention* allows the cognitive system to overcome real-time processing limitations (i.e., people cannot fully process all the information available to their sensory receptors at any given moment), and to prioritize certain aspects of the world as being of greater or lesser importance. Allport (1987) has stressed the concept of selection for action, by pointing out that there is a strict limitation on action in the world, which has yielded an evolutionary constraint on the attentional system. For example, a person's hand can only pick one of many possible apples from a tree at a time. Thus, the system has to choose which apple to select for action. One intriguing aspect of selective attention to be discussed below is the notion of inhibitory cognitive control during response selection. More specifically, how does the system process non-selected but compet-

ing informational sources or pathways for action? As we will see below, the topic of selective attention has clearly dominated work in the area of cognitive changes in DAT. *Sustained attention* makes sure that the cognitive system has the ability to extend the priorities set by selective attention in time (e.g., Parasuraman, Warm and See, 1998). One might argue that this is a fundamental aspect of the processing system because the individual must maintain attentional set across extended periods of time. *Divided attention* recognizes that solving real-world problems often requires multiple goals and priorities, in other words, multi-tasking. One might argue that in any processing context there is a multitude of processing pathways to which one might attend, and allocate processing resources to. Divided attention allows for high-level coordination and management of processing resources.

### Neural substrates for attention

Posner and colleagues (Posner and Dehaene, 1994; Posner and Petersen, 1990; Posner and Rothbart, 1991) have developed a model of the attentional systems of the brain that we will use to help motivate our discussion of attention and DAT (see Fig. 1). The model consists of three subsystems: the posterior, anterior, and vigilance networks. The posterior attention network involves the posterior parietal cor-

tex, the pulvinar, and the superior colliculus, which are proposed to be responsible for disengaging (e.g., Posner, Walker, Friedrich and Rafal, 1984), engaging or focusing (e.g., Rafal and Posner, 1987), and orienting or shifting visuospatial attention, respectively (e.g., Posner, Cohen and Rafal, 1982). The anterior attention network involves the anterior cingulate and selected frontal cortices, and is responsible for attentional or executive control. The vigilance network consists of locus coeruleus noradrenergic inputs to the cortex. The functions of the visuospatial orienting of attention associated with the posterior attention network are proposed to involve relatively automatic processes, whereas the anterior attention network is proposed to involve volition, resolution of conflict, and novelty (Posner and DiGirolamo, 1998). Recent neuroimaging results suggest that tasks requiring shifting of attention may activate portions of both the anterior and posterior systems (e.g., Corbetta, Akbudak, Conturo et al., 1998), suggesting that these subsystems often work together as a global distributed attentional system. We will use the Posner model shown in Fig. 1 as a basic organizational framework for our examination of attention in DAT.

### Neuropathology and cognition in DAT

There are two prominent neuropathological features of AD, senile plaques (SPs) and neurofibrillary tan-

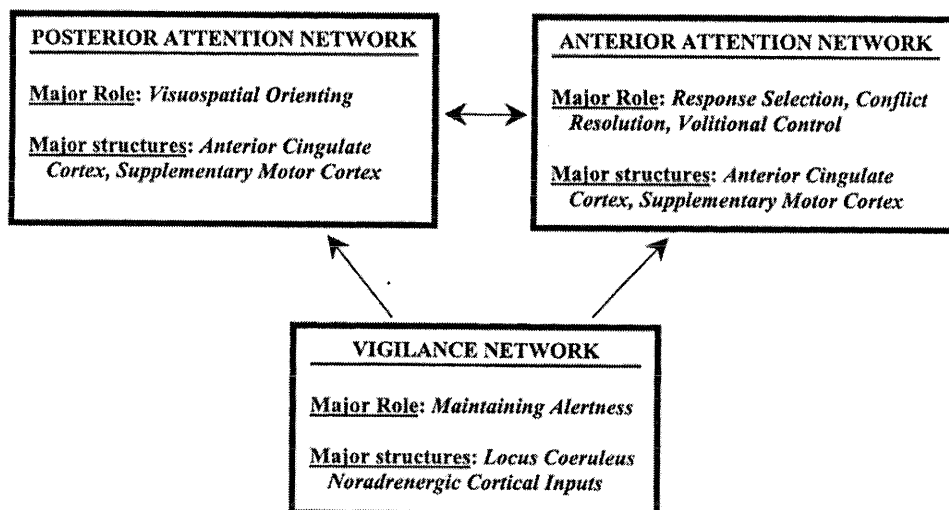


Fig. 1. A broad view of the neural network model of attention proposed by Posner and colleagues (e.g., Posner and Dehaene, 1994). Adapted from Webster and Ungerleider (1998).

gles (NFTs, Damasio, Van Hoesen and Hyman, 1990). Because some studies have found that many cognitively asymptomatic individuals who come to autopsy have some level of plaques and tangles (e.g., Davis, Schmitt, Wekstein and Markesbery, 1999), it is possible that these neuropathological changes overlap with normal aging. However, as more and more longitudinal studies are undertaken with increasingly sensitive cognitive measures, there is growing evidence in the literature that plaques and tangles are indications of a preclinical form of AD (e.g., Berg, McKeel, Miller et al., 1998; Fox, Warrington, Seiffer et al., 1998; Morris et al., 1996). More research needs to be conducted regarding the determinants of the plaque and tangle load an individual can carry presymptomatically. For example, one controversial hypothesis is that individuals with greater cognitive resources (e.g., high verbal individuals, Snowden, Kemper, Mortimer et al., 1996) can tolerate more neuropathology prior to the appearance of symptoms.

Typically, studies have found that NFTs are more strongly associated with cognitive impairment than are SPs (e.g., Arriagada, Growdon, Hedley-Whyte and Hyman, 1992; Berg et al., 1998; Bierer, Hof, Purohit et al., 1995; Duyckaerts, Colle, Dessi et al., 1998). The neuropathology associated with NFTs leads to cortical and subcortical atrophy, cell loss, and hypofunctionality (e.g., Nagy et al., 1999). The progression of NFTs clearly can be heterogeneous. However, some have argued that there is a characteristic pattern from medial temporal and associated cortex to basal forebrain and association cortex (mainly temporal-parietal, sparing primary sensory and motor cortex), with the frontal lobes remaining relatively intact until late in the disease progression (e.g., Braak and Braak, 1998; De Lacoste and White, 1993; Kemper, 1994). Having said this, there is clearly considerable senile plaque buildup in frontal areas early in the disease process (e.g., Morris et al., 1996), and there is evidence in the literature that the distribution of both SPs and NFTs affects the rate of cognitive decline in DAT.

There is a growing literature correlating the pattern of cognitive impairment with the pattern of either neuropathology, brain atrophy, or functional hypometabolism (e.g., Haxby, Grady, Koss et al., 1990; Jagust, Haan, Eberling et al., 1996; Kanne, Balota, Storandt et al., 1998; Morris, 1996b). Most research

has focused on temporal and parietal lobe pathology. For example, memory deficits have been related to temporal lobe hypofunction (e.g., Fox et al., 1998). This emphasis on medial temporal lobe hypofunction may in part reflect the strong emphasis on episodic memory loss in DAT and the evidence for the medial temporal areas in the classic cases of amnesia (e.g., H.M.). Becker, Bajulaye and Smith (1992) and Perry and Hodges (1999) have argued that the neuropsychological declines in DAT on executive tasks are disproportionate to the combined evidence of relatively minor frontal lobe impairments from studies of pathology and functional metabolism. However, recent studies using brain imaging and comparative analysis of neuropathology at biopsy and autopsy have demonstrated greater involvement of functional and neuropathological changes in the frontal lobes than has traditionally been thought (e.g., Di Patre, Read, Cummings et al., 1999; Gabrieli, 1996; Saykin, Flashman, Frutiger et al., 1999; Warkentin and Passant, 1997). Therefore, there is increasing evidence of frontal involvement in this disease.

Kanne et al. (1998) recently explored the relationship between neuropsychological test scores and cored or mature SPs, diffuse SPs, and NFTs in one of the largest samples of DAT ( $n = 407$ ) in the literature. These researchers found that the factor analytic structure of the neuropsychological profiles of a large sample of individuals with DAT on neuropsychological tests conformed to frontal, temporal, and parietal factor structure. More importantly, they were able to analyze autopsy data for 41 individuals, and found that relative performance on each factor (i.e., Frontal, Temporal, and Parietal) was significantly correlated with the relative presence of cored or mature SPs in the corresponding area. The picture that is emerging is one of cognitive declines in the early stages of DAT that match a circumscribed neuropathology, and that cored SPs can be predictive of the pattern of cognitive declines (see Morris and Price, 2001).

#### *Neural bases of attentional impairment in DAT*

One limitation with the regional view of the relationship between cognitive impairment and DAT espoused in the Kanne et al. paper is that many current models of the neural bases of attention (e.g., Mesulam, 1990; Posner and Petersen, 1990) propose

that attentional functions are subserved by several widespread neural regions that work together as a network. Thus, it seems most likely that understanding the neural bases of attentional impairments in DAT will require explanations including interactions of multiple and possibly widespread brain regions. There are three major hypotheses in the literature regarding the neurobiological basis of DAT-related cognitive declines in general (e.g., Morris, 1996b) that are applicable to attentional impairments in DAT. These are the subcortical disconnection hypothesis, the cortical disconnection hypothesis, and the cortical recruitment hypothesis. We shall now turn to a brief review of each.

#### *Subcortical disconnection*

Samuel, Terry, DeTeresa et al. (1994) suggested that neural loss in subcortical nuclei providing diffuse cortical inputs might have significant impact on cognitive declines in DAT. Of principal interest with regard to attention and DAT are neural loss in nuclei which comprise major cortical inputs for the cholinergic (nucleus basalis of Meynert), the noradrenergic (locus coeruleus), and the serotonergic (raphe nuclei) neurotransmitter systems (e.g., Wilcock, Esiri, Bowen and Hughes, 1988), all of which have been shown to be involved in attentional function (Morrocco and Davidson, 1998). Of particular note is the fact that recent evidence suggests that lesions to the nucleus basalis of Meynert (cholinergic) may play a more important role in attention than in memory (e.g., Lawrence and Sahakian, 1995; Voytko, 1996).

#### *Cortical disconnection*

The second major neurobiological hypothesis regarding attentional function in DAT is related to the emerging evidence that the neuropathology of DAT begins focally in and around the entorhinal cortex and progresses via cortico-cortico and subcortico-cortico connections resulting in a functional disconnection of normally cooperating cortical regions (e.g., De Lacoste and White, 1993). This neural disconnection hypothesis is supported by recent studies demonstrating that EEG coherence (i.e., coherence is a statistical measure of the degree of electrical synchrony between scalp electrode sites) was systematically reduced in DAT (e.g., Leuchter, Newton, Cook et al., 1992) in a manner consistent with an anterior-

posterior disconnection. Morris (1996b) has argued that DAT-related deficits in executive functioning may be due to the disconnection of a broadly distributed executive network. Support for this cognitive disconnection hypothesis also comes from a study by Dunkin, Osato and Leuchter (1995) who found that the pattern of EEG coherence reductions in DAT was related to impairments on neuropsychological tests. There is much work to be done in confirming the cognitive and neuropathological predictions of the disconnection hypothesis, but the evidence to date is promising (e.g., Lakmache, Lassonde, Gauthier et al., 1998).

#### *Cortical recruitment/inhibition*

Cortical disconnection in DAT can be seen to present the cognitive system with challenging processing resource allocation problems. From a capacity viewpoint, one important function of an attentional cognitive control system would be to recruit sufficient computational resources for the task at hand via neural recruitment. Several functional imaging studies of DAT individuals engaged in a cognitive task have found that individuals with DAT activate neural areas in addition to those activated by healthy controls (e.g., Bäckman, Andersson, Nyberg et al., 1999; Kessler, Herholz, Grond and Heiss, 1991; Woodard, Grafton, Votaw et al., 1998). This result stands in contrast to that of neuroimaging studies measuring resting cerebral metabolism (e.g., Haxby et al., 1990) which typically find hypometabolism in individuals with DAT. One explanation for the more widespread neural activation in DAT while performing cognitive tasks is that the DAT-associated neuropathology forces these individuals to utilize additional neural resources (i.e., the recruitment hypothesis). Another explanation is that cortical disconnection results in compromised cortico-cortico inhibitory control mechanisms required to focus neural resources efficiently (i.e., the inhibitory hypothesis, e.g., Balota and Ferraro, 1993, 1996; Faust and Balota, 1997; Faust et al., 1997; Spieler, Balota and Faust, 1996). At present, most neuroimaging studies have been interpreted in light of the recruitment hypothesis, but there is growing evidence for widespread breakdowns in inhibitory control in DAT. To date, these two hypotheses have not been directly pitted against each other in a single imaging study.

### Attention in DAT: review of the cognitive studies

As discussed earlier, studies using standard neuropsychological batteries often find disruptions in attentional function in DAT. However, most of the early studies have not used tasks that have been optimized to detect impaired performance amongst broad domains of cognitive function such as memory, language, and attention. Thus, the present review will concentrate on studies that have used tasks that are conducive to a componential approach in an attempt to identify attentional processes or mechanisms that may or may not be compromised in DAT. We will survey attentional function in DAT across the three broad functional subdomains of *sustained*, *selective*, and *divided attention*.

#### *Sustained attention in DAT*

Consider the tasks of (a) driving on a lonesome highway late at night, (b) trying to understand a monotonous speaker, or (c) simply trying to be ready for the next monster attack during a video game. All of these tasks involve sustained attention. Sustained attention studies typically involve vigilance over time, with an emphasis on identifying the factors leading to vigilance decrements over time (e.g., Parasuraman, 1985). There are two main questions of relevance to our discussion of vigilance in DAT. First, how does one measure vigilance, and by extension, the vigilance decrement? A vigilance decrement can be measured as a decline in the detection rate, or speed of detection. However, recent work has also emphasized the importance of a more sophisticated signal detection approach recognizing that both the sensitivity ( $d'$ ), and the response bias ( $B$ ) of the participant are critical (Parasuraman et al., 1998). Second, we need to determine a duration of interest for which attention must be sustained. One open area of controversy regards the question of whether vigilance over fractions of a second (i.e., phasic alertness) are similar in kind to vigilance over fractions of an hour (i.e., tonic alertness).

#### *Phasic alertness*

Phasic vigilance can be assessed by measuring the facilitation in reaction time to detect a stimulus following a brief warning stimulus, as opposed to

following no warning (e.g., Posner, 1978). Nebes and Brady (1993) found that although the individuals with DAT were overall slower than the controls, both groups showed a similar RT benefit when a warning tone preceded a target square, and that varying the warning–target delay interval affected both groups similarly. Sano, Rosen, Stern et al. (1995) found a similar result for simple RT (i.e., a go/no-go task with a single response). These researchers also reported that individuals with DAT did not take advantage of the consistency of the warning signal whereas the controls did, suggesting a potential decrement in controlled focusing of attention in DAT.

#### *Tonic alertness*

With regard to tonic vigilance, Lines, Dawson, Preston et al. (1991) tested individuals with mild DAT and healthy controls on both an auditory and visual test of sustained attention. No group differences were found on either task in terms of hits or false alarms. However, the time on task was only 10 min (auditory condition) and 5 min (visual condition), and no data regarding vigilance decrements were reported. Also, there were only eight individuals with DAT included, so power is suspect. Nebes and Brady (1993) had participants perform a self-paced simple choice RT task (targets were predictable in that a target appeared on each trial) for an extended period of 18 min. Both DAT and control groups produced equivalent increases in RT during the task, indicating equivalent vigilance decrements. However, there are again potential limitations with this study as target appearance was predictable and self-paced, leading to a potential confound with phasic vigilance.

A study by Brazzelli, Cocchini, Della Sala and Spinnler (1994) used a high non-target event rate and unpredictable targets and found similar vigilance decrements in RT for DAT and control groups, but a greater sensitivity decrement for individuals with DAT in terms of error rates. A similar finding was reported by Berardi, Gaillard, Haxby et al. (1992). In this study, participants had to detect a target letter in a sequence of distractor letters. The letters were presented at several levels of visual degradation. As the letters were degraded to a greater extent, the DAT group began to produce vigilance decrements in sensitivity, but the controls did not until the most



degraded level, which was too difficult to effectively test the DAT group.

In summary, it is somewhat surprising that there are not more studies of sustained attention in DAT given that the basal forebrain cholinergic and the locus coeruleus noradrenergic systems of diffuse cortical innervation have been implicated in sustained attention (e.g., Parasuraman et al., 1998) and it is these systems that show marked neuropathology in DAT (e.g., Wilcock et al., 1988). Although there are not yet enough studies of vigilance in DAT to form any detailed conclusions, several general results seem apparent at this point. First, early on in the disease progression, there are no gross impairments of vigilance. Second, when the vigilance task requires effortful processing, individuals in the early stages of DAT are more likely to show modest vigilance decrements.

#### *Divided attention*

Consider driving and carrying on a conversation, watching television and folding laundry, jogging and listening to the radio. All of these tasks involve some level of divided attention. Divided attention refers to the control processes associated with allocating limited processing resources across multiple simultaneous task demands. One might argue that all cognitive activity involves dividing a limited pool of attention resources amongst multiple domains (e.g., Kahneman, 1973). Sometimes divided attention is assessed through tasks requiring processing of multiple features or multiple targets simultaneously. More commonly, divided attention is assessed through use of dual-task procedures. Here, performance of a task is compared with performance when a second task is added and both are performed simultaneously (e.g., Somberg and Salthouse, 1982).

Several studies have reported sizable impairments in dual-task performance in DAT (e.g., Grady, Grimes, Patronas et al., 1989; Grober and Sliwinski, 1991). For example, Baddeley, Logie, Bressi et al. (1986) had participants manually track a moving square while repeating strings of digits. Both tasks were performed alone and together. Performance on the tracking task alone was unimpaired in individuals with DAT; however, there was a DAT-related decline in performance in the dual-task situation (see also Baddeley, Baddeley, Bucks and Wilcock, 2001).

A follow-up longitudinal study (Baddeley, Bressi, Della Sala, Logie and Spinnler, 1991) found that dual-task performance yielded far greater declines in performance associated with disease progression than did single-task performance. Interestingly, the practical significance of the DAT-related impairment in divided attention has recently been demonstrated by Camicioli, Howieson, Lehman and Kaye (1997) who found a greater slowing in walking speed in individuals with DAT when asked to simultaneously perform a verbal fluency test, a finding which may explain reports of increased risk of falling in DAT (e.g., Nakamura, Meguro and Sasaki, 1996).

Decrements in dual-task performance in DAT have also been associated with differences in cerebral metabolism (e.g., Nestor, Parasuraman, Haxby and Grady, 1991). Slowing of response latency in dual- as opposed to single-task conditions for both detection of an auditory tone and a yes/no visual pattern matching task was found to correlate with individual differences in resting cortical metabolism in right frontal areas in DAT but not controls. Johannsen, Jakobsen, Bruhn and Gjedde (1999) compared functional cortical activation using PET during sustained and divided attention tasks and found that more cortical activation areas differed between DAT and control groups for the divided as opposed to the sustained attention task, many of these areas being frontal.

It is clearly the case that DAT individuals have difficulty in divided attention tasks. It is again unfortunate that there has not been more work in this area. This is most likely due to the fact that DAT individuals often bottom out on such tasks. One might also question whether there is a qualitative difference between dual-task situations and attentional selection mechanisms. One of the debates in the divided attention literature is whether attention is actually divided amongst multiple tasks, or is simply a reflection of switching attention across tasks (i.e., a type of multiplexing). Although we will return to the issue of divided attention later, we shall now discuss the topic of selective attention, which has been the primary focus of research in the area of attention and DAT.

#### *Selective attention in DAT*

At any point in time, there is a multitude of potential processing pathways that might be attended. Con-



sider the fact that the third toe on your left foot is constantly providing a signal to the brain, but it is only when attention is directed to this target that such signals are selected for any extended processing. Attentional selection is required due to limitations on the central processing system and the virtually unlimited internal and external signals that are available to the individual for further processing. Selectivity has been proposed to act in two broad ways to insure that a subset of information consistent with current goals is selected for further processing. Some models stress selection mechanisms acting to facilitate processing of goal-relevant information (e.g., LaBerge and Brown, 1989), while other models stress selection mechanisms acting to inhibit processing of irrelevant information (e.g., Gernsbacher and Faust, 1991; Hasher and Zacks, 1988; Neill, 1977; Tipper, 1985). Posner and Dehaene (1994) have argued for a broad framework stressing the role of both facilitatory and inhibitory mechanisms. Not only does selective attention rely on two potential mechanisms, it also can act in two basic modes. Selection may be based on relatively automatic *exogenous* processes (e.g., exogenous orienting of attention to the abrupt onset of a new visual object, e.g., Yantis, 1994) or by controlled *endogenous* processes (e.g., endogenous orienting to a chosen location via an arrow cue to that location, e.g., Müller and Rabbitt, 1989; Posner, 1980; Theeuwes, 1994).

The area of selective attention in DAT is quite large compared to sustained attention and divided attention. As a way of organizing this literature, we will first review the standard studies of selective attention in visual domains. We will then extend this work to selective attention within linguistic domains, and finally review the implications of this work for recent models of memory.

#### *Selective attention within visual/spatial domains*

A substantial number of studies of attention have involved selective attention within visual/spatial domains. This work has been quite instrumental in identifying some fundamental aspects of visual selective attention that can be studied in relatively simple experimental paradigms. As discussed above, Posner and colleagues (Posner and Dehaene, 1994; Posner and Petersen, 1990; Posner and Rothbart, 1991) have

developed a model of the attentional systems of the brain consisting of three subsystems (see Fig. 1). The posterior attention subsystem involves primarily parietal cortex, thalamus, and superior colliculus, and is proposed to be responsible for the orienting of visuospatial attention to a particular location.

Visuospatial-selective attention is often assessed through use of cues which provide information regarding the likely location that a to-be-recognized or to-be-identified target item will appear (see sequence of events in Fig. 2). Targets are typically detected or identified more quickly at cued locations, presumably due to a prior orienting of attention to the cued location in anticipation of the appearance of the target (e.g., Posner, 1980), but also, perhaps, due to a dampening or withdrawal of attention to non-cued locations (e.g., Caputo and Guerra, 1998). Attention may be overtly oriented along with movement of the eyes, but it is more common for tests of visuospatial orienting to require covert orienting of attention while eye fixation is held constant (e.g., Abrams and Dobkin, 1994; Remington, 1980). As noted, it is common to compare the ability of peripheral luminance change cues to reflexively draw attention to a location (i.e., *exogenous* cueing) with the ability of symbols such as an arrow presented at eye fixation to lead to controlled orienting of attention (e.g., *endogenous* cueing, Theeuwes, 1994). Visuospatial attentional orienting can be thought of as requiring that attention be disengaged from its current location, shifted to a new location, and engaged at the new location (e.g., Posner, 1980). Damage to portions of the posterior attention network has been found to selectively impair the component operations of covert orienting of attention (e.g., Posner and Petersen, 1990). One important finding with regard to DAT is that damage to the parietal lobe often results in a decreased ability to disengage attention with relatively preserved ability to shift and engage attention (e.g., Posner et al., 1984). This result is of particular interest in relation to the finding of parietal hypometabolism in DAT (e.g., Haxby, Duara, Grady et al., 1985; Haxby, Grady, Duara et al., 1986).

#### *Location-based cueing in DAT*

Several studies have looked at cueing effects on attentional orienting in DAT. In an endogenous cueing experiment, Parasuraman, Greenwood, Haxby and

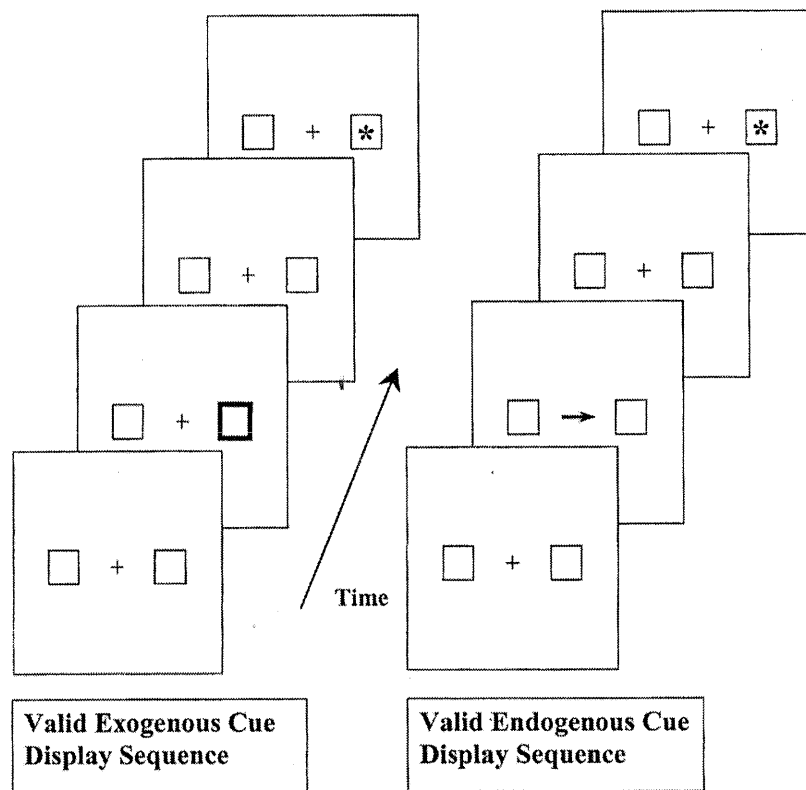


Fig. 2. Example stimulus display sequences for valid endogenous (arrow) and exogenous (box brightening) cue trials. The task is simple detection of a star.

Grady (1992) studied covert orienting in DAT using a letter categorization task. Individuals with DAT and healthy controls maintained eye fixation and indicated with a button response if a target letter, appearing 6.7 degrees to the left or right of fixation, was a vowel or a consonant. Prior to appearance of the target letter, a rightward or leftward arrow (the endogenous cue) appeared to indicate the potential location of the subsequent target letter. An asterisk was used as a neutral warning (i.e., no indication of potential location) on some trials. In general, letter categorization was faster on trials in which the target letter appeared in the cued location as opposed to the neutral cue trials. This cue benefit was equivalent for the DAT and control groups. It was also the case that participants were generally slower to categorize the letter if it appeared in an unexpected location (i.e., invalid cue) as opposed to the neutral cue trials, for central (endogenous) cues, and also in a subsequent exogenous (peripheral) cueing experiment. This cue cost (which was

larger in DAT individuals than the control group) has been argued to be a measure of the difficulty of disengaging attention from the invalidly cued location, with individuals with parietal lobe damage yielding increased cost effects (e.g., Posner et al., 1984) indicating a decreased ability to disengage attention. Parasuraman et al. (1992) interpreted their results as indicating a specific deficit with disengaging attention in DAT (also see Greenwood et al., 2000). Of further interest is the fact that a subset of the individuals in both groups was tested for resting cortical metabolism in four regions using PET and metabolic asymmetry scores were computed by taking the difference in resting metabolic rate in the left and right hemispheres for homologous regions. The only significant relationship found was a relationship between parietal metabolic asymmetry and cue validity (i.e., response latency for valid versus invalid cues) for the individuals with DAT. Greater hypometabolism in the right parietal lobe (in comparison to the left) was associated with larger cue

effects. These results suggest that DAT individuals with greater right-parietal pathology had greater disengagement impairment.

Oken, Kishiyama, Kaye and Howieson (1994) also found disproportionately larger overall cue effects (i.e., invalid minus valid response latency) in individuals with DAT using a circle/square discrimination task and centrally presented arrow cues. The DAT group produced a cost effect that was nearly twice that of the controls; however, no statistical test was reported for this comparison. The results of Oken et al. (1994) and Parasuraman et al. (1992) suggest that DAT results in a selective impairment in disengaging attention. However, some modification of this view is in order as studies using simpler detection tasks have typically failed to find DAT-related differences in cue effects.

In a study using peripheral luminance changes to induce reflexive (i.e., exogenous) covert orienting, Faust and Balota (1997, Experiment 1) reported equivalent overall cue effects for individuals with DAT and healthy older adults using a simple detection task (i.e., go/no-go press of single button). Caffarra, Riggio, Malvezzi et al. (1997) failed to find any DAT-related differences in covert orienting using a detection task and central (i.e., endogenous) cues. Several other studies have reported similar findings (e.g., Danckert, Maruff, Crowe and Currie, 1998, Experiment 3; Nissen, Corkin and Growdon, 1981, as cited in Parasuraman and Haxby, 1993; Parasuraman et al., 1992, using a letter detection task in addition to the categorization task discussed above). However, Faust and Balota (1997, Experiment 2), and Danckert et al. (1998, Experiment 1) found increased overall cue effects in individuals with DAT, but neither study had an adequate neutral condition to allow evaluation of relative costs. One possible reason for failures to find DAT-related changes in covert orienting when using detection tasks is that mild deficits in disengagement may only become apparent when the task requires a sufficient level of focus, as presumably would be required for a discrimination task (e.g., Parasuraman, 1998; Perry and Hodges, 1999). Another potential factor is heterogeneity of attentional impairment in DAT (e.g., Maruff and Currie, 1995). These two possibilities are not mutually exclusive, and, taken together may help explain the apparent discrepancies reviewed above.

Another aspect of visuospatial orienting that has recently been studied in DAT is inhibition of return (e.g., Posner and Cohen, 1984). Inhibition of return refers to a decreased ability to reorient to a previously attended location. For example, when sufficient time has passed, presumably covert attention will eventually drift back to a central fixation (e.g., Maylor, 1985). One can also redirect attention to the central fixation via a second exogenous cue (e.g., Posner, Rafal, Choate and Vaughan, 1985). After attention has returned to fixation, there is actually a slowing of detection to a just-attended location. This is thought to involve a bias in the orienting system against returning attention to a just-attended location, and has been referred to as inhibition of return. Faust and Balota (1997) examined inhibition of return effects in DAT both by use of a long cue-target interval (Experiment 1), and by use of a second exogenous cue at fixation (Experiment 2). They found no DAT-related differences in inhibition of return when the second exogenous cue was used to draw attention away from the originally cued location. However, the DAT group did perform somewhat differently from healthy older adults when no second cue was presented. In this particular version of covert orienting, a peripheral box was brightened, and remained so until participants responded to the target. While the DAT group did produce an almost complete reduction in facilitatory cue effects across short and long cue-target delays, they did not produce a reversal of the cue effect (i.e., inhibition of return), as found in the healthy older adults. Faust and Balota interpreted this result as an indication that, in the presence of the constantly visible luminance cues, individuals with DAT were slower to spontaneously reorient attention back to fixation in the absence of a second exogenous cue. Danckert et al. (1998, Experiment 3) noted that Faust and Balota (1997, Experiment 1) included 80% trials in which the target appeared in a peripherally cued location. They argued that these cues were also endogenous in nature in that they were informative as to the likely location of the subsequent target. In a replication of the Faust and Balota study with uninformative (i.e., 50% valid) cues, they found no DAT-related differences in inhibition of return. Taken together, the inhibition of return results converge on the notion that one finds a deficit with a type of endogenous

cueing (e.g., Faust and Balota, 1997), but not exogenous cueing (e.g., Danckert et al., 1998).

#### *Object- versus location-based cueing in DAT*

There is some disagreement in the literature as to the conditions under which visuospatial attention will be oriented to a location versus an object (e.g., Driver and Baylis, 1998). However, a recent study of cue effects by Egly, Driver and Rafal (1994) has demonstrated that object-based and location-based cue effects are impaired in individuals with left- and right-parietal damage, respectively. Given the finding of parietal hypometabolism in DAT (e.g., Haxby et al., 1985, 1986), and the decline in disengagement of attention during location-based cueing reported by Parasuraman et al. (1992), we should expect to find DAT-related declines in both location- and object-based cue effects in the task used by Egly et al. (1994). A recent study using a variant of this task has reported that the size of the object-based cue effect was correlated with left inferior parietal lobe hypometabolism, whereas location-based cue effects were correlated with right superior parietal lobe hypometabolism, in a group of individuals with DAT (Buck, Black, Behrmann et al., 1997).

#### *Summary*

Taken as a whole, the literature on visuospatial orienting of attention suggests that individuals with DAT are: (a) relatively unimpaired in their ability to use advance information to exogenously orient attention to a location, (b) likely, in the early stages of DAT, to suffer from a modest impairment in the ability to endogenously disengage attention under conditions requiring a higher-degree focusing of attention, and (c) likely to suffer from parietal hypofunction related to progression of neuropathology which, depending upon the laterality of the neural deficit, may lead to impaired location- or object-based attentional orienting. Moreover, the results suggest that low-level automatic processes associated with a bias against exogenously reorienting attention to a previously attended location remain intact. This latter finding is consistent with the fact that inhibition of return has been found to be reliant on subcortical structures not thought to be primarily affected in DAT (e.g., Posner et al., 1985).

#### *Visual search*

While the tasks often used to assess visuospatial orienting have been successful at identifying component operations of attention and relating them to neural function (e.g., Posner and Dehaene, 1994), these tasks typically involve responding to a target object presented against a relatively blank background. Given the DAT-related deficits in cued orienting discussed previously, one would expect to find similarly impaired performance in more realistic visual search tasks. For example, Duchek et al. (1998) recently reported that error rate and reaction time in a visual search task predicted driving performance in individuals with DAT beyond dementia severity or traditional psychometric tests.

Studies of visual search have often distinguished between situations where all locations can be searched in parallel and the target 'pop outs' in a relatively automatic fashion, and situations where at least some controlled sequential searching of different locations must be accomplished (e.g., Triesman and Gelade, 1980). As shown in Fig. 3, visual search based on a visual feature (e.g., searching for a gray 'L' amongst black 'L's) typically results in pop-out or parallel search, whereas, visual search based on a specific combination or conjunction of features (e.g., searching for a gray 'L' amongst black 'L's and gray 'T's) typically results in controlled search, although there are some exceptions to this general rule in the literature (e.g., Wolfe, Cave and Franzel, 1989).

Traditional psychometric tests of visual search often involve searching a page of randomly positioned target and distractor items and crossing out the tar-

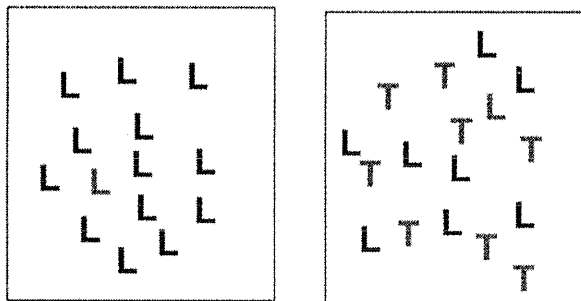


Fig. 3. Example stimuli demonstrating feature search (left panel) for a gray 'L' amongst black 'L's, and conjunction search (right panel) for a gray 'L' amongst black 'L's and gray 'T's.

gets (i.e., a cancellation task). Several studies using variants of a cancellation task have found impaired performance in individuals with DAT (e.g., Della Sala, Laiacina, Spinnler and Ubezio, 1992). Foldi, Jutagir, Davidoff and Gould (1992) found that individuals with DAT were more affected by an increase in the spatial density of distractors in a cancellation task. Furthermore, it has recently been reported that individuals with DAT may produce more errors of commission (i.e., crossing out a distractor) in a cancellation task when featural overlap between targets and distractors is high (Amieva, Lafon, Dartigues and Fabrigoule, 1999). Individuals with DAT have been found to show patterns of left- or right-hemifield neglect on such cancellation tasks (e.g., Mendez, Cherrier and Cymerman, 1997), presumably due to deficits in parietal functioning.

Recently, Corbetta, Shulman, Miezin and Petersen (1995) measured regional cerebral blood flow using PET while healthy adults performed either a conjunction or feature search and found that the conjunction task only involved activation of an area in superior parietal lobe previously associated with visuospatial orienting tasks. Given this result, and the finding discussed previously of DAT-related parietal hypofunction, conjunction search would be expected to be more impaired in DAT than feature search. To date, the literature supports the distinction of relatively spared feature/automatic search but impaired conjunction/controlled search in DAT (e.g., Foster, Behrmann and Stuss, 1999; Greenwood, Parasuraman and Alexander, 1997). Several models use metaphors for visuospatial attention such as a spotlight (e.g., Posner, 1980) or the focus of a zoom lens (e.g., Eriksen and St. James, 1986) which can, in principle, be varied in terms of spatial extent or width. One possible explanation for impaired controlled searches in DAT put forth by Greenwood et al. (1997) is that DAT produces an impaired ability to control the spatial extent of the focus of attention. This study found that the facilitatory effect of a spatial cue on visual search time increased as the size of the cue was reduced, and that individuals with DAT were less able than healthy older adults to take advantage of the more focal nature of the smaller cues (see also Greenwood et al., 2000). Additionally, as discussed further below, it is possible that DAT produces an impaired ability to exert in-

hibitory control over task-inappropriate information (i.e., distractors).

#### *Selective attention within the linguistic domain*

Although there have been many studies which have explored characteristics of attentional selection within the visual/spatial domain, there have also been studies which have extended these paradigms to tasks which involve more linguistic stimuli. In this section, we will review studies that have used linguistic materials, although the same principles may hold for other types of materials. We will first review some standard attention paradigms with linguistic materials, and will then turn to the brunt of this research that involves selection in the face of competing information, which is ideally suited to investigation with linguistic materials.

#### *Semantic priming*

There is an important linguistic analogue to the visual cueing experiments described earlier, which involve search of semantic (meaning based) knowledge networks. Just as in the Posner visual cueing paradigm describe above, a participant's attention can be directed to a visual/spatial location via either an exogenous or endogenous cue; likewise, one can manipulate cues/primes to direct attention (either exogenously or endogenously) within a semantic network, which is either predictive of the target or non-predictive of the target. This is the semantic priming paradigm (see Neely, 1991, for a review) in which one measures the influence of a prime (e.g., DOG) on naming or lexical decision performance to a target (e.g., CAT), compared to an unrelated baseline (e.g., PHONE). If the prime stimulus is presented relatively briefly, and there is little encouragement of the participant to direct attention to the prime-target relationship (as in simple speeded naming performance), the influence of the prime is more automatic, and this type of priming has a surface level similarity to exogenous visual/spatial cueing reviewed above. The influence of the prime under these automatic conditions has been accommodated most frequently within spreading activation frameworks. According to spreading activation frameworks (e.g., Collins and Loftus, 1975), the prime stimulus activates its underlying representation in semantic memory, and the

activation spreads along semantic links to related concepts, thereby facilitating response latency to the target item (see Masson, 1995; Ratcliff and McKoon, 1988, for alternative perspectives). The results of a number of studies in this area have reported similar or larger semantic priming effects in DAT individuals relative to age-matched controls (Balota and Duchek, 1991; Balota et al., 1999; Hartman, 1991; Margolin, 1988; Nebes, Boller and Holland, 1986; Nebes, Brady and Huff, 1989; Nebes, Martin and Horn, 1984; Ober, Shenaut, Jagust and Stillman, 1991; Ober, Shenaut and Reed, 1995; Shenaut and Ober, 1996).

As noted, there are both automatic and attentional mechanisms underlying semantic priming effects, just as there are both automatic and attentional mechanisms that appear to underlie visual cueing effects. Fortunately, the conditions under which semantic priming effects engage attentional processes have been well-defined (see Neely, 1991, for a review). The priming effect at long prime-target stimulus onset asynchronies (SOAs) is presumably more likely to reflect attentional selection mechanisms (Balota, 1983; Neely, 1977), wherein, the participant actually generates/selects an area of semantic memory to expect based on prime information. Interestingly, there appears to be a change in the nature of the priming effects at the long SOA in both healthy older adults compared to younger adults (Balota, Black and Cheney, 1992), and in DAT individuals compared to age-matched controls (e.g., Ober and Shenaut, 1995). However, as noted, in these same studies, there is little evidence of an age- or disease-related change in the priming effects at the short SOAs that presumably are more reflective of the automatic spread of activation. Ober and Shenaut (1995) have reported a meta-analysis which indicates that under conditions of automatic semantic priming there appears to be relatively little change in DAT individuals, whereas, under more attentional controlled processes, there does appear to be an increase in the magnitude of the priming effect in DAT compared to healthy age-matched control individuals.

The results from the semantic priming experiments reviewed above are quite intriguing because they shed some light on the nature of the deficits that are found in other semantic memory tasks. For example, DAT individuals perform more poorly

than healthy older adults on measures of verbal fluency and object naming (Kirshner, Webb and Kelly, 1984; Ober, Dronkers, Koss et al., 1986; Troster, Salmon, McCullough and Butters, 1989). Although these findings have been interpreted as evidence for a breakdown in semantic memory in DAT, other evidence from the semantic priming literature may question the notion that semantic memory is degraded in DAT, and suggest an attentional account. For example, in the category task (i.e., generating words from a specific semantic category), the participant must select words endogenously and keep track of generated words as they are selecting new items from semantic memory. It is possible that the attentional demands of keeping track of previously generated words, and endogenously selecting new items in a background of distractor words, produces the breakdown in this task instead of the integrity of the semantic network itself (see Troyer, Moscovitch, Winocur et al., 1998, for similar recent arguments concerning verbal fluency and DAT). This is precisely why the priming results have been so intriguing, because if there were a breakdown in the integrity of the network, then one would expect to find differences in the nature of the priming effects.

In sum, the results regarding priming tasks in DAT within the semantic domain appear to be relatively clear in suggesting that DAT individuals are more likely to produce deficits in the more attention demanding aspects of these tasks. One might argue from these results that the major deficit in the semantic tasks, at least early on, is not in the integrity of the semantic network but in the attentional systems that retrieve information from that network (see Ober, 1999, and the accompanying papers for a detailed discussion of this issue). Moreover, there does appear to be some convergence in that automatic exogenous visual cueing and automatic semantic priming effects appear to be relatively uninfluenced early in the disease process, but it is the more attentional mechanisms and endogenous control which appear to breakdown in early stage DAT. Future research is clearly needed to further substantiate this relation.

#### *Attentional selection and inhibition within the linguistic domain*

One area that has received considerable interest in the attentional selection domain with linguistic ma-

terials is the extent to which DAT individuals have difficulty controlling multiple sources of activation at any given point in time. Linguistic materials are especially suited for such study, because these stimuli typically have multiple codes that are afforded at a given point in time, e.g., the color, location, orthography, phonology, syntax, and semantics of any visually presented word are all simultaneously available codes that might be selected for further processing.

The emphasis on multiple codes available at a given point in time has increased the salience of models that emphasize the notion that efficient performance of tasks requires selection of task appropriate information, and filtering and suppression of irrelevant information (e.g., Balota and Duchek, 1991; Dempster, 1995; Gernsbacher and Faust, 1991). Our ability to maintain a stable focus of attention may depend not only upon our ability to select some information for further processing, but also upon our ability to inhibit information that is not currently relevant (e.g., Neill and Westberry, 1987; Stoltzfus, Hasher, Zacks et al., 1993). Interestingly, several studies of selective auditory attention have found fairly marked declines in the ability of individuals with DAT to selectively attend to a signal in one ear in a dichotic listening situation (e.g., Duchek, Thessing and Law, 1996; Grady et al., 1989; Mohr, Cox, Williams et al., 1990), indicating that DAT results in a decreased ability to appropriately apply the selective filter of attention to potentially distracting information. DAT has also been found to result in an increase in intrusion errors on tests in other cognitive domains (e.g., Butters, Granholm, Salmon et al., 1987; Loewenstein, D'Elia, Guterman et al., 1991). Similarly, several studies have demonstrated that breakdowns in handling inappropriate information in DAT can lead to situations where individuals with DAT will suffer from a breakdown at response selection, producing increased levels of intrusion errors. For example, Simone and Baylis (1997b) found quite large DAT-related increases in the effect of distractors on a reaching task where a target red button (i.e., one of nine possible) was pressed and a green button was to be avoided. These results highlight the particular impairment of individuals with DAT in the inhibition of inappropriate responses.

We shall now turn to a brief review of a series of standard attentional selection paradigms with lin-

guistic materials which share the same task characteristic that individuals are confronted with multiple informational sources or pathways and must select an appropriate pathway to accomplish the task goals. We will see that in each of these simple situations there is a breakdown in DAT of the inhibitory control over the influence of non-selected information.

### *Negative priming*

One paradigm that has received considerable discussion in the attentional selection literature is the negative priming paradigm (see Neill, Valdes and Terry, 1995 for a review). Here the question is not what is selected, but what happens when previously unselected or ignored information must now be attended. As shown in Fig. 4, in a standard negative priming paradigm participants are asked to make a response to a target, which is presented with at least one distractor on a given trial, and then on a subsequent trial, the non-selected distractor becomes the target. The typical negative priming effect refers to the finding that responses to a target item are slower when that target was a distractor on the previous trial in comparison to when it was not presented on the previous trial. Sullivan, Faust and Balota (1995) explored this paradigm with DAT individuals, and had participants name the red item in displays of

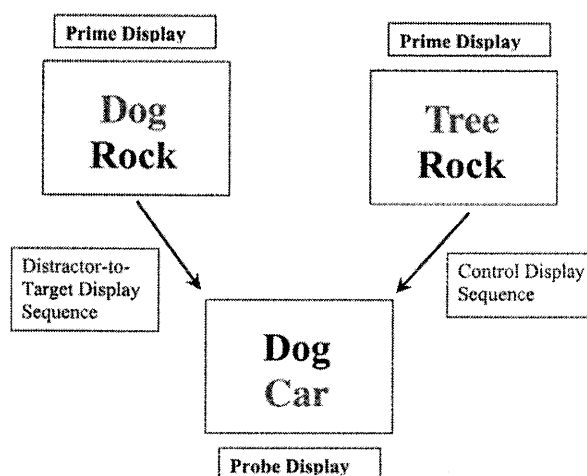


Fig. 4. Example stimuli for a typical negative priming trial where the task requires responding to a target item (i.e., the black item) in the presence of a distractor (i.e., the gray item). The second (i.e., probe) display requires responding to DOG following either an experimental prime display containing DOG as the distractor, or following a control prime display not containing DOG.



overlapping red and green words (Experiment 1) or overlapping red and green pictures (Experiment 2). The results were quite clear: in both experiments for the healthy young adults and healthy older adults, naming latency was slowed when the previously ignored item became the target on the next trial, i.e., a negative priming effect. On the other hand, for DAT individuals, there was no such cross-trial interference or negative priming. Interestingly, the DAT also produced more within-trial intrusion errors than did healthy older adults when the distractor item was semantically related to the target (e.g., dog-cat), but the groups did not differ in intrusion errors when the distractor was unrelated to the target (e.g., dog-table). These results suggest that individuals with DAT suffer from a breakdown in the control of non-selected information, resulting in reduced negative priming effects across trials, and in increased sensitivity to distraction within a trial.

It is worth noting here that Conway, Tuholski, Shisler and Engle (1999) and Engle, Conway, Tuholski and Shisler (1995) have recently reported evidence that simultaneously maintaining a set of items while performing a negative priming task can eliminate the negative priming effect even in healthy young adults. These researchers argue that this is due to a change in the representation needed to control the activated representation from the ignored stimulus. We shall return to this issue in the general discussion section. Although the negative priming results appear to suggest that DAT individuals experience some breakdowns in suppressing non-selected information, it should be noted here that there are alternative accounts of negative priming that have been advanced in the literature (see Neill et al., 1995, for a review).

#### *Reading with distraction*

Duchek, Balota and Thessing (1998) employed a reading with distraction task with DAT individuals. Duchek et al. used a task that was originally used by Connelly, Hasher and Zacks (1991) to explore changes in inhibitory control in healthy older adults. As shown in Fig. 5, subjects are asked to read upper case information that is embedded in different levels of distractor information, e.g., none (control condition), orthographic (xxxx), lexical (unrelated words), and semantic (related words). For the

present purposes, the most noteworthy finding is that individuals with mild levels of DAT were disproportionately influenced by the distracting information and this effect was magnified when the distracting materials were conceptually related to the target. It is also interesting to note that the mild DAT individuals false-alarmed in a later recognition test to the distractor information that was conceptually related. These results are reminiscent of the negative priming effects reviewed in the previous section in which conceptual information intruded when it was related to the target item. Thus, these results suggest that in early stage DAT, there appears to be an increased difficulty of inhibiting partially activated information, especially when it is related to the information currently being processed.

#### *Stroop performance*

The gold standard experimental paradigm to investigate attentional selection when multiple codes are activated is the Stroop paradigm (see MacLeod, 1991 for a review). The Stroop test is thought to involve response selection based on controlled or effortful processing of the color name with simultaneous control over automatic processes associated with word naming. Participants are typically slower and produce more errors when performing the color naming task in the presence of a conflicting color name (e.g., the word RED displayed in green) as opposed to color naming for neutral trials (e.g., the word DEEP displayed in green). Two qualitatively different levels of impaired ability in Stroop performance can be identified, either (a) a slowed ability to handle the conflicting word information leading to a larger Stroop interference effect in response latency, or (b) a decreased ability to control the tendency to inappropriately respond to the word leading to a greater Stroop interference effect in error rates. Although Fisher, Freed and Corkin (1990) and Koss, Ober, Delis and Friedland (1984) reported reliable increases in the Stroop effect in DAT individuals compared to healthy controls, we will focus on a study by Spieler et al. (1996) because this study provided a number of additional analyses that may shed some light on the underlying nature of the attentional deficits.

Spieler et al. (1996) found that while there was an age-related increase in interference from the word

The Party Paragraph

Control Condition

PAUL STARTED COOKING BY 7 A.M. TO PREPARE THE ITALIAN SAUSAGE FOR HIS GREAT-GRANDMOTHER'S BIRTHDAY PARTY. HE STOOD OVER A LARGE STEAMING POT OF SPAGHETTI AND WORKED FEVERISHLY TO GET THE SPICES JUST RIGHT FOR THE SAUCE...

Related Condition

PAUL STARTED COOKING BY *pepperoni* 7 A.M. TO PREPARE *juice great aunt* THE ITALIAN *juice* SAUSAGE FOR HIS *indian pepperoni* GREAT-GRANDMOTHER'S *great aunt* BIRTHDAY PARTY. HE *pepperoni juice* STOOD OVER *peppeorni* A LARGE STEAMING *great aunt* POT OF SPAGHETTI *juice* AND WORKED FEVERISHLY TO *indian pepperoni* GET THE SPICES *great aunt* JUST RIGHT *pepperoni* FOR THE SAUCE...

Unrelated Condition

PAUL STARTED COOKING BY *parachute* 7 A.M. TO PREPARE *jump grass arts* THE ITALIAN *jumps* SAUSAGE FOR HIS *ideas parachute* GREAT-GRANDMOTHER'S *grass arts* BIRTHDAY PARTY. HE *parachute jumps* STOOD OVER *parachute* A LARGE STEAMING *grass arts* POT OF SPAGHETTI *jumps* AND WORKED FEVERISHLY TO *ideas parachute* GET THE SPICES *grass arts* JUST RIGHT *parachute* FOR THE SAUCE...

XXXXXX Condition

PAUL STARTED COOKING BY *xxxxxxxxxx* 7 A.M. TO PREPARE *xxxxx xxxxx xxxx* THE ITALIAN *xxxxx* SAUSAGE FOR HIS *xxxxx xxxxxxxxxxxx* GREAT-GRANDMOTHER'S *xxxxx xxxx* BIRTHDAY PARTY. HE *xxxxxxxxxx xxxxx* STOOD OVER *xxxxxxxxxx* A LARGE STEAMING *xxxxx xxxx* POT OF SPAGHETTI *xxxxx* AND WORKED FEVERISHLY TO *xxxxx xxxxxxxxxxxx* GET THE SPICES *xxxxx xxxx* JUST RIGHT *xxxxxxxxxx* FOR THE SAUCE...

Fig. 5. Example stimuli used from the Duchek et al. reading with distraction task.

pathway as measured by response latency, there were no age-related differences in interference as assessed by errors. Thus, the healthy older and younger adults were equally able to exert inhibitory control for response selection, the older adults just took longer to do so. By contrast, there was a DAT-related increase in both the latency and error measures of interference, suggesting a qualitatively different impairment where individuals with DAT were less able to control the activation of the inappropriate word information

and allowed this information to drive the response on a significantly greater proportion of the trials. Spieler et al. (1996) applied a method used by Lindsay and Jacoby (1994) to isolate and map out the time course of the relative influence of the word and color information for each of the groups. This analysis indicated that there was a DAT-related change in the influence of the word code consistent with a breakdown in inhibitory control. Thus, the results from the Stroop task clearly indicate that DAT individuals

have a disproportionate breakdown in the ability to control non-selected information. The power of this task may in fact be useful as an early diagnostic tool.

#### *Homograph disambiguation*

Another issue which has received considerable attention within the attention/language processing domain is how the system deals with the multiple interpretations that are often available when a word is presented. For example, consider the word ORGAN. This word can refer to either a musical instrument or a body system. Just as attentional selection within the visual domain must select a position in space to attend to, likewise here the system must select which of two, or more meanings, must be selected for further processing.

Balota and Duchek (1991) explored how individuals with DAT use prior context to select an interpretation of an ambiguous word. Interestingly, there has been work suggesting that attention is needed to resolve ambiguity (e.g., Swinney, 1979), in that, context plays a larger role at a longer SOA (however, see Paul, Kellas, Martin and Clark, 1992), thereby suggesting that context works like endogenous attentional control. This of course is in part motivated by the semantic priming literature discussed above (e.g., Neely, 1977), in which long SOAs are more likely to reflect attentional processing. In the Balota and Duchek study, subjects named three sequentially presented primes on each trial. In the concordant condition (MUSIC–ORGAN–PIANO), the primes and targets were related to the same meaning of the homograph. In the discordant condition (KIDNEY–ORGAN–PIANO), the first prime and target were related to different meanings of the homograph, and these were compared to either a neutral (CEILING–ORGAN–PIANO), or an unrelated condition (CEILING–KIDNEY–PIANO). Naming latencies to the third word indicated that both groups produced facilitation in the concordant condition compared to the unrelated condition. Of greater interest was the pattern for the incongruent condition. For the healthy older adults, the latency in the discordant condition was equivalent to the unrelated condition, suggesting that the context word (KIDNEY) served to select the relevant interpretation of the homograph (ORGAN), such that there was no longer any priming of the target word

(PIANO). However, for the DAT individuals there was still substantial facilitation in the discordant condition. This would appear to suggest that DAT individuals were experiencing a breakdown in the attentional selection of the appropriate interpretation of ORGAN based on the context KIDNEY, and that there was little if any suppression of the context-inappropriate meaning related to PIANO.

A similar finding was observed by Faust et al. (1997) who used a sentence priming study. In this study, participants made relatedness judgements to a word (e.g., ACE) that either followed a sentence that ended with an ambiguous word (e.g., 'he dug with a spade') or a sentence that ended with an unambiguous word (e.g., 'he dug with a shovel'). In both cases, the correct response is 'No'. (There were an equal number of trials that produced a 'Yes' response such as 'he dug with a spade', with GARDEN being the target.) The major finding was that the DAT individuals again produced equivalent facilitation for the congruent trials, but they had more difficulty rejecting the word ACE when it followed the sentence context which ended with the ambiguous word SPADE, i.e., 'he dug with a spade'. This disruption occurred in both response latencies and errors rates. Thus, it appears that DAT individuals were keeping the context-inappropriate interpretation of SPADE (referring to playing card) available in the face of a disambiguating context. This result nicely converges with the results obtained by Balota and Duchek (1991), and the results of both studies are consistent with the notion that DAT individuals are having difficulty controlling/inhibiting partially activated processing pathways.

#### *Attentional selection of lexical and sublexical processing pathways*

A series of experiments by Balota and Ferraro (1993, 1996) explored the selection of two potentially distinct routes in lexical processing. According to dual-route models (Coltheart, 1978) readers of English can either generate the name code via the application of spelling to sound principles or map the whole lexical pattern onto a lexical representation to obtain a naming response (see Plaut, McClelland, Seidenberg and Patterson, 1996, for an alternative perspective). Because English spelling to sound correspondence is semi-regular at best, these two routes sometimes

produce a conflict. For example, in naming the word PINT, participants will have available both a sublexical output which produces an output that rhymes with HINT as well as the correct lexical output. This conflict in output can produce a slowdown in response latency. Interestingly, DAT individuals do not produce a slowdown in this condition, but are actually more likely to simply output the regularized code (see Balota and Ferraro, 1993; Patterson, Graham and Hodges, 1994). One might view these results as consistent with the notion that when the task demands attentional selection for the lexical route (name words), DAT individuals appear to produce some leakage from the sublexical route that produces regularization errors. Balota and Ferraro (1996) further pursued this selection issue in a subsequent study in which participants were encouraged to rely on the sublexical pathway, i.e., make rhyme decisions to words and nonwords. In this study, Balota and Ferraro found that there was increased influence from the lexical pathway in DAT individuals, as reflected by an increased word-frequency effect. (The dual route model suggests that the lexical route, but not the sublexical route, is frequency modulated.) Hence, the coupling of the Balota and Ferraro (1993, 1996) studies suggest that when task demands encourage attentional selection of the lexical route (speeded naming of words), DAT individuals produce an increased leakage from the sublexical route, and when the task encourages attentional selection of the sublexical route (speeded rhyme decisions for words and nonwords), there is increased influence from the lexical route. These results again suggest a breakdown in attentional selection, and the control of non-selected processing pathways.

#### *Attentional selection and memory in DAT*

Is there any relevance of these attentional selection breakdowns for the most apparent problem found in DAT, i.e., a profound loss in episodic memory? Researchers have long recognized the importance of attention to memory performance (e.g., Craik and Lockhart, 1972; Duchek, 1984; Jacoby, 1991; Moscovitch and Winocur, 1995). In fact, recent research on memory has specifically targeted the differing roles of attention at encoding and retrieval, suggesting that encoding operations are more con-

trolled and attention demanding, whereas, retrieval operations appear to be more automatic, and less controlled (see, Craik, Govoni, Naveh-Benjamin and Anderson, 1996). Moreover, recent neuroimaging studies of long-term episodic memory have highlighted frontal areas that some have argued are more tied to strategic attention demanding operations in memory, along with the medial temporal areas (e.g., Buckner, Kelley and Petersen, 1999, for a review). Thus, it is at least possible that part of the memory breakdown that occurs in DAT is not simply the result of the problems that are tied to medial temporal areas and the formation of declarative memories, as the legacy of HM would lead us to believe, but may also involve the more strategic attentional components that reflect frontal areas.

How might attentional selection influence memory performance? One very simple way is that what is attended to is in large part what is encoded. If there is less structure to what is encoded then one might produce a breakdown in the elaborative processes that have been found to influence memory performance (Craik and Lockhart, 1972). Similar influences of attention might occur at retrieval when subjects engage in strategic operations in an attempt to recall a list of items. Multiple sources of activation are clearly available at retrieval, and so if there is a disruption in attentional selection then one might expect a breakdown in memory performance.

In order to provide an example for the role of attentional selection in memory, we will briefly review a recent study by Balota et al. (1999). This study explored the false memory paradigm recently developed by Roediger and McDermott (1995) based on an initial study by Deese (1959), hereafter called the DRM paradigm, in which associatively/semantically related words converge on a critical non-presented item. For example, consider being presented with the following list of words: THREAD, PIN, EYE, SEWING, SHARP, POINT, PRICK, THIMBLE, HAYSTACK, PAIN, HURT, INJECTION. The non-presented critical target word is NEEDLE for this list. Roediger and McDermott reported that the likelihood of recalling the non-presented critical word NEEDLE was as high as the probability of recalling the items that were actually presented in the middle of the list (0.40 in both cases).

What are the implications regarding potential

breakdowns in attentional selection in DAT for performance in the DRM paradigm? False memories of the critical non-presented items in the DRM paradigm could be viewed as a situation wherein there are multiple sources of evidence at retrieval that the individual needs to discriminate to make the correct response, i.e., this could be viewed as an attentional selection problem. An intact processing system should be able to discriminate between sources of activation that are directly related to what was presented compared to sources that are only indirectly related, but are highly activated (see Johnson, Hashtroudi and Lindsay, 1993, for discussion of reality and source monitoring, and Multhaup and Balota, 1997, for evidence of source deficits in DAT individuals). Based on the evidence reviewed above regarding breakdowns in attentional selection, one might expect that DAT individuals would have difficulty controlling or inhibiting the highly activated (semantically related) non-presented item (e.g., NEEDLE in the above example). Thus, relative to their veridical recall, one might actually expect an increase in their false recall. In fact, this is precisely what was found in this study. Balota et al. also addressed an alternative account of these data. Specifically, these results may simply be due to the fact that the veridical pathway breaks down in DAT due to the declarative memory loss, and therefore is relatively weaker than the semantically based familiarity pathway. However, this does not seem to be the case. Specifically, this pattern held even after veridical recall was partialled out. Thus, it is not the case that the false memory differences were simply due to differences in recall but rather appeared to reflect differences in attentional selection at the time of retrieval. Interestingly, there is some evidence that when one puts healthy young adults under time pressure (decreasing time for attentional control), even young adults produce an increased likelihood of false recall (Benjamin and Craik, 1999). Finally, it should be noted that DAT individuals can also be led to rely on simple baseline word familiarity information and actually reverse the mirror word frequency effect in episodic recognition performance (see Balota, Cortese, Burgess and Adams, 2001; Wilson, Bacon, Kramer et al., 1983). One might again expect this pattern if attentional selection would break down and instead of relying on relative boost in familiarity

due to an earlier study episode, subjects were simply relying on baseline familiarity. Again, it appears that DAT individuals are having difficulty selecting the most relevant pathway out of a mix of partially activated processing pathways.

#### *Theoretical implications of the present review*

The review of the empirical literature indicates that DAT individuals produce a breakdown in many (but not all) attention demanding tasks. We have also shown that the breakdowns in standard attentional paradigms may actually extend to other standard cognitive tasks that include memory and comprehension performance. In this review, we have emphasized the notion that there may be a disproportionate breakdown in the suppression or control of partially activated representations.

Of course, at this point, one might ask if there is a theoretical framework that may help explain these cognitive deficits. One potentially unifying framework is the supervisory attention system proposed by Norman and Shallice (1986) (Shallice, 1988; also see Baddeley, 1986). Of particular interest is the proposal of a hierarchical scheme where low-level automatic processes compete with each other for processing resources and that higher-level supervisory control mechanisms modulate the resolution of this competition. This perspective is also quite consistent with Baddeley's executive control system and also his arguments that there is a selective deficit in this system in DAT individuals (see Baddeley et al., 1986, 1991). Regarding biological substrates, as discussed earlier, an anterior attention network involving the anterior cingulate and selected frontal cortices has been proposed by Posner and colleagues (Posner and Dehaene, 1994; Posner and Petersen, 1990; Posner and Rothbart, 1991) to provide cognitive control functions. Posner and DiGirolamo (1998) have argued that (a) anterior regions of lateral frontal areas are responsible for holding information not currently present in the environment active, (b) cingulate cortex is responsible for effortful control, and (c) basal ganglia are responsible for shifting mental set. The systems work together as part of the anterior attention subsystem required for supervisory control over automated routines. This view is quite consistent with the neuropathological evidence that frontal and

cingulate cortices undergo significant DAT-related pathology (e.g., Liu, Erikson and Brun, 1996; Vogt, Crino and Vogt, 1992).

How might such a framework be useful in accounting for the attentional breakdowns observed in DAT? For present purposes, we will consider the classic Stroop task. When confronted with this task, individuals must engage a representation that maintains the goals of the task and the operations needed to achieve these goals. One way of conceiving the task representation is to consider a production system which uses subroutines that are hierarchically organized to achieve the goals (see Anderson, 1976; Kimberg and Farah, 1993). It is quite possible that the frontal areas described by Posner and DiGirolamo would be necessary for implementing this aspect of performance. The goal of the task representation, and attention selection, is to increase the gain of the relevant processing pathway and decrease the gain on the partially activated but irrelevant pathways (see Cohen and Servan-Schreiber, 1992, for an example of a connectionist model implementing this approach). As shown in Fig. 6, in the Stroop color naming task, the individual needs to increase the gain on the color pathway while at the same time decreasing the gain on the word naming pathway. The efficiency of the attentional selection system in achieving the goals of a task depends on: (a) the integrity and maintenance of the task representation across time; (b) the number of competing pathways; and (c) the relative strength of the competing pathways compared

to the correct pathway. We believe that psychologists often undervalue the importance of the task representations needed to achieve task goals, and researchers often assume that there is no problem if the subject achieves some acceptable level of accuracy. However, it is clearly the case that large changes in accuracy and speed do occur across groups of participants, and it is also possible that these changes may reflect differences in the ability to implement and maintain stable task representations across time. Thus, we would argue that the integrity of the supervisory attentional system is not stable across DAT individuals and also is not consistent across time within an individual, but likely needs to be refreshed much as items need to be rehearsed to be maintained in short-term memory (see Kane, Bleckley, Conway and Engle, 2001, for similar arguments). In this light, it is possible that DAT individuals produce larger Stroop effects than healthy older adults (e.g., Spieler et al., 1996) because of breakdowns in the integrity of the attentional control system that maintains the task requirements across time.

Why might the task representation break down in DAT individuals? One might argue from an evolutionary perspective that these systems may have developed most recently, and that these systems may need to be the most flexible within the cognitive system. Specifically, one of the unique aspects of the human cognitive system is the flexibility with which it deals with the diverse processing demands across language, memory, and problem solving contexts. Because of the necessary flexibility of this system to accommodate to these diverse task demands, it will be relatively less-practiced compared to the lower-order pathways that have received more consistent stimulus to response mapping (e.g., Schneider and Shiffrin, 1977). The notion is that lower-order pathways are more automated, and hence, one might expect these pathways to be a bit more resilient to degradation, precisely as one finds in some of the semantic and visual exogenous cueing situations described above. However, the higher-order supervisory systems need to be adjusted according to task demands in a more flexible manner and hence appear to be more susceptible to the widespread degradation found in DAT.

What are the implications for such an attentional framework for the observed memory deficits in DAT

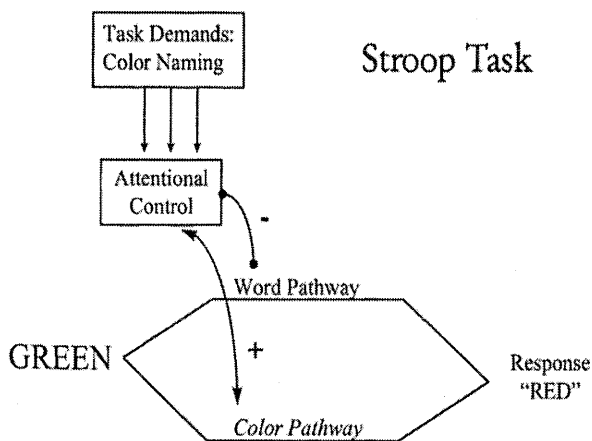


Fig. 6. An attentional control framework for the Stroop Task. In this example the word GREEN is presented in red.



individuals, i.e., the most salient problem in these individuals? In this light, we are quite sympathetic to the arguments made by Moscovitch and Winocur (1995) who suggested that there are two systems involved in memory performance. First, the medial temporal areas are at the core of an associative system that relatively automatically binds together what is consciously apprehended (see also Cohen and Eichenbaum, 1993; Kroll, Knight, Metcalfe et al., 1996). The notion is that at any point in time a number of distinct neural networks/pathways are activated via both internally generated and externally available stimuli. The medial temporal system has been viewed as binding these distinct patterns in a relatively automatic/modular manner to produce a record of the conscious experience. Clearly, as noted earlier, there is degradation in this system in DAT individuals. In addition to the medial temporal system, however, there is a frontal system serving to select appropriate pathways for accomplishing the goals of the task (e.g., Buckner, 1996; Shimamura, 1995; Tulving, Kapur, Craik et al., 1994). This system operates on both the input to the medial temporal system and the output from it. Presumably, the frontal areas provide attentional control over the networks that become activated during encoding and become available during retrieval. Interestingly, Shimamura (1995) has argued that frontal systems provide an important gating or inhibitory function in declarative memory performance, and it is this inhibitory or gating function that appears to be disrupted in healthy older adults. This of course is quite consistent with the arguments that we have made regarding the attentional selection problems found in DAT individuals.

Fig. 7 reflects an idealized attentional selection framework (similar to the Stroop model) that could be used to account for the increased susceptibility to false memories in DAT individuals. Here, the goals of the task reflect recalling source information from an earlier encoded episode. However, at retrieval, there is also competing information available based on overall familiarity from the convergence of the list item on the critical non-presented item. Thus, one can see that this is a type of attentional selection problem. Again, just as in the Stroop task, because of this competing information and potential degradation in the supervisory system, DAT individuals may be less likely to control the incorrect familiarity-based

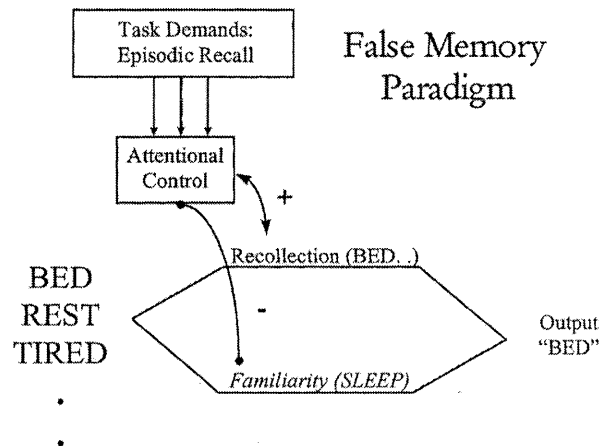


Fig. 7. An attentional control framework for the False Memory Paradigm.

information and respond based on this incorrect information. It should also be noted here that the false memory susceptibility has been attributed to frontal functioning (e.g., Schacter, Curran, Galliccio et al., 1996).

In this light, one might argue that at least some of the DAT-related deficits might reflect a breakdown in the integrity and maintenance of the task representations/goals across time which in turn provide the controlling device for attentional selection. Frontal areas have clearly been implicated in such processes (e.g., West, 1996, for a review). Interestingly, there is a recent study by Collette, Van der Linden and Salmon (1999) which supports just this position. Collette et al. (1999) gave both DAT individuals and healthy control individuals a set of six tasks that may tap into executive supervisory functioning. They found large breakdowns in each of these tasks, but most importantly, found that the tasks loaded quite clearly on two factors. The factors were interpreted as inhibition abilities, and the coordination and storage of multiple sources of information. They also found that the inhibition factor was more related to cerebral blood flow in frontal areas, whereas, the second factor that presumably reflects coordination of multiple sources of activation was more related to a set of posterior/parietal areas. Clearly, multiple systems are involved in attentional operations, but the relation between the inhibition-related factor to blood flow in the frontal lobes in these individuals is promising.



Finally, one might ask whether there would be a way of increasing the salience of task supervisory systems within an individual. An intriguing study by Multhaup (1995) provides some support for the emphasis on the integrity of maintaining task representations/goals in memory performance. In this study, healthy older adults were given additional cues during a memory test concerning sources of possible memory events. Interestingly, when older adults were given these additional cues, there was an elimination of the age-related changes in the false fame effect (i.e., an increased susceptibility to rely on familiarity of a stimulus vs. direct recollection). Clearly, future work is necessary to extend this work to DAT individuals. It would be quite important to determine if increasing the salience of the appropriate task goals might help alleviate some of the cognitive changes that occur in this population.

## Conclusion

In the present chapter, we have reviewed some of the major findings in attention in individuals with dementia of the Alzheimer type. The present review is consistent with the notion that there may be a breakdown in endogenously controlled attentional selection processes. This pattern is compatible with a breakdown in the system that maintains task demands across time, and modulates the relevant pathways to achieve the current goals of a task. Because of the central nature of such attentional processes to virtually all cognitive tasks, we believe that a breakdown in such a system would produce the relatively widespread cognitive deficits that occur in DAT. We also believe that those operations that place a high demand on such a system (e.g., attentional selection amongst competing pathways, as in Stroop, divided attention tasks, and memory encoding and retrieval operations), will produce the greatest breakdown early in the disease process.

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