

# Inhibition, Facilitation, and Attentional Control in Dementia of the Alzheimer's Type: The Role of Unifying Principles in Cognitive Theory Development

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A central problem in cognitive science is understanding how the cognitive system, embedded in the environment, modulates the activation or accessibility of information in real time in the direction of thought and action. One attractive method of approaching this problem has been to assume a set of cognitive control processes that work to either enhance or inhibit dedicated task-related processes (e.g., Balota & Faust, 2001; Gernsbacher & Faust, 1991a, 1991b; Hasher, Zacks, & May, 1999; Smith & Jonides, 1999). Given this perspective, it is not surprising that measuring the empirical footprint of inhibitory control processes has been an important goal for many researchers (Dagenbach & Carr, 1994; Dempster & Brainerd, 1995).

Experimental paradigms such as negative priming (Sullivan, Faust, & Balota, 1995; Tipper, 1985), inhibition of return (Faust & Balota, 1997; Posner & Cohen, 1984), Stroop color naming (MacLeod, 1991; Spieler, Balota, & Faust, 1996), task switching (Mayr & Keele, 2000), directed forgetting (Zacks, Radvansky, & Hasher, 1996), and stop-signal processing (Logan, Cowan, & Davis, 1984) have all played a prominent role in this research effort. However, as reflected in the motivation for this volume—to discuss the utility of inhibitory mechanisms in cognition—there are some who now seriously question the utility of inhibition at the level of explaining cognitive processes both within and across groups of subjects (e.g., Burke, 1997; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003). These recent arguments have been driven by the following:

- the failure to find a consensus inhibitory account of some phenomena consistent with the extant data (e.g., see Neill & Valdes, 1996; for the

debate on the interpretation of negative-priming effects, see Tipper, 2001),

- the appearance in the literature of hard-to-dismiss noninhibitory accounts of other phenomena that do have a consensus inhibitory interpretation (e.g., inhibition of return; Pratt, Spalek, & Bradshaw, 1999), and
- lack of a consistent definition of inhibition in the literature.

Although these debates have often focused on the need for specific inhibitory mechanisms in theoretical explanations of processing in a specific task under specific controlled conditions, we argue in this chapter that a broader view of these issues is possible and useful.

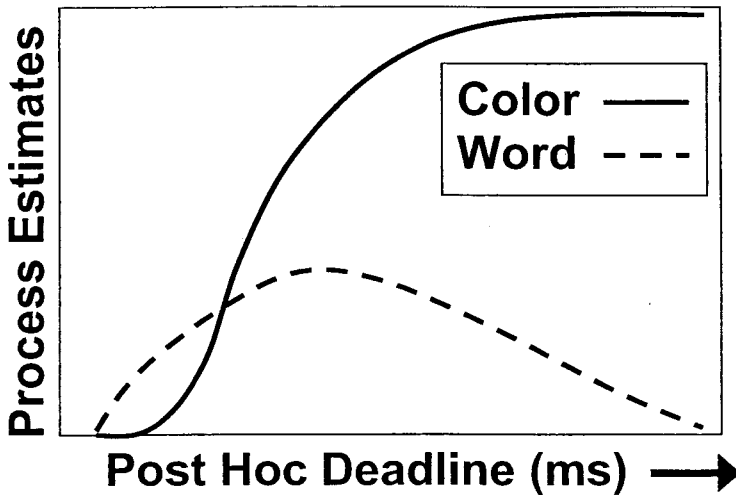
### **Questions About the Utility of Inhibitory Mechanisms**

Before detailing the particular theoretical perspective we have taken in our work, it is useful to specify our position on the topic that is the motivation for this volume: to discuss the utility of inhibitory mechanisms in cognition.

First, we consider inhibitory accounts to be useful in a number of empirical domains, and we believe that alternative accounts have not been sufficiently detailed to understand how noninhibitory accounts handle the data. Second, we argue that ultimately, one could raise concerns about the utility of activation mechanisms that are similar to those raised about inhibitory mechanisms. Of course, it is always useful to consider the explanatory power of a mechanism within a particular task, but to question the general utility of activation and inhibition mechanisms in accounting for cognitive behavior seems far too limiting a stance.

#### *Inhibition or Conflict Resolution?*

We believe that logical argument and empirical evidence indicate that although there may be alternative accounts of some inhibitory processes, the vast majority of the data are best understood in terms of inhibitory mechanisms. For example, the finding from the simple Stroop color-naming task is that subjects are slower to name the color of a word when it is in an incongruent color name (e.g., the word *red* presented in green) compared with when the color and word are congruent or when a “neutral” stimulus is presented such as a row of Xs or an unrelated word. One noninhibitory account of the observed behavioral slowing involves a type of conflict resolution in which subjects experience no need to inhibit the word dimension in this task but rather are slower because there is a conflicting dimension, and resolution of the conflict simply takes longer (similar arguments have been made concerning the negative-priming task). We are confused as to how dimension selection might occur in this stage of processing in the 50- to 75-millisecond time frame reported by many studies in the literature (e.g., Spieler et al., 1996) if it does not involve a type of inhibitory control over task-inappropriate information. This resolution-of-conflict approach needs to be specific enough to indicate how the subject selects



**Figure 11.1.** Color and word process estimates in the Stroop task as a function of time using the process dissociation procedure (Lindsay & Jacoby, 1994). Process estimates were obtained by gradually increasing the post hoc time deadline for responding (see Spieler et al., 1996, for details). Adapted from "Stroop Performance in Healthy Younger and Older Adults and in Individuals With Dementia of the Alzheimer's Type," by D. H. Spieler, D. A. Balota, and M. E. Faust, 1996, *Journal of Experimental Psychology: Human Perception and Performance*, 22, p. 473. Copyright 1996 by the American Psychological Association.

the appropriate dimension in the face of a strong prepotent pathway without some control of that pathway. Moreover, once one assumes "control" of the prepotent pathway, how does this occur without inhibition?

An inhibitory account that we favor suggests that when the stimulus is presented, multiple pathways are automatically engaged and compete for output. Of course, the greater practice on the word dimension results in early word processing that is initially stronger than the processing of the color dimension. Hence, the word dimension initially pulls attention and must be controlled. We argue that across time, a top-down control signal tied to the representation of task demands begins to exert control over the prepotent word dimension. Figure 11.1 displays the influence of the word and color pathway across time as estimated by Jacoby's process dissociation procedure (Lindsay & Jacoby, 1994) from a study by Spieler et al. (1996). As is evident in the figure, initially there is a strong signal from the word dimension that indeed is suppressed across time. It is this inhibition of partially activated but irrelevant pathways that we argue is fundamental to conflict resolution across many domains.

Such inhibition could be short lived during the act of conflict resolution and may not have lingering effects beyond the act of selection. It is unclear, at least to us, how the time course of conflict resolution occurs without such an inhibitory mechanism. Our analysis of the contributions of the word and color processes during the typical Stroop task (Spieler et al., 1996) leads us to question whether other approaches that fail to modulate strength of processing

in the irrelevant pathway, such as that of Cohen, Dunbar, and McClelland (1990), where control processes simply globally enhance the color pathway, can produce the basic pattern depicted in Figure 11.1.

### *Is There Unequivocal Evidence for Activation Mechanisms?*

The current volume emphasizes the discussion of the utility of inhibitory mechanisms to explain aspects of cognitive performance. However, no one is actively questioning the utility of facilitatory processes. In fact, one could argue that facilitatory mechanisms are just as vulnerable to these concerns. For example, for the Stroop facilitation effect, one clearly needs to include some neutral baseline to measure facilitation. In the Stroop task, this typically involves a row of Xs or a noncolor word. How can one be assured that the facilitation in the Stroop task is due to the facilitation of the color response being primed by the word dimension? Is it not possible that the reason one observes facilitation in the Stroop task is because there is inhibition from the neutral noncolor words in color naming? What independent evidence is there that there is facilitation? The answer would seem to depend on the appropriate baseline condition against which to measure facilitation and inhibition. More than 20 years ago, Jonides and Mack (1984) critically reviewed the literature on the selection of an appropriate neutral condition and emphasized the importance of converging evidence. We argue that the vast majority of the paradigms that have measured facilitation and have interpreted the facilitatory effects as reflecting activation mechanisms fall prey to many of the same concerns that have been leveled against inhibitory mechanisms (MacLeod et al., 2003). However, instead of promoting dustbowl empiricism and simply identifying conditions in which behavioral facilitation (benefits) and behavioral inhibition (costs) occur, we believe that the mechanisms of both activation and inhibition are very useful in helping guide cognitive theory.

### **Aging and Dementia of the Alzheimer's Type: Toward an Attentional Control Framework**

The global cognitive deficits associated with dementia of the Alzheimer's type (DAT) provide an opportunity to demonstrate the usefulness of viewing inhibitory and facilitatory processes as meaningful categories of processing that transcend the specifics of the particular process accounts of phenomena associated with specific experimental paradigms and allow a broader picture of the underlying processing deficit. Evidence from broad batteries of neuropsychological tests (Salthouse & Becker, 1998) and from studies of the progression of neurodegeneration (Wenk, 2003) suggests that the global cognitive deficit that marks DAT has at its core impairment of attentional control (Balota & Faust, 2001; Perry & Hodges, 1999). In fact, measures of executive function and attentional control may be the best predictors of progression to clinically diagnosable dementia (Rapp & Reischies, 2005). In this chapter we present evidence from a variety of experimental tasks suggesting that individuals with DAT

experience a deficit in inhibitory control processes associated with regulation of task-inappropriate information in contrast to a relative preservation of facilitatory processes that activate information related to objects and events in the environment. Our proposed inhibitory control deficit for DAT bears some resemblance to the proposal by Hasher and Zacks and their colleagues (e.g., Hasher et al., 1999) of a similar, albeit less pronounced, deficit in healthy aging.

We begin with presentation of an attentional control framework to motivate the examination of empirical work testing three general processing hypotheses regarding the processing deficits underlying the cognitive decline in DAT. We then discuss the neuropsychology and neuropathology associated with the cognitive decline in DAT. We present a line of research motivated by the attentional control framework addressing three major classes of processing deficits: (a) facilitatory processes associated with stimulus-driven activation of information, (b) inhibitory control over task-inappropriate pathways, and (c) the representation and maintenance of task goals and strategies.

### *Attentional Control*

The environment provides people with multiple objects and events simultaneously toward which they can act in a variety of ways. A large body of research suggests that visual objects and events can initiate a cascade of processes that capture response systems even when there is little or no conscious intention to act (Tipper, 2001). In the case of eating dinner, for example, because of moment-by-moment changes in goals, one might pick up a fork to eat or pick up a cup to drink. This example has important implications. First, a wider range of information is activated by perceptual processes (e.g., cup and fork) than is appropriate given the physical constraints of motor output systems (e.g., pick up the fork). Second, processing pathways associated with multiple objects, events, or stimulus characteristics (e.g., color, form, or motion of an object) compete to drive output systems. Hence, a central function of selective attention is to prevent actions from being inappropriately driven by the most perceptually salient object or event (Diamond, 1990).

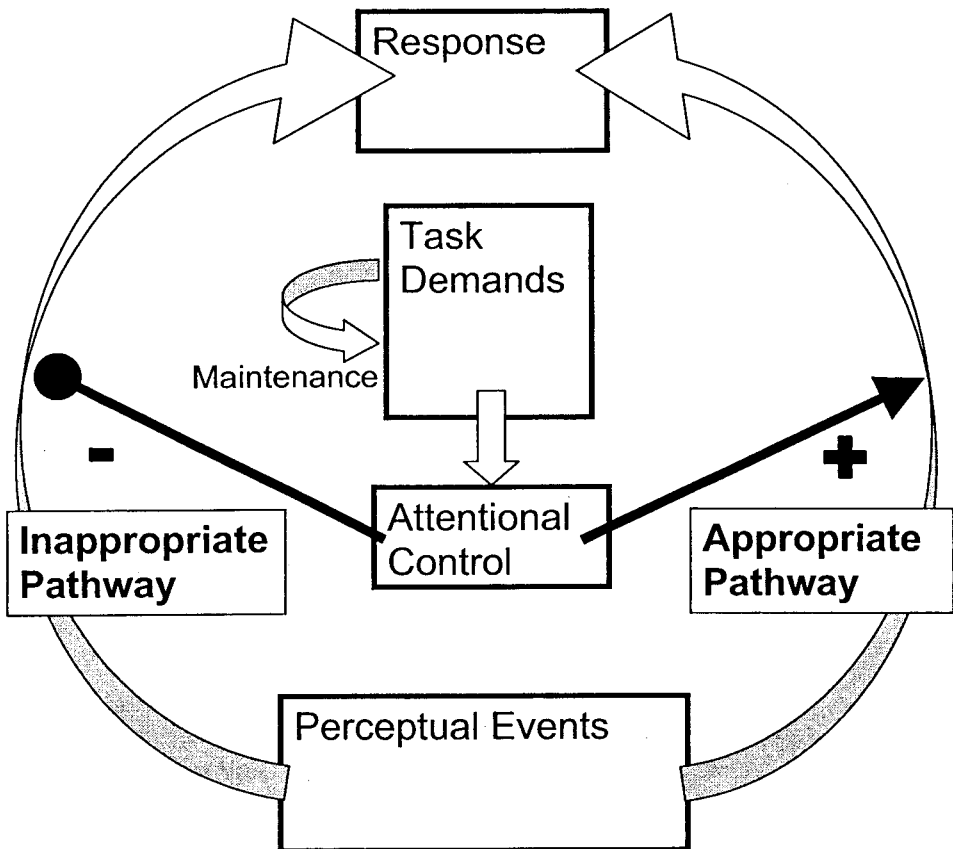
Another issue highlighted by the choice to act toward an object at the dinner table involves the role of mental set in representing task demands that differentiate task-appropriate and task-inappropriate information (Norman & Shallice, 1986; Rogers & Monsell, 1995). This perspective stresses the role that the representation of goals and strategies plays in selecting the appropriate action given the current task goal (e.g., pick up the fork with the dominant hand); in avoiding other, less-appropriate actions (e.g., pick up the cup with the dominant hand); and in constraining other possible actions (e.g., it is impolite to pick up the fork and cup simultaneously with different hands).

What this analysis suggests is a global view of everyday cognition where well-learned stimulus-driven processing pathways compete to activate well-learned motor sequences to act toward these objects and events. Control over these processing pathways is required in a variety of situations (e.g., Posner & DiGirolamo, 1998), such as when new or complex actions are required, when error checking is emphasized, or when task goals change. The present

discussion centers on attentional control in situations where task-appropriate and task-inappropriate pathways interfere with each other in the sense that they push toward mutually exclusive responses from the same effector (Balota & Faust, 2001).

### *Attentional Control Framework*

Balota and Faust (2001) proposed a theoretical framework for understanding DAT-related changes in attentional control (see Figure 11.2). Central to the attentional control framework is the hierarchical control over low-level perceptual and memory processes that compete for processing resources and access to response systems. Control over processing pathways is most directly exerted by the attentional control system responsible for detecting conflict between



**Figure 11.2.** An attentional control framework applicable to situations where the task set must regulate potential conflict from task-appropriate and task-inappropriate processing pathways. From *The Handbook of Neuropsychology: Aging and Dementia* (2nd ed., p. 71), by F. Boller and S. Cappa (Eds.), 2001. New York: Elsevier Science. Copyright 2001 by Elsevier. Adapted with permission from Elsevier.

processes (Botvinick, Braver, Barch, Carter, & Cohen, 2001) and for selecting task-appropriate pathways as well as attenuating processes in task-inappropriate pathways. The notion is that there needs to be a signal that the current configuration of control signals is not appropriate to accomplish the task goals. Hence, when relatively poor performance (i.e., failure to accomplish the task goals) occurs, there is a signal (possibly from the anterior cingulate) that indicates a need for reconfiguration of the attentional control system. This system is in turn controlled by memory representations of the task goals and procedures and strategies for task performance (Cohen, Aston-Jones, & Gilzenrat, 2004). We propose that the effectiveness of attentional control depends on the ability to regulate the relative strength of task-appropriate and task-inappropriate pathways and the ability to maintain the representation of task demands.

This framework gets much of its inspiration from the supervisory attention system proposed by Norman and Shallice (1986), as well as Baddeley's (1986) proposals regarding executive control of working memory (see also Engle, Tuholski, Laughlin, & Conway 1999). We suggest that this framework is useful for understanding performance in a wide range of tasks involving processing of multiple objects or stimuli with multiple dimensions (e.g., the form and color of words during the Stroop color-naming task).

With regard to the neural substrates underlying control over low-level processing pathways, a network of frontal and cingulate areas has been found to be related to the selection of appropriate processing pathways and detection of conflict in processing pathways (Cohen et al., 2004; Posner & DiGirolamo, 1998) as well as the maintenance of task demands (Smith & Jonides, 1999). Many of these areas overlap with the areas identified in the studies reviewed later in this chapter as being involved in the neurodegenerative changes in DAT. Consideration of the attentional control framework (Balota & Faust, 2001) and the pattern of neuropsychological and neurodegenerative deficits in DAT, one might predict that DAT would lead to impairments in the ability to regulate the processes in task-inappropriate pathways and maintain a stable representation of task demands but would most likely not lead to significant impairments in the automatic activation of information related to perceptual events.

### **Cognitive Decline in Dementia of the Alzheimer's Type: A Brief Review**

DAT is the most common dementing illness, with a prevalence of 3% for the 70- to 74-year-old age range, rising to 24% in the 85- to 89-year-old age range that represents 60% to 70% of dementia diagnoses overall (Fratiglioni & Rocca, 2001). DAT involves progressive neuropathological changes, including but not limited to the growth of amyloid-containing plaques and neurofibrillary tangles (NFTs). Of particular interest for our discussion are neurodegenerative changes in the cingulate and frontal cortices (Choi, Lim, Monteiro, & Reisberg, 2005; Thompson et al., 2003; Wenk, 2003), areas that have been associated with executive function and attentional control (Botvinick et al., 2001; Posner &

Dehaene, 1994; Smith & Jonides, 1999). NFT-related neuropathology is typically most pronounced in the medial temporal lobe early and spreads along cortico-cortico connections to temporal, parietal, and frontal lobe association cortices (Nagy et al., 1999), with a relative sparing of primary and secondary sensory and motor areas until very late in the progression. It has only recently become possible to image the distribution of amyloid, the primary component in amyloid plaques, *in vivo*. Positron-emission tomography (PET) studies using newly developed radiotracers that bind to the form of amyloid in amyloid-containing plaques have found marked amyloid depositions in the frontal, posterior temporal, and inferior parietal lobes (Klunk et al., 2004; Verhoeff et al., 2004). The radiotracer binding was greatest in the frontal lobes of DAT patients, in contrast to almost nondetectable binding in the frontal lobes of healthy controls. These results suggest an amyloid-related disease process that is most pronounced in the frontal lobes early in DAT.

The relationship of amyloid plaques and tangles to cognitive declines in DAT has been controversial. Whereas most studies have found that NFTs are more strongly associated with dementia severity than are amyloid plaques (e.g., Berg et al., 1998), the density and distribution of amyloid plaques may be better at discriminating DAT and healthy brain aging (e.g., McKeel et al., 2004) and in predicting the relative decline among broad domains of cognitive functioning (e.g., Kanne, Balota, Storandt, McKeel, & Morris, 1998).

DAT is a progressive dementia syndrome involving gradual declines in at least two broad domains of cognitive function, usually including memory, in the absence of other dementing disorders such as stroke, vitamin deficiency, or thyroid malfunction (McKhann et al., 1984). Definite DAT can be determined only by a brain biopsy for DAT-related plaques and NFTs. DAT has been traditionally characterized as primarily involving early impairments of memory, expanding to include impairments in other domains such as language, executive, and perceptual functions. It is now clear that DAT involves impairments in attention and executive function, and there is broad support in the literature suggesting that declines in attention and executive function are present in the earliest stages of DAT (Baddeley, Baddeley, Bucks, & Wilcock, 2001; Balota & Faust, 2001; Parasuraman & Greenwood, 1998; Perry & Hodges, 1999). Recent studies of broad batteries (i.e., including multiple tests across several cognitive domains) of neuropsychological tests indicate that most of the DAT-related variability (i.e., predictive of diagnostic group in the early stages) in scores can be explained by a general factor (Ownby, Loewenstein, Schram, & Acevedo, 2004; Salthouse & Becker, 1998). This finding suggests that early in the progression of DAT, a limited number of cognitive processes common to a wide range of tasks are impaired.

Ownby et al. (2004) also found that memory and verbal tests contributed to prediction of diagnosis above and beyond the ability of the general factor. This finding suggests that early DAT tends to be dominated by a progressive memory impairment and by a general cognitive deficit reflecting a breakdown in attention and executive function. In support of this view, a growing number of studies have reported that performance on tasks of attention and executive control in preclinical populations are the best predictors of later diagnosis of DAT (Amieva et al., 2004; Fabrigoule et al., 1998; Rapp & Reischies, 2005).



Interestingly, there is evidence from behavioral genetic studies that also is consistent with the role of early attentional breakdowns in DAT. In particular, there has been considerable work investigating the influence of the apolipoprotein E (*APOE*, related to amyloid regulation in the brain; Lahiri, Sambamurti, & Bennett, 2004) on genetic subtypes as predictors for the development of DAT. There are three allele types of the *APOE* protein,  $\epsilon 2$ ,  $\epsilon 3$ , and  $\epsilon 4$ .  $\epsilon 4$  carriers have a greater risk of developing the disease than  $\epsilon 2$  or  $\epsilon 3$  carriers. Work by Greenwood, Lambert, Sunderland, and Parasuraman (2005) showed that healthy control  $\epsilon 4$  carriers appear to have deficits in spatial attention tasks compared with  $\epsilon 2$  or  $\epsilon 3$  carriers, even though these groups do not differ on standard psychometric tasks. Moreover, a recent meta-analysis by Small, Rosnick, Fratiglioni, and Backman (2004) showed that differences in performance on attention and working memory tasks was the strongest discriminator (as reflected by effect size) between  $\epsilon 4$  carriers and noncarriers. Small et al. also pointed out that unfortunately, this is the area where there is the least empirical evidence.

In a similar vein, Rosen, Bergeson, Putnam, Harwell, and Sunderland (2002) explored the relationship between *APOE* status and the central executive component of working memory. Using an operation span task (Engle et al., 1999) that requires subjects to divide their attention between performing math operations and remembering words, Rosen et al. found that even though the  $\epsilon 4$  and non- $\epsilon 4$  individuals did not differ on a set of standardized neuropsychological tests, the  $\epsilon 4$  group showed divided attention deficits on the working memory task compared with the non- $\epsilon 4$  group. It is interesting that the  $\epsilon 4$  group also showed primacy deficits on the operation span task, which requires divided attention, yet there was no *APOE* group difference for primacy scores from the standard Buschke selective reminding task (Buschke, 1973), which does not require divided attention. Thus, *APOE* genotype was specifically related to attentional deficits in the absence of overall cognitive deficits as measured by standard neuropsychological tests.

More recently, Rosen et al. (2005) reported category fluency deficits in nondemented individuals with the  $\epsilon 4$  allele compared with individuals without the  $\epsilon 4$  allele. They also found a negative relationship between operation span performance and between-cluster retrieval time, suggesting that deficits in attentional capacity in the  $\epsilon 4$  group may interfere with the ability to shift attention among categories in the fluency task. Again, the  $\epsilon 4$  group exhibited normal performance on standardized neuropsychological tests. Taken together, these studies indicate that subtle aspects of attentional processing may be deficient in nondemented individuals with the  $\epsilon 4$  allele and may serve as an early marker for DAT in the absence of deficits in more global measures of cognition.

### Facilitatory Processes in Task-Appropriate Pathways

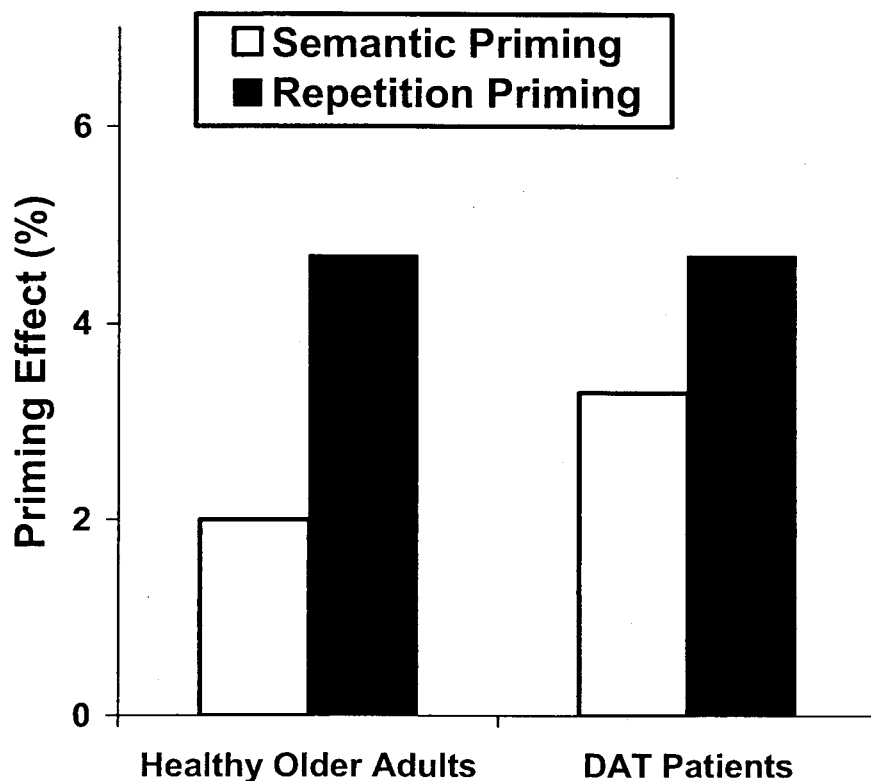
We now turn to an examination of candidate-processing deficits motivated by the attentional control framework (Balota & Faust, 2001). We first consider evidence for a preservation of the processes that allow context (e.g., cues and

primes) to activate task-appropriate information. Faust and Balota (1997) used a variant of the spatial cueing procedure developed by Posner and colleagues (e.g., Posner, 1980) and found that the appearance of a peripheral spatial cue facilitated later target detection equivalently for healthy older adults and individuals with DAT. Similarly, Parasuraman, Greenwood, Haxby, and Grady (1992) reported equivalent facilitatory spatial cue effects using a target discrimination task. The ability of individuals with DAT to use a spatial cue to facilitate early perceptual processing seems to be relatively preserved in early DAT (Balota & Faust, 2001).

Another method of probing the ability of the cognitive system to use prior context to facilitate the activation of task-appropriate information is repetition priming, in which prior presentation of pictures or words facilitates subsequent identification on a second presentation. Balota and Duchek (1991) assessed word-naming performance for words that either had or had not been named in a previous block of naming trials. As depicted in Figure 11.3, the results indicated equivalent repetition-priming effects in healthy older adults and individuals with DAT. A similar finding has been reported for repetition priming in picture naming in DAT (Gabrieli et al., 1999) and in lexical decision tasks (Balota & Ferraro, 1996). In general, repetition priming in identification tasks has been found to be preserved in DAT (Russo & Spinnler, 1994).

*Semantic priming*, the facilitation of word identification when a target word is related to a just-presented word (e.g., *nurse* following *doctor*) in comparison with *word identification*, when a target word is unrelated to a just-presented word (e.g., *nurse* following *chair*), has been argued to involve a component of the automatic spread of activation through semantic memory that facilitates identification of a related target word (Balota, 1983). It has been well documented that DAT results in impaired semantic memory (Greene & Hodges, 1996). Some studies have found evidence in support of disruptions in the organization and structure of semantic knowledge such that concepts, concept attributes, and the links between concepts are lost or degraded because of neural degeneration in critical cortical areas (e.g., Salmon, Butters, & Chan, 1999). Other researchers have suggested that DAT, at least in the early stages, reflects a relative preservation of the structure and organization of semantic knowledge accompanied by a breakdown in controlled attentional processes associated with accessing semantic information (e.g., Balota & Faust, 2001; Chenery, 1996). Studies of semantic priming using brief prime–target intervals (i.e., stimulus onset asynchrony) and/or word naming to assess mechanisms of automatic spreading activation throughout semantic networks have typically found preserved automatic priming in DAT (Balota & Faust, 2001; Chenery, 1996). Some studies of semantic priming have found hyperpriming (i.e., larger priming effects) in DAT groups (e.g., Chertkow, Bub, & Bergman, 1994), but the demonstration of consistent hyperpriming of automatic semantic priming above and beyond general slowing of response remains controversial.

For example, Balota and Duchek (1991) used a word-naming task to assess semantic-priming effects (e.g., naming *organ* following *kidney*). As depicted in Figure 11.3, the results indicated equivalent, or perhaps somewhat increased, semantic priming effects in healthy older adult and DAT groups. Participants in this study named both the prime and target items, and so prime–target



**Figure 11.3.** Repetition- and semantic-priming effects in word naming (Balota & Duchek, 1991) as a function of group. Priming effects are presented as a mean percentage; that is, the priming differential (i.e., mean response latency for the experimental condition, repetition or related, minus the comparison condition, nonrepetition or unrelated) is expressed as a percentage of the comparison mean. DAT = dementia of the Alzheimer's type. From "Semantic Priming Effects, Lexical Repetition Effects, and Contextual Disambiguation Effects in Healthy Aged Individuals and Individuals With Senile Dementia of the Alzheimer Type," by D. A. Balota and J. M. Duchek, 1991, *Brain and Language*, 40, p. 190. Copyright 1991 by Elsevier. Adapted with permission from Elsevier.

onsets were not under strict control. Studies that have used briefly presented primes and brief stimulus onset asynchronies have also reported preserved automatic semantic priming in DAT (e.g., Balota, Watson, Duchek, & Ferraro, 1999; Hartman, 1991; Ober & Shenaut, 1995). Interestingly, Balota, Black, and Cheney (1992) reported age-related changes in semantic priming at longer stimulus onset asynchronies, and similar findings have been reported for DAT (Ober & Shenaut, 1995), consistent with declines in attentional control over the access to semantic information in DAT (Balota & Faust, 2001; Chenery, 1996). In fact, a meta-analysis (Ober & Shenaut, 1995) indicated that there appears to be relatively little DAT-related change in automatic semantic priming, but semantic-priming effects do appear to increase under conditions that

promote attentional control. Moreover, there is some evidence that as DAT progresses in severity, semantic impairments move from problems with attentional control to degradation of representations (e.g., Daum, Riesch, Sartori, & Birbaumer, 1996).

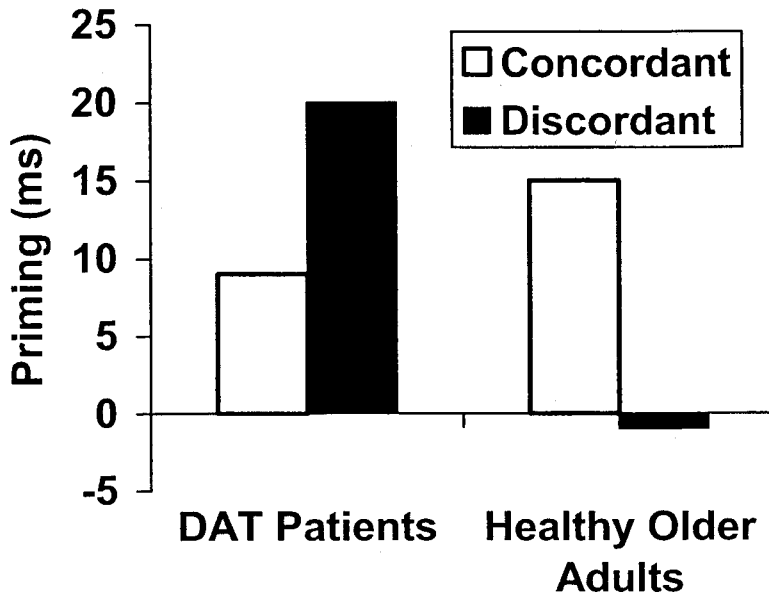
The findings from studies of spatial cueing, repetition-priming, and semantic-priming tasks converge on a consistent conclusion that the ability of contextual information to drive low-level automatic activation of task-relevant information is relatively well preserved in DAT. This conclusion contrasts with the findings we present in the next section: that tasks that involve informational conflict result in DAT-related declines in performance.

### Inhibitory Control Over Task-Inappropriate Pathways

Many words have multiple meanings, and therefore one central task of language comprehension is to use the prior context to enhance the context-appropriate word meanings and suppress the context-inappropriate word meanings (Gernsbacher & Faust, 1991a, 1991b). For example, the word *organ* is a homograph in that the same written form can refer to a musical instrument or a body part. If DAT results in a breakdown in the ability to exert cognitive control over situations where task-appropriate and task-inappropriate information is active, then one might observe DAT-related deficits in how the language comprehension system deals with the multiple interpretations that are often available when a word is presented.

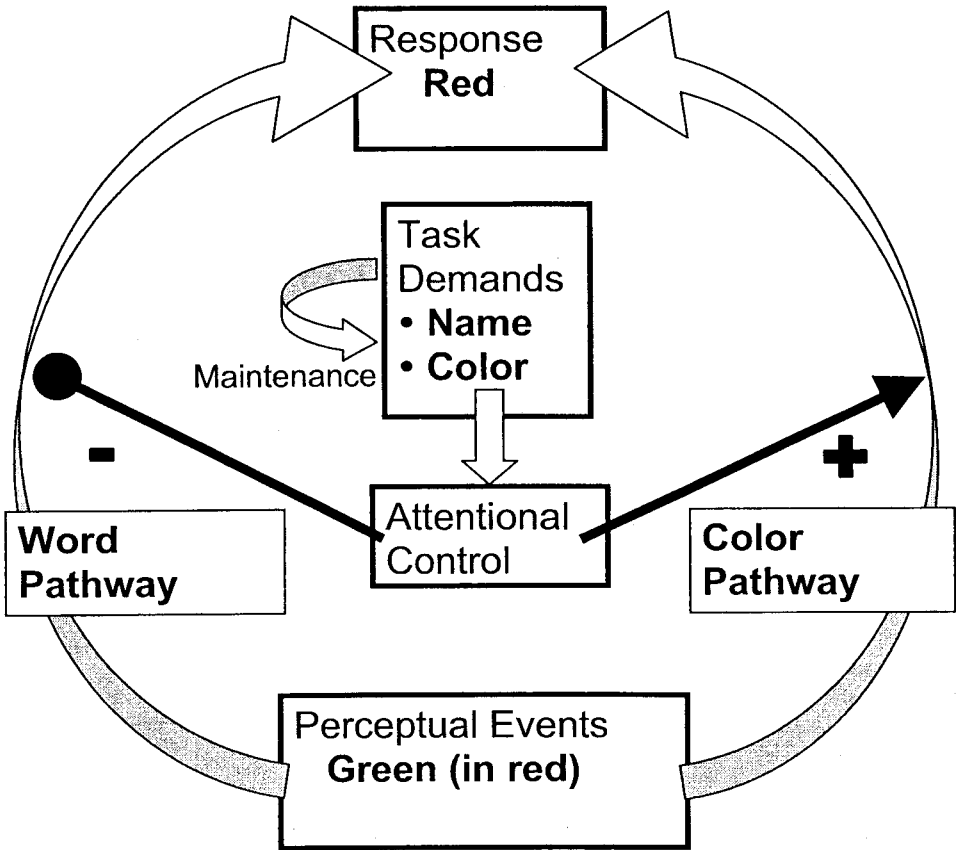
Balota and Duchek (1991) had participants name three different types of sequentially presented (one word at a time) word triplets: concordant (*music-organ-piano*), discordant (*kidney-organ-piano*), and unrelated (*kidney-ceiling-piano*). The basic idea of the experiment was to see how varying the prime words (i.e., the first and second words in each triplet) would affect the size of the semantic-priming effect for naming the target (third) word. For the concordant triplets, the first prime and the target were related to the same meaning of the intervening homograph (*organ*). That is, the first prime should bias the meaning of the subsequent second prime that is consistent with (i.e., related to) the target. The discordant triplets, by contrast, included first primes and targets that were related to different meanings of the intervening homograph. That is, the first prime should bias the meaning of the subsequent second prime that is inconsistent with the target. As presented in Figure 11.4, naming latencies to the third word indicated that both groups produced semantic priming in the concordant condition compared with the unrelated condition. However, only the DAT group produced semantic priming for the discordant condition. This result suggests that individuals with DAT experienced a breakdown in the attentional selection of the appropriate interpretation of the homograph (*organ*) based on context in that there was a decline presumably due to a breakdown in the ability suppress the context-inappropriate meaning of the intervening homograph.

Faust, Balota, Duchek, Gernsbacher, and Smith (1997) observed a similar DAT-related decline in the ability to use context to suppress the contextually appropriate meaning of a homograph during sentence comprehension. Partici-



**Figure 11.4.** Semantic-priming effects (in milliseconds) in naming the third word in a triplet (Balota & Duchek, 1991) as a function of cue (second word) type and group. DAT = dementia of the Alzheimer's type. There were three types of triplet: concordant (*music-organ-piano*), discordant (*kidney-organ-piano*), and unrelated (*kidney-ceiling-piano*). Priming is presented as mean response time for the third word in unrelated triplets minus the concordant or discordant triplet mean. From "Semantic Priming Effects, Lexical Repetition Effects, and Contextual Disambiguation Effects in Healthy Aged Individuals and Individuals With Senile Dementia of the Alzheimer Type," by D. A. Balota and J. M. Duchek, 1991, *Brain and Language*, 40, p. 192. Copyright 1991 by Elsevier. Adapted with permission from Elsevier.

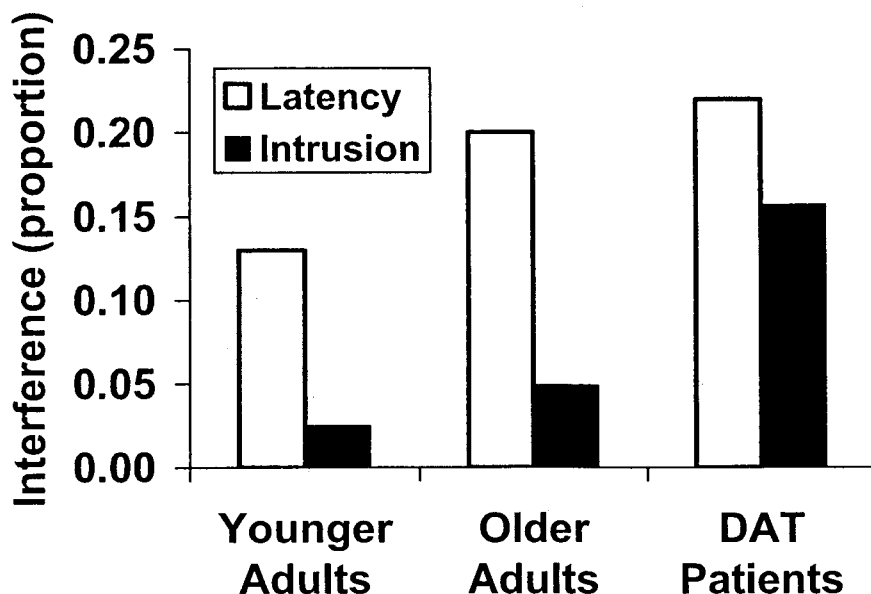
pants made a relatedness judgment to a word (e.g., *ace*) following either a sentence with a sentence-final homograph (e.g., "He dug with a spade") or a sentence that ended with an unambiguous word (e.g., "He dug with a shovel"). The major finding was that individuals with DAT had more difficulty rejecting the word *ace* when it followed the sentence context that ended with the homograph (*spade*). Thus, it appears that individuals with DAT were failing to use the disambiguating sentence context to guide suppression of the context-inappropriate interpretation of the homograph. This result converges with the results obtained by Balota and Duchek (1991), and the results of both studies are consistent with the notion that DAT individuals have difficulty controlling or inhibiting partially activated processing pathways associated with context-inappropriate information. This observation also fits nicely with the attentional control framework (see Figure 11.2), in which the task demands of language comprehension require use of the prior context to select for context-appropriate information and against context-inappropriate information activated in low-level word-recognition processing pathways.



**Figure 11.5.** The attentional control framework applied to the Stroop color-naming task. From *The Handbook of Neuropsychology: Aging and Dementia* (2nd ed., p. 71), by F. Boller and S. Cappa (Eds.), 2001. New York: Elsevier Science. Copyright 2001 by Elsevier. Adapted with permission from Elsevier.

The Stroop color-naming task (MacLeod, 1991) has become the gold standard task for studying informational conflict. Figure 11.5 presents a schematic representation of the Stroop task from the viewpoint of the attentional control framework (Balota & Faust, 2001). Of central interest to the current discussion is the proposal that attentional control works to detect conflict between task goals and low-level activation-processing pathways and regulates the relative strength of processing in the word- and color-processing pathways. We do not take a stance on whether this is done dynamically in response to the appearance of conflict within the system or using expectancies to put in place a more stable regulatory regime. In fact, there is evidence that both strategies may be used to control Stroop conflict (e.g., West & Alain, 2000).

Spieler et al. (1996) administered a computerized Stroop color-naming task to younger and healthy older adults and to individuals with DAT. Figure 11.6 presents the Stroop conflict effect (conflict trials minus noncolor word trials)



**Figure 11.6.** Stroop color-naming interference effects (Spieler et al., 1996) for mean response latency and intrusion errors as a function of group. DAT = dementia of the Alzheimer's type. Interference effects are expressed as a proportion of the neutral condition.

in terms of the difference in proportional latency (i.e., each person's mean latency for a condition divided by his or her overall mean) and the difference in proportion intrusion errors (i.e., saying the word instead of the color). As depicted in Figure 11.6, there was a dissociation in Stroop performance such that healthy older adults produced a larger Stroop conflict effect in color-naming latency compared with younger adults. This finding suggests that the healthy older adults were able to suppress the dominant word pathway but that it took additional time. In contrast, the DAT group did not produce a larger cost in Stroop performance in response latencies but did produce an increase in intrusion rates compared with the healthy older adults. This latter pattern suggests a more complete breakdown in attentional control over the partially active word-processing pathway, leading to the word process inappropriately driving the incorrect response to a much larger extent for the DAT group. Hence, instead of taking more time to suppress the dominant word pathway, the DAT individuals were simply outputting this pathway.

[Au: okay to delete?]The DAT individuals also produced greater facilitation (not depicted in Figure 11.6). If indeed they were more likely to intrude the word dimension, then one would expect to observe greater facilitation. Because word processing is overall faster than color processing, an increased propensity toward word intrusion errors, presumably because of an increased reliance on the inappropriate word pathway, should result in a speeding up of the congruent condition.

The finding of an increase in Stroop conflict effects is consistent with the findings of many other studies in the literature (e.g., Amieva et al., 2004) and again supports our contention of a general impairment in the ability to exert inhibitory control over partially active, yet task-inappropriate, pathways. It is also consistent with recent studies using newly available brain-imaging techniques to image the degenerative changes associated with DAT in vivo and document the degeneration of cingulate and frontal areas along with connecting cortico-cortico white matter tracts in the cingulate and frontal cortices (e.g., Choi et al., 2005; Thompson et al., 2003). Functional imaging studies have consistently found that activation of the anterior cingulate and prefrontal cortex is associated with monitoring and cognitive control of color-word conflict during the Stroop task (e.g., Kerns et al., 2004). Using dense electrode event-related potential methodology, Markela-Lerenc et al. (2004) found evidence for a prefrontal generator that directly preceded an anterior cingulate generator, suggesting a network for monitoring and then controlling conflict (Cohen et al., 2004).

The attention control framework can also be applied to DAT-related changes in memory. Recent approaches to memory in experimental psychology have stressed the fact that memory and attention are more closely linked than has traditionally been thought (e.g., Cowan, 1995; Oberauer, Lange, & Engle, 2004). To provide an example of the application of the attentional control framework to memory and DAT, we briefly review a recent study of false memory by Balota, Cortese, et al. (1999; see also Watson, Balota, & Sergeant-Marshall, 2001). This study used what has come to be called the Deese-Roediger-McDermott (DRM) procedure (Deese, 1959; Roediger & McDermott, 1995), in which a list of words is presented (e.g., *thread, pin, eye, sewing, sharp, point, prick, thimble, haystack, pain, hurt, injection*) that converges on a nonpresented item (e.g., *needle*). This procedure has been found to generate fairly robust false recall of the nonpresented target item (Roediger & McDermott, 1995), often as high as recall for presented items.

Balota, Cortese, et al. (1999) argued that the false memory generated in the DRM procedure can be viewed as a situation in which low-level memory retrieval processes generate multiple sources of conflicting evidence. The basic idea is that an intact processing system should be able to discriminate between information activated because of truly presented items and information that is active because it is related to the items presented (for a discussion of reality and source monitoring, see Johnson, Hashtroudi, & Lindsay, 1993; for evidence of source deficits in DAT individuals, see Multhaup & Balota, 1997). On the basis of consideration of the attentional control framework (see Figure 11.2), one might expect that individuals with DAT would experience a breakdown in the ability to exert inhibitory control over the activated but nonpresented item (e.g., *needle* in the example), leading to an increased production of false recall. This was, in fact, the finding reported in this study, and the DAT-related increase in false recall held up even after correction for group differences in overall memory performance. Hence, according to this framework, it appears that DAT individuals have difficulty selecting the most relevant pathway (i.e., what was earlier presented in the experiment) in the face of conflict from a partially activated competitor (i.e., the critical nonpresented word).



At this point, one might suggest that if the declines in Stroop and false memory performance in individuals with DAT have a common processing source, then researchers should find evidence for a relationship between these two impairments. Sommers and Huff (2003) confirmed our prediction that the same attentional control system that underlies selection in the Stroop task is related to the false memory effect. They found that the size of the Stroop interference effect predicted false memory above and beyond baseline response latencies (i.e., any general slowing across groups; Faust, Balota, Spieler, & Ferraro, 1999). Moreover, Benjamin (2001) provided evidence that if one stresses attentional control at retrieval by using response deadlines, one can also mimic the increased susceptibility to false memory in younger adults (see also Balota, Burgess, Cortese, & Adams, 2002). The important point is that memory breakdowns, the primary diagnostic criteria for DAT, may also reflect attentional mechanisms that may contribute to these memory breakdowns.

### Integrity of the Task Set

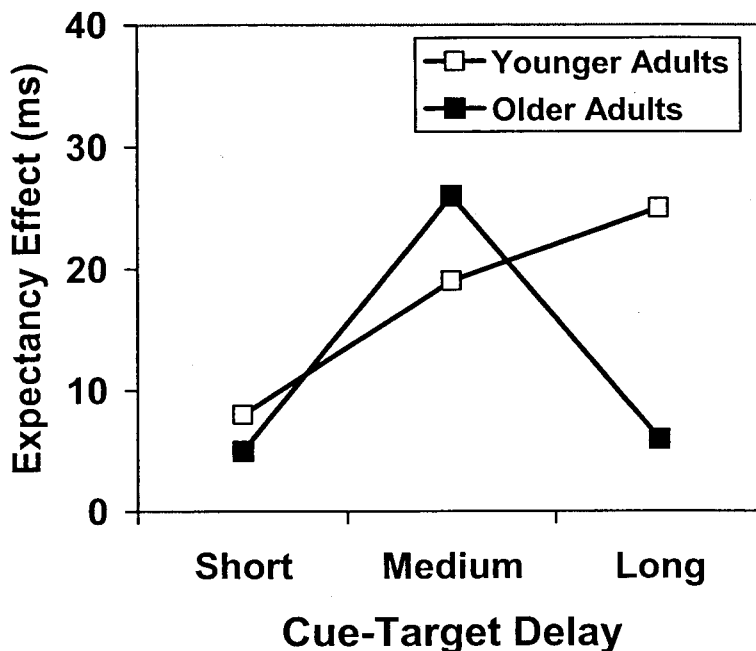
The attentional control framework also suggests that the quality of the representation of the task set is a critical aspect of control that may be impaired in DAT. In particular, it is likely that although subjects have an understanding of the task goals via instruction, there is variability across individuals in their understanding of what to do to accomplish the goals. Moreover, it is likely that there is variability across time within an individual in the quality of the task set that would be reflected in task set parameters. Multhaup (1995) provided one example of the importance of the task set. This study explored the *false fame effect* (Jacoby, Kelley, Brown, & Jasechko, 1989), the biasing effect of familiarity due to prior presentation during an experiment on fame judgments of famous and nonfamous people. Under typical conditions, when the different sources of familiarity and recollection were not stressed, older adults produced a larger false fame effect than younger adults. However, when the testing procedures were modified so that older adults were explicitly required to directly specify the source of the familiarity, the age-related differences disappeared. Hence, the age-related differences disappeared when subjects were given a more specific retrieval set.

Watson, McDermott, and Balota (2004) also explored the role of the task set in a false memory study comparing healthy younger and older adults. In this study, participants received repeated study tests on the same DRM lists. Half of the participants were directly warned about outputting the critical nonpresented item in a DRM paradigm, whereas the remaining half of the participants did not receive a warning. The interesting finding is that both younger and older adults clearly benefited from the explicit warning. However, even in the nonwarning condition, the younger adults decreased their false recall across trials, whereas the older adults did not. Hence, only the explicit warning helped the older adults avoid outputting the critical nonpresented item. One could consider this an example of explicitly implementing the appropriate task set. Clearly, further work is needed to explore possible ways of implementing the appropriate task across different experimental contexts.

A second issue regarding representation of the task set is the ability to maintain the appropriate task set across time. We believe that this is critical in achieving task goals and that there is considerable variability in maintaining a well-tuned representation across time. It is at least possible that such control states need to be refreshed across time to avoid decay, almost akin to the rehearsal of information in short-term memory. In fact, simple participation in the Stroop task can demonstrate such loss of control when one outputs the word dimension instead of the color dimension. We believe that such slips are due not to random variation but rather likely to a momentary loss of control over attention.

Indeed, there is evidence of breakdowns in the maintenance of attentional control across time in both healthy aging and in early-stage DAT. For example, West (1999) explored the nature of age-related increases in the Stroop interference effect. Across three experiments testing healthy younger and older adults on the Stroop task, older adults produced more numerous and longer lapses of attention leading to intrusion of the conflicting word. De Jong, Berendsen, and Cools (1999) presented a similar view in arguing that interference effects such as those obtained with the Stroop task may be due to transient failures to fully apply inhibitory processes, which they termed *goal neglect*.

Balota et al. (1992, Experiment 1) tested the ability of younger and older adults to maintain an expectancy across time by using a paradigm developed by Neely (1977) that factorially crosses prime–target expectancy and prime–target relatedness. In this study, subjects were given two categories for each block of trials. For example, before a block of trials, subjects might be told that whenever they receive the category *flower*, they should expect to receive types of flowers (e.g., *daisy*, an expected related condition); however, whenever they received the category *body*, they should expect to receive a type of building part (e.g., *door*, an expected unrelated condition). Of course, subjects could also receive unexpected targets (e.g., *iron* for the prime *flower* in the unexpected unrelated condition or *arm* for the prime *body* in the unexpected related condition). Following Neely, Balota et al. varied the cue–target delay. (For simplicity, we collapse across relatedness, which did not modulate the critical comparisons.) The results indicated that both younger and older adults produced an expectancy effect (i.e., targets from expected categories were named faster than targets from an unexpected category) that increased across the short (250-millisecond) and the medium (1,000-millisecond) delays. However, as depicted in Figure 11.7, at the longest (1,750-millisecond) delay, the younger adults continued their trend for an increasing expectancy effect, but the expectancy effect was almost nonexistent for the older adults. This pattern was replicated in a subsequent experiment with a greater range of prime–target intervals. These results suggest that the older adults experienced a decreased ability to maintain an attentional set for an extended time (see also Amrhein, Stemmlach, & Goggin, 1991). It is interesting that Johnson, Mitchell, Raye, and Greene (2004) reported that older adults were slower than younger adults to reinstate a just-viewed item and also showed reduced neural activity, as measured by functional magnetic resonance imaging, associated with refreshing the representation of a just-viewed item. These results suggest an age-related decline



**Figure 11.7.** Expectancy effects (ms) during cued word naming as a function of delay and group. Expectancy effects are computed as mean latency to name a test word from the expected category minus mean latency to name a test word from an unexpected category. Adapted from "Automatic and Attentional Priming in Young and Older Adults: Reevaluation of the Two-Process Model," by D. A. Balota, S. R. Black, & M. Cheney, 1992, *Journal of Experimental Psychology: Human Perception and Performance*, 18, p. 489. Copyright 1992 by the American Psychological Association.

in control processes responsible for holding the task set in a stable active form across time.

Our interest in the simple maintenance operation and the role of this mechanism in early-stage DAT, and hence its potential as an early marker for DAT, was recently piqued by a study reported by Grady, Furey, Pietrini, Horwitz, and Rapoport (2001). In this study, subjects were presented simple faces to maintain for 1 to 16 seconds and then were presented two faces for a forced-choice matching decision. The interesting pattern in this study was that individuals with early-stage Alzheimer's disease produced a clear decrement in accuracy across delays, but there was no effect of delay in the healthy older individuals. We believe that these data may be symptomatic of a simple breakdown in maintenance of a task set across time. The novel twist in Grady et al.'s experimental procedure was the maintenance of a set across relatively longer delays, on the order of seconds, to maximize the load on the maintenance operation.

Braver, Satpute, Rush, Racine, and Barch (2005) provided more direct evidence of a DAT-related decline in the ability to maintain representations.

They reported a study using a version of the continuous performance task (Servan-Schreiber, Cohen, & Steingard, 1996), in which participants respond to serially presented letters by pressing a target button, with a target response for the letter *X* but only when it directly succeeds an *A*. Participants responded by pressing a nontarget button otherwise. A high proportion (70%) of *AX* letter pairs were presented, encouraging false alarms to *AY* (with *Y* indicating any non-*X* letter) and *BX* (with *B* indicating any non-*A* letter) pairs. Efficient performance on this task requires effective encoding and maintenance of a continuously changing stream of context letters (i.e., the previously presented letter) to discriminate target from nontarget events. The critical manipulation with respect to questions of context maintenance was that the delay between letters was either shorter (1,000 milliseconds) or longer (5,000 milliseconds), leading to differential context maintenance demands.

The results yielded a larger increase in target misses (i.e., a nontarget response following *AX* pairs) and increasing delay for the individuals with DAT than for the healthy older adults. Of greater interest were the DAT-related changes in false alarms: Whereas the younger adults and the healthy older adults produced an increase in false alarms, with increasing delay for the *AY* trials, and a decrease in false alarms, with increasing delay for the *BX* trials (indicating a greater controlling influence of the previous context letter with increasing delay), the DAT individuals produced the converse pattern of changes in errors. That is, as delay increased, individuals with DAT produced a decrease in *AY* false alarms, consistent with a decline in the use of the context letter to drive the expectation that an *X* is most likely to follow an *A*, and an increase in *BX* false alarms, consistent with a decline in the use of the non-*A* context letter to recognize the subsequent appearance of the *X* as a nontarget event. This pattern of results cannot be explained by a general DAT-related decline in memory for the prior items because of the crossover interaction pattern across groups. We take the results of this study as strong support for the proposal that DAT results in a deficit in maintaining the task set over time.

## Conclusion

We have presented arguments in favor of the concepts of inhibitory and facilitatory processes as useful building blocks for general theories of cognition. It has been pointed out by those critical of the use of inhibition (e.g., Burke, 1997; MacLeod et al., 2003) that reasonable noninhibitory accounts exist for specific empirical effects (e.g., Stroop, negative priming, and inhibition of return) that have widely accepted inhibitory accounts. Although we are sympathetic to this view, and although we recognize the importance of developing and testing competing models of cognitive processes within task domains, we do feel that it is important to develop more general cognitive frameworks designed to provide a theoretical perspective across a wide range of cognitive tasks. However, we have concerns about the parsimony of noninhibitory explanations proposed by critics of inhibitory accounts of specific empirical effects. More important, our central point is that development of more general models will require

inclusion of cognitive control processes that come from two general categories of inhibitory and facilitatory processes.

As a demonstration of this approach, we have presented an attentional control framework (see Figure 11.2) that can be adapted to a variety of situations where the cognitive system must deal with multiple sources of information that compete for response systems. We have presented a brief selective review demonstrating how this framework can be applied to explain the cognitive deficits of groups, such as those with DAT, that have broad yet circumscribed patterns of neurodegeneration. The attentional control framework is based on the assumption that much of the low-level processing of information from the environment involves strongly stimulus driven and relatively automatic activation of internal representations. In a well-learned task environment, low-level stimulus-driven processes associated with multiple sources of information from the environment will come to compete directly for response systems. From this perspective, it appears that competent and appropriate behavior across a wide variety of situations involves control over low-level stimulus-driven processes to efficiently reach goals.

Accordingly, the attentional control framework stresses the importance of representing and maintaining the task set and of using the task set to regulate stimulus-driven processes. Specialized attentional control processes that can act to inhibit or facilitate are proposed as a general set of mechanisms that can provide appropriate control signals across a variety of tasks and situations. Our brief review of cognitive deficits in DAT presented evidence supporting the contention that individuals with DAT experience deficits both in the representation/maintenance of task sets and in inhibitory control over task-inappropriate processing pathways.

From a traditional viewpoint, inhibitory control might be seen to act on the activation of representations, leading to the expectation that the empirical footprint of inhibition would be reduced access to some representations below some baseline control level. We find such a view too constraining, preferring to view the cognitive system in more neural terms as a distributed processing system that relies on pathways of information flow that transmit and transform information as it moves from sensory input to motor output. In this view, inhibitory control can be seen to regulate the signal-to-noise ratio (i.e., task-appropriate and task-inappropriate information processing) through down-regulation of the task-inappropriate processing pathways. This perspective leads us to disagree with some who have, for example, suggested that a model of Stroop performance (Roelofs, 2003) that includes a control parameter that represents the overall strength of processing of the inappropriate (in relation to the task of color naming) word identity does not include inhibitory control processes (MacLeod et al., 2003). To the contrary, we propose that it is exactly this type of down-regulation of information-processing pathways that is prototypically inhibitory in nature.

Much work remains to be done to move the attentional control framework presented in this chapter to the level of a fully specified theory. Of foremost interest to us is the issue of volitional control. We suspect that inhibitory control processes can be seen as hierarchically organized, ranging from high-level control processes that require volitional initiation to low-level control

processes that are more automatic in nature. This view leads to the prediction that within the context of repetitive cognitive tasks, control over inappropriate processing pathways will become relatively automated as participants learn the task.

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