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Selective attention in early Dementia of Alzheimer Type

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Abstract

This study explored possible deficits in selective attention brought about by Dementia of Alzheimer Type (DAT). In three experiments, we tested patients with early DAT, healthy elderly, and young adults under low memory demands to assess perceptual filtering, conflict resolution, and set switching abilities. We found no evidence of impaired perceptual filtering nor evidence of impaired conflict resolution in early DAT. In contrast, early DAT patients did exhibit a global cost in set switching consistent with an inability to maintain the goals of the task (mental set). We discuss these findings in relation to the DAT literature on executive attention, dual-tasking, and working memory.

Keywords: Alzheimer's disease; Executive processing; Dual tasking; Conflict resolution; Mild cognitive impairment

1. Introduction

In recent years, several studies have explored whether selective attention is impaired at early stages of Dementia of Alzheimer Type (DAT) (Baddeley, Baddeley, Bucks, & Wilcock, 2001b; Belleville, Rouleau, & Van der Linden, 2006; Fernandez-Duque & Black, 2006; Levinoff, Li, Murtha, & Chertkow, 2004; Levinoff, Saumier, & Chertkow, 2005; Logie, Cocchini, Della Sala, & Baddeley, 2004; Perry & Hodges, 1999; Rizzo, Anderson, Dawson, Myers, & Ball, 2000). This is important from a theoretical standpoint, since clinical changes in attention may provide a window into the neural mechanisms of attention. It is also important from a clinical perspective because understanding attention in DAT may aid its early diagnosis and treatment.

Selective attention refers to a variety of cognitive processes by which individuals flexibly choose which stimuli to process and which to ignore. It includes the ability to ignore perceptual distractors (i.e., *perceptual filtering*) as well as the ability to withhold responses that conflict with one's goals (i.e., *conflict resolution*). As such, selective attention is central to goal-directed behavior. Selective attention in the visuospatial domain has been studied extensively with the visual search task (Wolfe, 2003). For this task, reaction time increases as a function of the number of distractors when the search is attentionally demanding. In those searches, DAT patients are abnormally slow (i.e., have a steep slope function). However, it is unclear whether this deficit is due to slowness in shifting attention from item to item or to ineffective processing of each item (Foster, Behrmann, & Stuss, 1999; Tales, Muir, Jones, Bayer, & Snowden, 2004). DAT patients are also impaired in rescaling the focus of attention, benefiting less than healthy subjects from cues that provide only approximate information about the target location in the search display (Parasuraman, Greenwood, & Alexander, 2000).

Unlike the visual search task, the spatial cueing task requires subjects to maintain central fixation while attending to the direction of a cue. This constraint allows the assessment of spatial selective attention independent from eye movements. Although the spatial cueing task is a rather simple task with easily understood instructions, its requirement to maintain central fixation may disproportionately

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tax DAT patients. For example, DAT patients may have difficulty keeping such instruction in mind and/or inhibiting saccades to peripheral stimuli. These confounds complicate the interpretation of DAT deficit in the spatial cueing task (Buck, Black, Behrmann, Caldwell, & Bronskill, 1997).

Selective attention can also be studied in non-spatial tasks. One popular method is to instruct participants to ignore some stimulus dimensions (e.g., identity, location) and respond based on a target dimension (e.g., color).[1] For example in the Stroop task, subjects ignore the word meaning and respond instead to the ink color. The stimulus ambiguity in tasks such as this forces participants to mentally keep track of the instructions by which the target response is to be selected. Such an ability to flexibly bind perception and response dispositions is sometimes called *mental set* and allows subjects, upon seeing the word RED written in blue ink, to disregard the redness of the word meaning and focus instead on the blueness of the ink, a phenomenon labeled *conflict resolution*. The ability to maintain a mental set is related to working memory capacity. Since working memory capacity may be compromised in healthy aging and DAT, impaired performance in conflict resolution in Stroop-like tasks is difficult to interpret (De Jong, 2001; Kane & Engle, 2003; Mayr, 2001; Nieuwenhuis, Broerse, Nielen, & de Jong, 2004; Fernandez-Duque & Black, 2006; Spieler, Balota, & Faust, 1996); it may reveal a deficit in selective attention proper, or an inability to maintain the mental set instead.

Mental set (aka *task set* or *goal set*) is the high-level control setting that serves as the basis for target selection. The ability to maintain a *mental set* has been studied extensively in set switching paradigms. These studies have revealed that performance deteriorates when the mental set alternates across trials instead of remaining constant throughout the experiment. In part, this decrease in performance is due to a local switch cost: after having focused on color ink in trial $n - 1$, the mental set needs to switch to word meaning. This process requires effort and usually leaves a residual cost that cannot be eliminated until the occurrence of the new item. This local switch effect, although important, cannot fully account for the performance cost brought about by the presence of set switching. More precisely, response to ambiguous stimuli suffers even in non-switch trials, provided that these occur in a block that also contains switch-trials. This cost is sometimes referred to as the 'global set-selection cost' and seems to be related to the capacity to maintain the currently relevant mental set in the presence of distracting information.

Global set-selection cost has been reported to become larger during healthy aging (Kray & Lindenberger, 2000; Mayr, 2001). There is also neuropsychological evidence to suggest that patients with DAT might be impaired in their global set-selection. For example, the ability to switch mental sets is impaired even at early stages of the disease: patients with mild DAT perform poorly in the set shifting task of the CANTAB (Cambridge neuropsychological tests automated battery) which requires subjects to alternate between two stimulus dimensions (e.g., color and shape) (Dorion et al., 2002; Robbins et al., 1994; Sahakian et al., 1990). Furthermore, poor set switching performance in neuropsychological tasks is a good predictor of disease progression in patients at the pre-clinical stage (Albert, 1996; Albert, Moss, Tanzi, & Jones, 2001). One of these predictors is the Trail Making task—part B, in which letters and numbers are randomly distributed on a sheet of paper and the subject has to trace the items in ascending order alternating between letter and number (e.g., 1-B-2-C-3). In healthy adults, performance in this task relates to performance in experimental set switching tasks (Arbuthnott & Frank, 2000).

These findings are consistent with the hypothesis that the ability to maintain mental set may be affected even at very early stages of DAT, including the prodromal stage labeled Mild Cognitive Impairment (MCI). Patients with a diagnosis of MCI have subjective memory complaints and perform below normal in neuropsychological tests of long-term memory. However, they are able to carry out normal activities of daily living and have normal general cognitive function in intelligence tests. Although as a group MCI patients may be impaired in response inhibition and set switching, a substantial number of patients seem to show only deficits in episodic memory (Perry, Watson, & Hodges, 2000). This latter group of patients fits the criteria for amnesic Mild Cognitive Impairment (MCI-a) (Petersen et al., 1999). Nonetheless, even the MCI-a is a heterogeneous group, and subtle deficits of attention are revealed in experimental designs. In one such study, researchers divided MCI-a patients by those who had mostly hippocampal atrophy and those who had mostly small vessel cerebrovascular disease (as revealed by white matter hyperintensities in the MRIs) (Nordahl et al., 2005). Although both groups were equally impaired in episodic memory, those with small vessel disease were significantly impaired in tasks that required maintenance of a mental set, such as working memory and continuous performance tasks.[2] Even healthy adults with a genetic risk of developing DAT may experience difficulties in some of these functions (Parasuraman, Greenwood, & Sunderland, 2002).

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[1] Another popular method to study non-spatial attention is the negative priming paradigm. This task measures the cost in performance when the target of a current trial was also the distractor in the preceding trial. Effective inhibition in trial $n - 1$ leads to a cost (negative priming) when the item reoccurs as a target in trial n. DAT reduction in negative priming has been found in some studies but not others, and it is unclear whether the reduction is due to a deficit in selective attention or in memory (Amieva, Phillips, Della Sala, & Henry, 2004; Ko, Kilduff, Higgens, Milberg, & McGlinchey, 2005; Vaughan, Hughes, Jones, Woods, & Tipper, 2006).

[2] Obviously, this is not to say that all the deficits exhibited by these patients can be traced back to an inability to sustain a mental set.

In sum, the literature in early DAT suggests deficits in a variety of selective attention tasks but less is known about the precise mechanisms underlying those deficits. The difficulty of interpretation stems in part from confounding selective attention with other factors (e.g., eye fixation, working memory, mental set maintenance). Experiment 1 addressed this problem by studying selective attention—perceptual filtering and conflict resolution—in a task that posed minimal demands on eye fixation, working memory, and mental set maintenance. Experiment 2 generalized those findings to a version that posed slightly larger memory demands. Experiment 3 asked whether *mental set maintenance* was disproportionately impaired in early DAT.

2. Experiment 1

Experiment 1 assessed two aspects of selective attention (perceptual filtering; conflict resolution) under conditions of minimal memory demands. In a speeded reaction time task, subjects responded to the direction of the target arrow while ignoring distracting stimuli. By using an over-learnt stimulus–response rule (i.e., point in the direction of the arrow), the paradigm freed subjects from remembering which key to press, as information about which key to press was present in the stimulus (i.e., direction of target arrow). Comparing trials with neutral distractors to trials with a lone target provided a measure of *perceptual filtering*. Comparing trials in which distractor and target pointed in opposite directions to trials in which they offered congruent information provided a measure of *conflict resolution*. We explored possible deficits due to healthy aging and DAT.

2.1. Methods

2.1.1. Participants

Patients for this and the other experiments were recruited through the Cognitive Neurology Unit at Sunnybrook Health Science Centre in Toronto, where the project received approval from the Research Ethics Board. Age-matched normal controls were recruited from a pool of healthy elderly volunteers at the same Cognitive Neurology Unit and at Baycrest Centre for Geriatric Care. The group of young adults consisted of undergraduate students who participated in the task for course credit. Consent for participation in the study was obtained from all subjects, as well as from the patients' caregivers. All subjects had normal or corrected-to-normal vision.

Thirteen undergraduates, 12 healthy elderly subjects, and 12 patients with Dementia of Alzheimer's Type (DAT) participated in this experiment. All patients met criteria for probable Alzheimer's Disease (probable AD), as established by the workgroup of the National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) (McKhann et al., 1984). In this and the other experiments, only patients with mild dementia were selected (MMSE > 20). Participants in the clinical and healthy elderly groups were matched for age and years of education (see Table 1).

Table 1
Demographic information

	Young	Elderly	DAT
Experiment 1			
Number of participants	13	12	12
MCI/probable AD	n/a	n/a	0/12
Male/female	5/8	5/7	6/6
Age	19.7 (1.9)	72.9 (5.0)	75.3 (6.0)
Years of education	13.8 (0.6)	14.2 (3.3)	13.8 (3.7)
Experiment 2 & 3			
Number of participants	19	19	19
MCI/probable AD	n/a	n/a	11/8
Male/female	8/11	11/8	11/8
Age	18.8 (1.0)	71.5 (6.8)	71.1 (8.0)
Years of education	13.9 (0.6)	14.9 (3.5)	14.5 (4.1)

To characterize the cognitive deficits, a full neuropsychological battery was administered to all 12 patients and to 8 healthy elderly subjects (see Table 2A). The other 4 healthy elderly participants completed a subset of tests performing within normal levels (MMSE, the digit span task, the verbal fluency tasks). As expected, the DAT group was impaired relative to the normal controls in many domains.

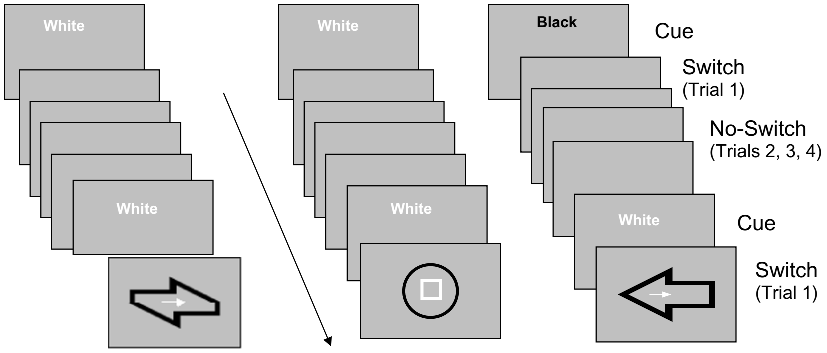
2.1.2. Equipment

In this and all other experiments, stimuli were displayed on a 19-inch monitor set to a screen resolution of 1024×768 pixels. Data were collected via the keyboard of a Dell computer equipped with a Pentium III processor and Windows 98. The timing of stimulus display and data collection were managed using E-prime, a commercial experiment application.

2.1.3. Stimulus and procedure

The target arrow was defined by its color (e.g., the 'white arrow') which remained constant over the course of the experiment. Subjects were instructed to respond in the direction of the target arrow and to ignore any stimuli displayed in the other color (e.g. "if the white arrow points to the right, press the right key"). The target arrow could be large or small ($19° \times 10.7°$ VA; $1.6° \times 0.8°$ VA). In different blocks of trials, the target could appear alone (block 1), with a neutral distractor (block 2), or with a distracting arrow (block 3). Target and distractor were always of different size and displayed concentrically against a gray background. The neutral distractor was created by horizontally flipping the bottom half of an arrow. The basic display is illustrated in the left side of Fig. 1.

The target remained on display until response, or for a maximum of 5 s. Trials in which subjects were slower than 2000 ms were followed by visual feedback that read "too



	Experiment 1	Experiment 2	Experiment 3
S-R Rule	Over-learnt	Arbitrary	Over-learnt
Switch Component	No	No	Yes
Memory Demands	Minimal	Low	Low

Fig. 1. The main characteristics of each experimental paradigm.

slow", for the first 1000 ms of the inter-trial interval (ITI). To increase the demands on selective attention, we used a variable target onset with an ITI ranging from 1700 to 3500 ms. This aimed to prevent participants from using ITI as a cue to when to pay attention.

Subjects received instructions and practiced 10 trials with no distractors. Following, they completed a block of 64 trials in which the target appeared by itself (no distractor) and a block of 64 trials in which the target appeared with a neutral distractor. In the final block of 192 trials, the target appeared with a distracting arrow that could point in the same (congruent) or opposite (incongruent) direction. Subjects sat approximately 50 cm away from the screen, and used their left and right index fingers to press keys S and L on the keyboard.

2.2. Results and discussion

Error trials and trials immediately following an error were excluded from the RT data. From the remaining trials, median RTs were calculated for each Group (young, healthy elderly, DAT) and Distractor Type (absent, neutral, congruent, incongruent) (see Table 2A). The main findings are illustrated in Fig. 2 and the full data are reported in Table 3.

2.2.1. Perceptual filtering

The cost of perceptual filtering was assessed by comparing trials with no distractor and trials with a neutral distractor. To control for group differences in overall speed of response we computed proportional scores, using as baseline the trials with no distractor [(neutral – absent)/absent]. Unless otherwise noted, the untransformed data yielded the same results as the proportional data in all the analyses reported in this article. Thus, we report the analyses run on the transformed data. For completeness, we also provide as footnotes the analyses run on the untransformed data.[3]

The presence of a distractor slowed down RTs in all groups, as revealed by one-sample t-tests against the null hypothesis (i.e., a proportional score of zero) ran separately for each group, $ts(11) > 3.9$, $ps < .01$. More importantly, the cost of distraction was not increased by healthy aging, as revealed in an independent-samples t-test on the proportional scores comparing the young and healthy elderly groups, $t(23) = .5$, $p > .50$. Neither was distraction significantly larger for the DAT group than for the healthy elderly group, $t(22) = .6$, $p > .50$. Finally, the error data revealed no significant differences between groups.

2.2.2. Conflict resolution

The cost of resolving conflict was assessed by comparing congruent trials (i.e., trials in which target and distractor pointed in the same direction) and incongruent trials (i.e., trials in which target and distractor pointed in opposite direction). To control for group differences in general slowing, we computed proportional scores with congruent trials as the baseline [(incongruent – congruent)/congruent].[4] One-sample t-tests against a proportional score of zero revealed significant conflict cost in every group,

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[3] Healthy elderly participants were slower than young adults in their overall speed, as revealed by a main effect in a 2×2 analysis of variance that included group as a between-subjects factor and Distractor Type (absent, neutral) as a within-subject factor, $F(1,23) = 30.0$, $p < .001$, $MSE = 7303$. DAT patients were significantly slower than the healthy elderly, as revealed in an ANOVA on data from these two groups, $F(1,22) = 4.7$, $p < .05$, $MSE = 6768$.

[4] Healthy elderly were slower than young adults in an analysis that included Group (young, healthy elderly) as a between-subjects factor and Distractor Type (congruent, incongruent) as a within-subject factor, $F(1,23) = 29.6$, $p < .001$, $MSE = 1072$. DAT patients were slower than healthy elderly in analysis of these two groups, $F(1,22) = 6.1$, $p < .05$, $MSE = 1085$.

Table 2A
Neuropsychological information for participants of Experiment 1

	Maximum score	Healthy Elderly	DAT
MMSE	30	28.9 (0.5)	24.6 (3.2)*
MMSE range	0–30	27–30	20–29
DRS (total)	144	141.9 (1.5)	124.0 (12.6)*
Attention	37	36.3 (0.7)	34.2 (1.9)*
Initiation	37	36.8 (0.5)	31.1 (5.2)*
Praxis	6	5.8 (0.5)	5.1 (0.8)
Conceptualization	39	38.6 (0.7)	35.5 (3.2)*
Memory	25	24.5 (0.9)	18.2 (5.0)*
NART-R FS-IQ	n/a	118.1 (3.3)	107.3 (7.9)*
Boston naming	30	28.9 (1.1)	20.4 (6.2)*
Western aphasia battery	100	99.3 (0.6)	92.6 (4.5)*
Rey-Osterrieth	36	31.4 (3.1)	25.6 (6.5)^
Line orientation task	30	25.5 (3.8)	22.6 (3.7)
Visual memory immediate	41	30.4 (7.5)	16.8 (3.2)*
Visual memory delayed	41	22.6 (9.0)	5.3 (6.2)*
Semantic fluency (animals)	n/a	17.9 (2.0)	12.1 (5.9)^
Verbal fluency (FAS)	n/a	47.4 (8.5)	32.3 (12.6)*
CVLT			
Acquisition (Trial 5)	16	11.2 (1.8)	7.1(2.3)*
Short delay free recall	16	10.0 (3.7)	3.3 (3.7)*
Short delay cued recall	16	11.0 (2.3)	5.6 (3.5)*
Long delay free recall	16	9.6 (3.8)	3.2 (4.3)*
Long delay cued recall	16	10.9 (2.7)	4.7 (4.1)*
Forward digit span	12	8.8 (1.3)	8.1 (2.0)
Backward digit span	12	7.0 (1.3)	6.1 (2.1)
Trails A (secs)	240	38.5 (8.9)	42.7 (8.7)
Trails B (secs)	240	78.3 (17.1)	171.6 (66.0)*
Trails B errors		0.0 (0.0)	1.4 (1.3)^
Raven's progressive matrices	36	32.3 (1.5)	26.8 (5.6)^

Non-parametric statistic, Mann–Whitney *U*, $^*p < .01$; $^\wedge p < .05$. MMSE, mini-mental state examination; DRS, dementia rating scale; NART-R, National Adult Reading Scale-revised; CVLT, California verbal learning task; In Trails tasks, higher scores signify worse performance.

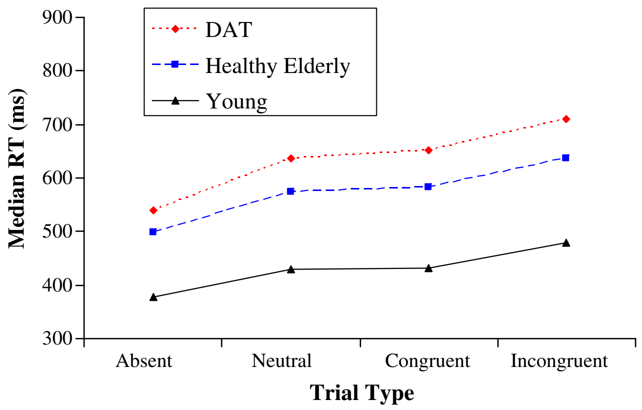

Fig. 2. Median RT in Experiment 1.

Table 2B
Neuropsychological information for participants of Experiments 2 and 3

	Maximum score	Healthy Elderly	DAT
MMSE	30	28.8 (1.0)	27.1 (2.2)*
MMSE range	0–30	27–30	23–30
DRS (total)	144	140.8 (2.0)	134.3 (6.0)*
Attention	37	36.2 (0.8)	35.8 (1.4)
Initiation	37	36.1 (0.5)	35.1 (2.4)
Praxis	6	5.6 (0.9)	5.3 (0.8)
Conceptualization	39	38.4 (0.8)	37.4 (1.9)
Memory	25	24.5 (0.8)	21.0 (3.5)*
NART-R FS-IQ	n/a	115.9 (4.4)	110.3 (7.8)
Boston Naming	30	28.2 (1.7)	24.6 (4.7)*
Western Aphasia Battery	100	99.3 (0.9)	96.1 (3.5)*
Rey-Osterrieth	36	32.5 (3.4)	30.2 (6.3)
Line Orientation Task	30	26.6 (4.0)	23.1 (5.2)
Visual memory immediate	41	31.5 (6.0)	23.4 (7.7)*
Visual memory Delayed	41	24.5 (9.0)	10.1 (8.3)*
Semantic Fluency	n/a	19.5 (2.2)	16.4 (4.8)^
Verbal Fluency (FAS)	n/a	45.7 (9.7)	36.1 (10.6)*
CVLT			
Acquisition (Trial 5)	16	11.7 (1.9)	8.6 (2.7)*
Short Delay Free Recall	16	10.0 (2.8)	4.8 (3.5)*
Short Delay Cued Recall	16	10.8 (2.7)	6.9 (3.3)*
Long Delay Free Recall	16	9.9 (3.4)	4.4 (4.1)*
Long Delay Cued Recall	16	10.5 (3.1)	6.4 (3.8)*
Forward digit span	12	8.6 (1.7)	9.2 (2.3)
Backward digit span	12	7.8 (2.1)	7.2 (2.5)
Trails A (secs)	240	37.1 (7.8)	38.4 (10.7)
Trails B (secs)	240	73.0 (16.1)	112.4 (60.8)^
Trails B errors		0.1 (0.3)	0.5 (0.7)^
Raven's Progressive Matrices	36	32.6 (3.0)	29.1 (4.7)*

$ts(11) > 4.8$, $ps < .001$. More importantly, independent *t*-tests on the proportional scores revealed no significant differences between groups in conflict resolution, $ts(23) < .7$, ns. The error data revealed no significant differences between groups.

In sum, Experiment 1 revealed remarkably few differences among groups other than general slowing due to normal aging and DAT. DAT patients and healthy elderly subjects were spared in their ability to filter information and resolve conflict in this paradigm with minimal memory demands. However, it remained possible that increased demands would reveal specific group deficits in attention, particularly in the ability to resolve conflict. We addressed this possibility in Experiment 2.

3. Experiment 2

To increase memory demands, Experiment 2 asked subjects to respond based on arbitrary stimulus–response rules. Instead of an arrow pointing toward the correct response, geometric figures were displayed and subjects had to respond based on initial instruction (e.g., press 'left' if the target is a circle and press 'right' if the target is a square). A comparison of congruent trials and trials with no distractor provided a measure of *perceptual filtering*.

Table 3
Median reaction time (*SD*) and percentage of errors in Experiment 1

Group	Absent	Neutral	Congruent	Incongruent	Distraction	Conflict
RT						
Young	378 (51)	431 (69)	432 (69)	478 (61)	13.9 (8.4)	11.4 (7.1)
Healthy Elderly	499 (66)	574 (64)	582 (84)	637 (75)	15.6 (8.7)	9.9 (4.9)
DAT	540 (67)	637 (64)	653 (72)	709 (59)	19.2 (17.2)	9.1 (6.5)
Errors						
Young	2.2 (1.6)	1.8 (2.3)	0.2 (0.6)	3.5 (1.9)		
Healthy Elderly	1.1 (1.2)	1.1 (1.9)	0.2 (0.4)	2.0 (1.8)		
DAT	1.1 (2.6)	1.3 (1.5)	0.8 (1.7)	1.9 (1.5)		

Right columns show percentage cost due to distraction and conflict.
Note: Distraction Cost: [(neutral − absent)/absent]; Conflict Cost: [(incongruent − congruent)/congruent].

A comparison of congruent and incongruent trials provided a measure of *conflict resolution*.

3.1. Method

3.1.1. Participants

Nineteen subjects per group participated in the study. Five DAT patients and 8 healthy elderly had participated in Experiment 1. For these subjects, the two sessions were spaced by at least four weeks. In the DAT group there were 8 patients who met criteria for probable early Alzheimer's Disease (AD) (McKhann et al., 1984) and 11 patients who met criteria for Amnesic Mild Cognitive Impairment (MCI-a), the prodromal phase of Alzheimer's disease in which cognitive deficits are limited to episodic memory (Petersen et al., 1999).

All 19 patients and 13 healthy elderly subjects completed general neuropsychological testing (Table 2B). The other 6 healthy elderly subjects completed a subset of tests (MMSE, the digit span task, the verbal fluency tasks) performing within normal levels. As part of the standard work-up of DAT, brain imaging was obtained for all the patients.

3.1.2. Stimuli and procedure

The stimuli consisted of a geometric figure (e.g., a small white circle) inside of a geometric figure of a different shape and color (e.g., a big black square). The large figure fit in a $9.6° \times 9.6°$ VA panel, and the small figure in a $1.6° \times 1.6°$ VA panel, displayed in the center of the screen. The target color remained constant across the experiment and was counterbalanced across subjects. The order of this task was counterbalanced across subjects with the order of the task described in Experiment 3. Two different combinations of geometric figures were used across experiments (a circle and square, a cross and triangle), counterbalanced across subjects.

Subjects sat 50 cm away from the screen, and pressed keys S and L in the keyboard using left and right index fingers. The keys were labeled with an icon of the response (e.g., a circle). The task started with a block of 48 trials with single figure displays. This block served as baseline measure of reaction time. It was followed by a block of 144 trials with double figure displays (e.g., a small white circle and a big black square). Distractor (congruent, incongruent), response side (left, right), and target size (big, small) were balanced, with equal number of trials in each combination.

Every four trials, a cue reminded subjects of the target color. The cue (the word ‘black’ in black ink or the word ‘white’ in white ink) was displayed for 700 ms, 2 cm below the center of the screen, in Courier New 32 pt. font. A 500 ms blank interval followed the cue, after which the first trial of the 4-trial run appeared, remaining until response. Inter-trial interval within the run was variable, ranging between 800 and 1800 ms. At the end of the run, there was a variable delay of 100–1100 ms, after which a new run started with the display of the cue.

3.2. Results and discussion

Incorrect responses and trials immediately following them were excluded from the RT analyses. Median RTs were calculated for each type of distractor (absent, congruent, incongruent). The main findings are illustrated in Fig. 3 and the full data are reported in Table 4.

3.2.1. Perceptual filtering

The cost of perceptual filtering was assessed by comparing congruent trials and trials with no distractor. To control for group differences in overall speed of response we computed proportional scores, using trials with no distractor as the baseline (congruent-absent/absent).[5] The presence of a congruent distractor slowed down RTs in all groups, as revealed by one-sample t-tests against the null hypothesis (i.e., a proportional score of zero) run separately for each group, $ts(18) > 6.2$, $ps < .001$. More importantly, young adults were no better than healthy elderly at

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[5] Healthy elderly participants were slower than young adults in their overall speed, as revealed by a main effect in a 2×2 analysis of variance that included Group as a between-subjects factor and Distractor Type (absent, congruent) as a within-subject factor, $F(1,36) = 27.5$, $p < .001$, $MSE = 12800$. DAT patients were significantly slower than the healthy elderly, as revealed by an ANOVA of these two groups, $F(1,36) = 12.3$, $p < .01$, $MSE = 20297$.

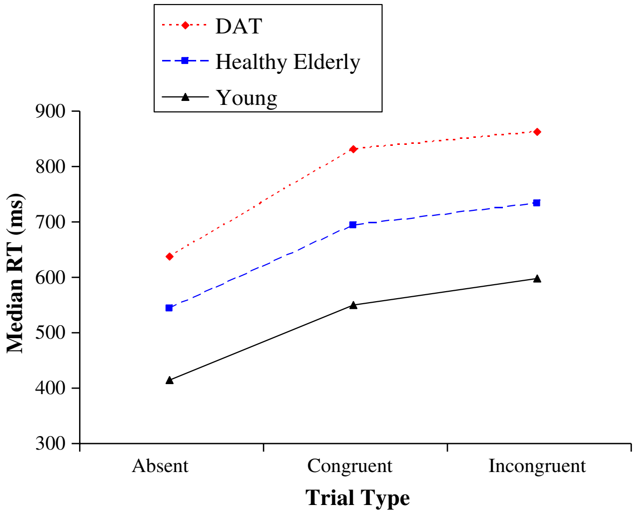

Fig. 3. Median RT for Experiment 2.

Table 4
Median reaction time (*SD*) and percentage of errors in Experiment 2

Group	Absent	Congruent	Incongruent	Distraction	Conflict
RT					
Young	415 (39)	551 (85)	597 (92)	32.6 (13.6)	8.5 (9.8)
Healthy Elderly	544 (99)	694 (101)	734 (93)	28.6 (11.4)	6.1 (5.7)
DAT	637 (105)	831 (140)	862 (143)	31.8 (22.1)	4.1 (7.0)
Errors					
Young	1.1 (1.8)	2.2 (1.8)	2.7 (2.1)		
Healthy elderly	1.5 (2.4)	2.5 (2.9)	2.5 (2.7)		
DAT	1.8 (2.2)	3.7 (3.6)	4.8 (6.3)		

Right columns show percentage cost due to distraction and to conflict.
Note: Distraction cost: [(congruent − absent)/absent]; Conflict cost: [(incongruent − congruent)/congruent].

filtering distractors, as revealed by an independent sample *t*-test on the proportional scores, $t(36) = 1.0$, $p > .30$. Neither were healthy elderly more effective than DAT patients, $t(36) = .5$, $p > .30$. The error data revealed no significant differences between groups.

3.2.2. Conflict resolution

The cost of resolving conflict was assessed by comparing congruent and incongruent trials. To control for group differences in general slowing, we computed proportional scores with congruent trials as the baseline (incongruent−congruent/congruent).[6] One-sample *t*-tests against a proportional score of zero revealed significant conflict cost in every group, $ts(18) > 2.5$, $ps < .05$. More importantly, independent *t*-tests on the proportional scores revealed no significant differences between groups in conflict resolution, $ts(36) < 1$, ns.[7] The error data revealed no significant differences between groups.

In sum, Experiment 2 revealed no group differences in the ability to filter distraction or to resolve conflict, despite the increased demands posed by an abstract S-R rule. It suggests that attentional deficits characteristic of early DAT may reside in some other cognitive processes, such as the ability to maintain an alternating mental set in the presence of distraction. We addressed this possibility in the next experiment.

4. Experiment 3

In Experiment 3, we explored whether healthy aging and early DAT led to increased costs of set switching. In particular, we assessed the *global set-selection cost*. An initial block had trials displaying a single arrow, which alternated color every four trials. In this block the response was fully determined by the target as there was no distractor. This was followed by a second block in which two concentric arrows (one black, one white) were simultaneously displayed (see Fig. 1, right side). The two arrows could point in same or opposite directions. Which arrow was the target and which one the distractor was determined by their color. The color target alternated every four trials. This required that subjects kept track of the changing target color and used that information to select their response.

4.1. Method

4.1.1. Participants

The same participants participated in Experiment 2 and 3.

4.1.2. Stimuli and procedure

The procedure was the same as in Experiment 2 except for the following modifications. Rather than using arbitrary S-R associations, the stimuli consisted of a small arrow (1.6° × 0.8° VA), inside of a big arrow (19° × 10.7° VA). More importantly, the color of the target was not constant but rather alternated every four trials. To reduce memory demands, a salient cue at the beginning of each 4-trial run reminded subjects which color to attend (e.g., the word ‘black’ in black ink).

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[6] As in the previous analyses, the overall speed of response was slower for DAT patients than for healthy elderly, as revealed by an analysis that included Group as a between-subjects factor and Distractor Type (congruent, incongruent) as a within-subject factor, $F(1,36) = 11.7$, $p < .01$, $MSE = 28306$. In turn, healthy elderly were slower than young adults, $F(1,36) = 23.1$, $p < .001$, $MSE = 16074$.

[7] Patients with early DAT and patients with amnesic MCI were treated as a single group, as preliminary analyses revealed no significant differences. There were no significant difference between these two groups in proportional distraction cost, nor were there differences in the proportional conflict cost, $ts(17) < 1.2$, ns. Furthermore, there were no significant differences in the overall speed of response (MCI = 757 ms, early DAT = 852 ms), as tested in an analysis of variance that included Group as a between-subject factor and Trial Type (absent, congruent, incongruent) as a within-subject factor, $F(1,17) = .7$, ns.

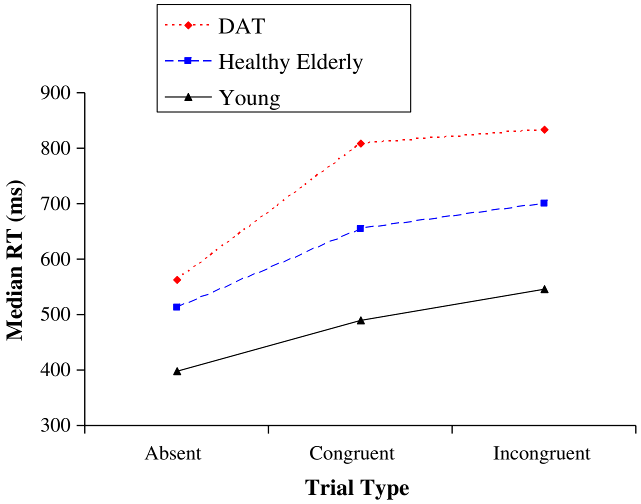

Fig. 4. Median RT for Experiment 3.

4.2. Results and discussion

Incorrect responses and trials immediately following them were excluded from the RT analyses. Median RTs were calculated for Distractor Type (absent, congruent, incongruent) and Trial Position in the run (Switch, No Switch) (see Table 5).

4.2.1. Global set-selection cost

In the initial block the target appeared by itself and the response was fully determined by the stimulus. In the second block the target co-occurred with a distractor and choosing the correct response required keeping track of the color by which the target was selected. Comparing congruent trials in the second block and trials with no distractor in the first block provided a measure of the global cost incurred in alternating between two mental sets (global set-selection cost). To control for group differences in overall speed of response we computed proportional scores, using trials with no distractor as the baseline [(congruent – absent)/absent].[8] An independent t-test on the proportional scores revealed no significant difference between young and healthy elderly, $t(36) = .6$, $p = .50$.

In contrast, an independent t-test on the proportional scores did reveal that DAT patients were impaired in global set-selection cost relative to healthy elderly, even after controlling for differences in overall speed processing, $t(36) = 2.3$, $p = .03$ (see Fig. 4). Thus, DAT patient's impairment at global switching could not be fully explained by their slower general processing speed.[9]

4.2.2. Local switch cost and conflict resolution

Data from young and healthy elderly participants were entered in a $2 \times 2 \times 2$ mixed analysis of variance that had Group as a between-subjects factor and Distractor Type (congruent, incongruent) and Trial Position (switch, no switch) as within-subject factors. The cost of processing incongruent information was significant, $F(1,36) > 75.1$, $p < .001$, $MSE = 1280$, but did not interact with group, $F(1,36) = .8$, $p = .37$, $MSE = 1280$. In other words, the healthy elderly did not show a deficit in conflict resolution relative to the young adults. The error data revealed a main effect of conflict, $F(1,36) = 21.6$, $p < .001$, which was qualified by an interaction with trial position, $F(1,36) = 4.2$, $p < .05$, errors to incongruent trials being somewhat more frequent in the switch trials.

The analysis of data from DAT and healthy elderly groups revealed the same pattern of findings. Responses were slowed down by conflict, $F(1,36) = 17.0$, $p < .002$, $MSE = 2806$, but this did not interact with Group, $F(1,36) = 1.3$, $p = .27$, $MSE = 2806$. Importantly, there was no significant interaction between group and trial position, $F(1,36) = .3$, $p = .55$, $MSE = 5412$. This lack of interaction argues against local switch costs as the mechanism for group differences in global costs. Finally, the error data showed that conflict led to increased number of errors, $F(1,36) > 19.2$, $p < .001$.

In sum, Experiment 3 revealed a global cost of switching that was increased in early DAT, even after correcting for differences in the speed of processing. This abnormal global set-selection cost was not due to an increased deficit in conflict resolution nor was it due to an abnormal increase in the residual cost of local switching. Instead, the deficit seems to stem from DAT patients' inability to maintain an alternating mental set in the presence of distracting information.

5. General discussion

Experiments 1 and 2 assessed selective attention (perceptual filtering, conflict resolution) under low memory demands and found no evidence of impairment in early

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[8] Healthy elderly participants were slower than young adults in their overall speed, as revealed by a main effect in a 2×2 analysis of variance that included Group as a between-subjects factor and Distractor Type (absent, congruent) as a within-subject factor, $F(1,36) = 28$, $p < .001$, $MSE = 13135$. Also as expected, there was a significant global cost: RTs for congruent trials were significantly slower than for trials with no distractor, $F(1,36) = 136$, $p < .001$, $MSE = 1943$. This global cost was larger for healthy elderly participants than for young adults, as revealed by a significant interaction, $F(1,36) = 5.7$, $p < .02$, $MSE = 1943$. Group differences in general processing speed account for this interaction.

[9] DAT participants were slower than healthy elderly in their overall speed, as revealed by a main effect in a 2×2 analysis of variance that included Group as a between-subjects factor and Distractor Type (absent, congruent) as a within-subject factor, $F(1,36) = 10.6$, $p < .002$, $MSE = 18534$. Also as expected, there was a significant global cost: RTs for congruent trials were significantly slower than for trials with no distractor, $F(1,36) = 106$, $p < .001$, $MSE = 6707$. This global cost was larger for the DAT patients than for the healthy elderly, as revealed by a significant interaction, $F(1,36) = 7.5$, $p < .01$, $MSE = 6707$. Group differences in general processing speed cannot account for this interaction, as it remained significant when using proportional scores.

Table 5
Median reaction time (*SD*) and percentage of errors in Experiment 3

Group	Absent		Congruent		Incongruent		Global Switch
	Switch	No Switch	Switch	No Switch	Switch	No Switch	
RT							
Young	393 (90)	400 (98)	484 (81)	497 (72)	548 (75)	543 (73)	25.5 (14)
Healthy elderly	515 (87)	510 (79)	663 (124)	647 (91)	702 (84)	698 (80)	28.5 (14)
DAT	557 (74)	567 (68)	820 (178)	796 (185)	847 (188)	821 (141)	43.7 (25)
Errors							
Young	0 (0)	1.8 (2.9)	0.3 (1.4)	0.5 (3.5)	5 (6.1)	3.1 (3.5)	
Healthy elderly	1.1 (3.2)	0.5 (1.2)	0.6 (1.9)	1.4 (1.9)	5.1 (6.2)	4.1 (5)	
DAT	1.6 (3.7)	1.1 (1.9)	1.8 (3.8)	1.1 (1.8)	7.8 (10)	8.7 (9.4)	

Right column shows percentage cost due to the global switching cost.

DAT. Experiment 3 assessed the ability to maintain an alternating mental set in the presence of distraction. Patients with early DAT were impaired in Experiment 3, showing a large cost of *global* set-selection. This deficit was not accounted for by group differences in the overall speed of information processing. Nor was it secondary to a deficit in conflict resolution or to a deficit in local set switching. Rather, the data reveal a primary deficit in set maintenance: patients had difficulty holding in mind the rule for target selection, especially when the rule was not constant throughout the experiment (Experiment 3). In other words, patients with early DAT had difficulty ignoring distracting information when it was potentially relevant. Consistent with this interpretation, studies have reported that patients with DAT have reduced working memory capacity. While DAT patients exhibit normal recency effect in free recall and a relatively spared forward memory span, they are greatly impaired in tasks of working memory, including the backward visual memory span task, the *n*-back task, and the operation-span task (Belleville, Peretz, & Malenfant, 1996; Cherry, Buckwalter, & Henderson, 1996; Kensinger, Shearer, Locascio, Growdon, & Corkin, 2003; Lamar, Price, Davis, Kaplan, & Libon, 2002; Rosen, Bergeson, Putnam, Harwell, & Sunderland, 2002). DAT patients' increased cost in global set-maintenance cost is also consistent with frontal lobe pathology, as patients with left frontal lesions show a deficit in global set selection (Mayr, Diedrichsen, Ivry, & Keele, 2006).

Recasting the attentional deficit of early DAT patients as an inability to maintain mental set may help to interpret the DAT literature on selective attention. It will reconcile the current findings of spared selective attention (Experiments 1 and 2) with previous findings of impaired DAT performance. In most previous studies subjects had to keep a rule in mind (eye fixation, response to non-salient dimension). For example, nothing in the visual display of the Stroop task reminds subjects that they should respond to ink color. Unlike those studies, our paradigm, especially in Experiment 1, required maintaining only the most minimal amount of information. The hypothesis that mental set maintenance—and its impairment in early DAT—may play an important role in selective attention tasks receives support from studies in which mental set availability is systematically manipulated (De Jong, 2001; De Jong, Berendsen, & Cools, 1999). At the same time, failure to maintain mental set is unlikely to be the sole explanation of DAT's difficulties in conflict resolution. If that were the case, increased demands in set maintenance would always lead to increased conflict costs. This was not the case in Experiment 3, in which DAT patients exhibited normal conflict costs despite the increased demands in mental set. Future studies should address this question more directly by systematically manipulating the mental set demands in patients with DAT (Kane & Engle, 2003). It is also important to emphasize that conflict resolution and other attentional processes are likely to become affected as the disease progresses (Amieva et al., 2004; Perry & Hodges, 1999; Spieler et al., 1996). The findings from our study merely suggest that at very early stages in the disease there is already a deficit in the ability to maintain a mental set. This raises the important question of whether deficits in mental set maintenance could predict who is at risk for the disease and who will progress from a preclinical stage to a clinical one.

A difficulty in maintaining mental set also helps explain DAT's deficit in areas of higher cognition. Dual-task studies have argued that dual-task deficit in DAT is not due to increased perceived load by the DAT patients but rather is due to a deficit coordinating the two tasks (Logie et al., 2004). Although 'task coordination' is a concept that needs to be developed further, one of its constituent parts might be the ability to maintain a mental set about task A while performing task B (Baddeley, Chincotta, & Adlam, 2001a). This leads to the testable prediction that DAT deficit in dual task will be mediated, at least in part, by the inability to maintain set. Finally, studies of deductive reasoning have shown that DAT performance is relatively spared for the sequential processing of single relations (e.g., "Mary is taller than Joan, Joan is taller than Emma") but is greatly impaired for the integration of two relations (e.g., "Mike is taller than Joe, Ed is taller than Mike," therefore "Ed is taller than Joe") (Waltz et al., 2004).

This process of integration requires the maintenance of a mental set. This raises the possibility that DAT's deficit in reasoning is related to a deficit maintaining mental set, such as the one described in our study.

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