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A goal activation approach to the study of executive function: An application to antisaccade tasks[☆]

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Abstract

We argue that a general control process, responsible for the activation and maintenance of task goals, is central to the concept of executive function. Failures of this process can become manifest as *goal neglect*: disregard of a task requirement even though it has been understood (Duncan, 1995). We discuss the results of several published and new experiments using various versions of the antisaccade task in order to investigate the circumstances under which goal neglect is likely to occur. Potentially conflicting results in the literature on adaptive control of saccadic eye movements are argued to be attributable to the extent to which different task versions elicit goal neglect. The results suggest an increased susceptibility to goal neglect of high-functioning older adults (Experiment 1) and of first-episode schizophrenia patients (Experiment 2), but not of patients with obsessive-compulsive disorder (Experiment 3). However, the degree to which such differences in susceptibility become manifest in task performance, is shown to be strongly influenced by manipulations of the relative saliency of task requirements. Theoretical and methodological implications for the study of executive function are discussed.

1. Introduction

Much work in cognitive neuropsychology has been guided by the intuition that somewhere in the cognitive processing system resides a control mechanism, which implements functions such as "planning", "monitoring", and "inhibition". These functions are commonly referred to as *executive functions* (Monsell, 1996) and are thought to rely heavily on the frontal lobes. The assumption of a functional and anatomical distinction between a control mechanism and a set of controlled mechanisms (e.g., memory) has in particular been reinforced by neuropsychological reports describing patient populations with frontal lobe damage, who may show severe executive deficits in the context of intact crystallized intelligence (e.g., Shallice & Burgess, 1991). A range of neuropsychological tests have been designed with the aim of tapping the cognitive deficits underlying the general disturbances of behavior often seen in these patients. However, it has become clear that most classical "executive" tasks, such as the Wisconsin Card Sorting Task and the Tower of Hanoi, are unreliable at discriminating patients with frontal lobe lesions from patients with more posterior lesions (Reitan & Wolfson, 1994; Tranel, Anderson, & Benton, 1994). A likely reason for the poor *discriminant* validity of many of these tasks is that they tap executive functions as well as multiple non-executive functions, such that task performance may be disrupted in many ways (Burgess, 1997; Pennington, Bennetto, McAleer, & Roberts, 1996).

Another, more fundamental concern is the questionable *construct* validity of the hypothetical constructs that conventional executive tasks aim to measure. For

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instance, Rabbitt (1997) has pointed out that popular constructs such as "inhibition" are often operationalized in terms of a set of exemplary tasks (e.g., Stroop task, A-not-B task), which are typically not validated against each other or against an independent standard. As a result, it is well possible that despite the face validity of most of these tasks, their performance outcomes may tell us little about the functional processes *underlying* performance. Indeed, a number of studies have addressed the construct validity of conventional executive tasks by examining the intercorrelations of performance scores on batteries of executive and other tasks administered to large groups of people. The standard finding is a matrix of positive but predominantly low correlations with little or no substantial clusterings of executive tasks or subsets of seemingly similar executive tasks (e.g., Duncan, Johnson, Swales, & Freer, 1997; Kopelman, 1991; Obonsawin et al., 2002; Rabbitt, 1997; but see, e.g., Segalowitz, Unsal, & Dywan, 1992). This suggests that many conventional executive tasks have as little in common between them as they have in common with other, presumably non-executive tasks. Thus, if there exists indeed a distinct executive control mechanism,[1] then variation in its efficiency is not easily discerned as a systematic, replicable pattern of associations between mean performance scores on current neuropsychological tasks. The increasingly recognized difficulty of finding a reliable measure of executive deficit (Burgess, 1997; Miyake et al., 2000; Rabbitt, 1997) seems to suggest the need for a different, complementary approach to the study of executive function.

In this paper, we advocate the view that when comparing groups with known or suspected frontal lobe dysfunctioning with control groups, differences in the variability of their task performance can be at least as informative about executive dysfunction as the mere shift in average level of performance. More specifically, previous work has suggested that performance variability *within* tasks may arise from failures to fully or consistently focus attention on task requirements. Such failures have been interpreted using the concept of *goal neglect* (De Jong, Berendsen, & Cools, 1999; Duncan, 1995; Duncan, Emslie, Williams, Johnson, & Freer, 1996): although task requirements may be understood and remembered, they are not turned into active goals or adequately maintained as such, so that control over behavior is lost. As will be discussed below, there is good evidence that goal activation is central to the concept of executive function. In this paper, the main focus is on performance variability *between* tasks from the same task domain. We argue that this type of performance variability, though usually ignored, can often be attributed to one of several factors (differentiating seemingly functionally identical task versions) that have been proposed to stimulate the process of goal activation through their potential to have people focus their attention more tightly on demanding task requirements.

In order to illustrate the importance of such factors and their influence on the hypothesized goal activation process, we review a set of new and some already published experiments using several versions of the *antisaccade task*. We demonstrate that between-task variability of performance on these task versions is considerable in two subject groups often associated with executive dysfunctioning (individuals at older age and first-episode schizophrenia patients). We argue that the factors underlying this between-task variability suggest that these groups tend to exhibit excessive goal neglect. Finally, we contrast these groups with a group of patients with obsessive-compulsive disorder, who display no evidence of goal neglect. Because "goal activation' is simply a verbal label for a hypothetical psychological construct, it necessarily lacks the conceptual clarity that would be desirable in theories of executive function. In Section 5, we therefore consider this limitation, and discuss how the concept of "goal activation" may be understood in the context of more formal models of executive function.

1.1. Goal neglect

The positive correlation between performance measures of almost any pair of cognitive tasks has been accounted for in terms of one general ability factor, Spearman's *g* (Spearman, 1927), which contributes to successful performance on a large number of very different cognitive tasks. Indeed, although such a factor may manifest itself in a wide range of cognitive activities, the only unique aspect of these cognitive activities might be the involvement of that factor (Burgess, 1997). Duncan and colleagues (Duncan, 1995; Duncan et al., 1996) have proposed that the *g* factor may reflect the efficiency of a general goal activation process, which is involved in "constructing an efficient task plan by activation of appropriate goals or action requirements" (Duncan et al., 1997, pp. 716). Inefficiency of this process is revealed by a phenomenon called goal neglect, operationalized by Duncan (1995) as disregard of a task requirement even though it has been understood and remembered. Several examples of goal neglect in laboratory tasks will be given below. Although performance on almost any task may depend, to some extent, on a common goal activation process, other "executive" functions involved in task performance (e.g., those responsible for inhibiting motor reflexes, or those involved in planning an action sequence) may be

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[1] Although the typical pattern of correlations between conventional executive tasks can be taken to infer the existence of multiple control mechanisms, each implementing a distinct executive function, Della Sala, Gray, Spinnler, and Trivelli (1998) have pointed out that such a conclusion is impeded by the theoretical and methodological limitations of the correlational and associated factor-analytic approach.

extremely domain-specific (Rabbitt, 1997). This might explain why correlations between most cognitive performance scores are so low.

Consistent with the hypothesis that *g* reflects the efficiency of a general goal activation process, Duncan and colleagues (Duncan et al., 1996, 1997) showed that individual differences in *g* could well account for interindividual variation in a measure of goal neglect obtained in a prospective memory task. Indeed, goal neglect is strongly characteristic of individuals with frontal lobe damage (e.g., Duncan et al., 1996; Milner, 1963), who also tend to show poor performance on standard tests of fluid intelligence (Duncan, Burgess, & Emslie, 1995), which, in general, have high *g* correlations. The existence of a general goal activation process, which contributes to successful performance on a wide range of tasks, is consistent with the observation that individuals with frontal lobe damage routinely demonstrate generalized neuropsychological impairment in the absence of any specific deficits (Reitan & Wolfson, 1994). However, it should be emphasized that problems with the consistency of goal activation are, to some extent, also visible in the normal population, as illustrated below.

Two experimental task domains, in particular, have inspired the systematic study of goal neglect and the factors influencing its probability of occurrence. First, in prospective memory tasks, subjects are required to place a task on hold and to resume it only when some memorized trigger condition is fulfilled. This "prospective" task is typically embedded in another, ongoing ("primary") task meant to direct the focus of attention away from the intention to react to the prospective trigger. For instance, in the experiments reported by Duncan et al. (1996), the subjects' primary task was to monitor two streams of random letters and digits and to repeat out loud any letters that appeared on one side. The prospective task was to respond to an occasionally presented central, symbolic cue ("+" for right, "−" for left), indicating subjects on what side to continue reading. Even though virtually every subject was able to recall this rule correctly when prompted, goal neglect, evident as a failure to switch sides if required, was not uncommon among young and healthy subjects. However, the severity of goal neglect was markedly increased in individuals with frontal lesions, and, to a lesser extent, in older adults. Patients with parietal lesions did not exhibit more goal neglect than matched controls. As mentioned above, initial performance on the letter-monitoring task was well predicted by subjects' estimates of *g* (see also Duncan et al., 1997), which, according to those researchers, suggests that the task may be a relatively pure measure of executive function. Goal neglect was especially apparent in early phases of the experiment (i.e., when the task was still novel), and when a second prospective task was added. Furthermore, if subjects displayed neglect of the switching rule, this almost always disappeared immediately after verbal prompts drawing attention to the task requirements.

Compared with the study by Duncan et al. (1996), most prospective memory studies have incorporated a longer delay between the instruction phase and the moment to carry out the memorized intention (Brandimonte, Einstein, & McDaniel, 1996). These studies have confirmed that the prospective component of performance depends on the activation level of this representation (Mäntylä, 1996), as well as on the saliency of environmental prompts (Einstein & McDaniel, 1996). For instance, the effect of age on prospective memory performance is particularly evident in task versions in which the resumption of the prospective task is signaled by a time marker (e.g., a specific time of the day), as compared to some external event (Maylor, 1996). Obviously, in the former case the environmental support is low, whereas in the latter case the event may be a powerful trigger of the action schema. As noted above, Duncan et al. emphasized novelty as another factor giving rise to goal neglect. However, their finding that goal neglect was restricted to behavior before the first correct trial has not been replicated in subsequent prospective memory studies (e.g., Maylor, 1998). Finally, it is important to note that most studies have managed to exclude the possibility that retrospective memory problems are responsible for neglect (e.g., Brandimonte et al., 1996). Thus, an important part of the trial-to-trial performance variability in prospective memory tasks may be attributed to failures to act upon the instructions at the appropriate moment, rather than to mere forgetting of the task instructions. The probability of such goal neglect can be influenced by environmental prompts, the number of concurrent task requirements, and, possibly, novelty.

A second class of experimental tasks that can yield a relatively pure manifestation of goal neglect are conflict tasks, which require responding to one set of stimuli or rules, even when more compelling stimuli or rules are available. A classical example of goal neglect in conflict situations was reported by Milner (1963) using the Wisconsin Card Sorting Task, in which card stimuli must be sorted according to a sequence of conflicting rules. Milner noted that frontal patients may continue to sort according to a set of recently activated but now inappropriate rules, even though they verbally acknowledge that the old rules should be abandoned. A similarly striking dissociation between what is known of task requirements and what is actually attempted in behavior has been noted by Zelazo, Frye, and Rapus (1996) in three-year old children performing a card-sorting task. After a verbally announced switch of rules, many of the children continued to use the preswitch rules despite correctly answering questions about the new, postswitch rules. These results suggest an inability to turn explicit knowledge of task requirements into an active goal, necessary to guide behavior.

Recent evidence suggests that Stroop-type conflict effects may also stem from goal neglect, rather than from fundamental inhibitory limitations as has often been suggested (see De Jong et al., 1999). In the original Stroop task, subjects are instructed to name the ink color of a color word (e.g., the word *red* printed in blue) and to ignore the meaning of the word. The Stroop effect refers to the cost in speed and accuracy of color naming when the ink color and word name do not correspond, as compared to a situation where they correspond. West (1999) observed that color-naming errors tend to occur during periods of slowed responding, and hypothesized that during these periods attention is not sufficiently focused on the color naming task requirement. According to this hypothesis, task conditions that promote the effective mobilization of attention should be associated with a reduced Stroop effect. At least two types of evidence have confirmed this prediction. First, it has been demonstrated that increasing the relative frequency of demanding, non-corresponding trials in a mixed trial block decreases the magnitude of the Stroop effect (Logan & Zbrodoff, 1979; see also Kane & Engle, 2003), and even more so for older adults (West, 1999). A second type of evidence was presented by De Jong et al. (1999), who manipulated the time interval between subsequent Stroop stimuli. De Jong et al. reasoned that a fast pace of stimulus presentation might help subjects to remain well-focused on the task, whereas a slower pace might give rise to attention fluctuations. Indeed, the Stroop effect was notably reduced in the fast pace condition. These findings show that one should be cautious in attributing the Stroop effect and, possibly, other conflict effects to an absolute inability to respond very quickly and accurately on conflict trials. The finding that these effects can be largely eliminated when task demands increase the necessity to fully focus attention on the task requirements, suggests that goal activation failures may be an important underlying cause of suboptimal performance in conflict situations.

We now turn to the antisaccade task domain, which serves as illustration for the present purposes. Being a prominent example of a conflict task because it involves the competition between an endogenously generated and an inappropriate, reflexive eye movement, it is currently a popular tool for measuring "inhibitory deficits" in clinical neuropsychology and related fields (see Everling & Fischer, 1998; for a review).

1.2. Antisaccade task

In the antisaccade task (e.g., Hallet, 1978; Roberts, Hager, & Heron, 1994), subjects are confronted with a series of peripherally presented abrupt onset stimuli. The basic task requirement is to suppress the prepotent tendency to look toward the stimulus (henceforth: the *cue*), and instead move the eyes to the diametrically opposed location as quickly as possible. In a frequently employed version of the task (see Fig. 1), a target is then very briefly presented at this location, and subjects receive the additional instruction to give a non-speeded two-choice response on the basis of the target identity. Thus, the cue serves as a fully reliable indicator of the target location, prompting subjects to produce fast antisaccades in order to optimize choice performance. An elegant control condition is provided by the prosaccade task, in which the target appears at the *same* side as the cue. Here, subjects are required to make a simple, visually guided saccade toward the cue. The difficulty of overriding the prepotent response in the antisaccade task is generally expressed in increased saccade onset latencies if the eyes move directly in the correct direction. In addition, reflexive glances in the direction of the cue (i.e., antisaccade errors) are common, whereas in the prosaccade task subjects rarely make errors.

Because we were primarily interested in the effect of factors affecting goal activation on *overall* pro- and antisaccade performance, it was convenient for the present purposes to obtain a single, overall performance measure. We have recently shown (Nieuwenhuis, Ridderinkhof, De Jong, Kok, & Van der Molen, 2000) that the various oculomotor performance indices of pro- and antisaccade performance can be adequately summarized by one compound measure: the accuracy of target

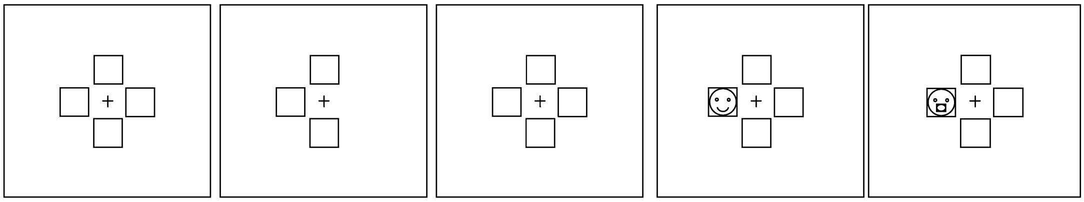

Fig. 1. Example of sequence of events for an anticue trial. See text for actual size. Subjects fixated on the central cross. One of the boxes was then turned off for 67 ms and then turned on again, providing a spatial cue and prompt to generate a saccade. After a variable stimulus onset asynchrony the target appeared for a variable duration before being masked.

identification associated with the additional choice response task. The value of this measure is based on the rationale that, if the stimulus onset asynchrony (SOA) between cue and target is systematically manipulated, then the time needed to (overtly) attend to a certain location can be inferred from the accuracy of identifying targets at that location at various points in time (Gottlob & Madden, 1998). For example, slow saccade onset latencies and frequent saccade errors in the antisaccade task will manifest as relatively poor target identification at short SOAs, because the eyes arrive too late to foveate the target. Alternatively, long SOAs (e.g., 1.5 s) should maximize the probability of correct identification, for instance because they allow potential saccade errors to be corrected in time. Importantly, we ensured that baseline accuracy of target identification in an additional, neutral cue condition (i.e., in which the cue was not predictive of the target location) was equalized across the tested groups. This was accomplished by adjusting the presentation duration of the target on an individual level in the practice phase, and taking the resulting duration as outset in the experimental phase. On the assumption that the neutral and experimental cue conditions differed only in the possibility to move the eyes to the target location in advance, this method enabled us to control for group differences in sensory and oculomotor speed.

2. Experiment 1: Cognitive aging

Above, we have reviewed evidence in support of the view that performance on many psychological tasks is dependent on a common process of goal activation: turning a task requirement into an appropriate goal and maintaining this goal over time, and doing so in the face of competing response tendencies. Goal neglect, a repeated failure of this process, has been proposed to be a central element of executive dysfunction, and is revealed as a sensitivity to variations in the degree to which attention is focused on the instructed task. As we have seen, three factors that can induce such variability are the availability of environmental prompts, the necessity of tightly focused attention as dictated by specific task features, and the number of concurrent task requirements. In order to demonstrate how these factors can affect antisaccade performance, we first present a set of data collected with the previously described version of the antisaccade task (i.e., with a secondary, target identification task). These data, described in Experiment 1, provide a good starting point from which to develop our argument. The experiment involved a comparison between a group of younger and older, healthy and highly educated adults, and was originally conducted to investigate the manner in which and degree to which inhibition of prepotent responses is compromised in older age.

2.1. Method

2.1.1. Subjects

Sixteen young (eight women) and 16 older (three women)[2] adults participated in this experiment. The young subjects (*M* age = 22.3, range 20–27) were undergraduate students at the University of Groningen. The older subjects (*M* age = 72.4, range 65–82) were all retired university professors, non-institutionalized, and relatively healthy and alert according to self-report. The experiment lasted 1.5 h. All subjects were paid fl. 10 per hour for their participation.

2.1.2. Stimuli

Stimuli (see Fig. 1) were presented in white on a black computer screen. The fixation display consisted of a central fixation cross, subtending 0.7°, surrounded by four boxes that were symmetrically positioned above, below, to the left and right of the cross. The boxes each subtended 3.2°, both horizontally and vertically, and the visual angle between fixation and the center of each box was 4.0°. The target consisted of a schematic face in the shape of a circle with a diameter equal to the length of the side of a box. The mouth, which differentiated between a happy and a sad face, subtended $1.5° \times 0.5°$.

2.1.3. Design

There were two experimental cue conditions: (1) the *procue condition* in which the face appeared in the cued box (i.e., a prosaccade task); (2) the *anticue condition* in which the face appeared in the box opposite from the cued box (i.e., an antisaccade task). In addition, there was a neutral control condition in which each of the boxes was cued at the same time, thus providing no information about the location of the target. In this condition, the onset of the target itself provided the only cue as to where to attend or move the eyes. After having received 210 practice trials with the neutral condition, subjects entered the experimental phase which consisted of four sets of four blocks. Cue condition (procue or anticue) was held constant within each set and was varied across sets according to an ABBA design with half of the subjects starting in the procue condition. One third of the trials in each block were neutral. These were randomly intermixed with the experimental trials. The first of every four blocks consisted of 24 trials, all of which were discarded because of carry-over effects from the other cue condition. The other three blocks consisted of 96 experimental trials each. SOA (100, 200, 300,

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[2] Unfortunately, in Experiments 1 and 2, the groups were not properly matched for gender, and our database did not allow us to correlate gender with task performance of individuals in these experiments. However, to our knowledge there is no literature suggesting a gender-related difference in antisaccade performance.

400, 600, 800, 1000, or 1500 ms) was randomly varied within blocks, but the percentage of trials with each SOA was controlled in order to yield approximately 17% trials with the four shortest SOAs and 8% with the four longest SOAs.[3] Cue location was randomly determined on each trial.

2.1.4. Procedure

Each trial started with the presentation of the fixation display. After a fixed duration of 750 ms, one of the boxes was turned off for 67 ms and then turned on again, providing a clearly perceptible spatial cue. After a variable SOA, starting at cue offset, the face was displayed until a (non-speeded) response was registered by the computer keyboard. Response keys, "v" for happy and "n" for sad, were operated by the left and right index fingers. Importantly, the discriminative feature of the face, the mouth, was masked after an individually based duration. The practice phase was used to determine the time that the mouth should be displayed, before being masked, in order to yield 67% correct responses (averaged across SOAs) with the neutral cue for that particular subject. This was done by means of a staircase-tracking algorithm. The resulting target duration was used as initial duration in the experimental phase, but, if necessary, target duration was adjusted at the start of a new experimental set with the aim of maintaining subjects at a 67% percent accuracy level in the neutral cue condition. Mean target duration was 111 ms for the young and 158 ms for the older adults, $F(1,30) = 11.21$, $p < .005$.

Subjects were explicitly informed about the informative value of procues and anticues, and they were instructed to make active use of any informative cue to improve choice performance. To underline these instructions, subjects were shown cartoon-like illustrations of a typical procue and anticue trial. Importantly, subjects were neither instructed to make eye movements nor to keep fixation. Possible eye movements were not recorded, but pilot work established that if subjects were told to keep fixation, their discrimination accuracy hardly exceeded chance levels. Alternatively, if they received no eye movement instructions, an eye movement was almost always observed. Before the start of each block, subjects were informed about the upcoming cue condition. At the end of each block, feedback about manual response accuracy was presented on the computer screen. Subjects were allowed a 10 min rest break after each experimental set.

2.2. Results

The analysis of the discrimination accuracy data included all experimental trials except the first trial of each block. The results are shown in Fig. 2. Accuracy in the procue condition quickly rose to a high asymptote as a function of SOA for both age groups. In contrast, the function for the anticue condition revealed marked age-related differences. For young adults, the function briefly dipped below the control level for the neutral cue but then rose quickly to the same asymptotic level as that reached with procues. For the older adults, however, accuracy in the anticue condition remained well below the neutral control level for at least 300 ms, suggesting a much stronger tendency for the cue to pull attention to the wrong location. Also, unlike for young adults, the asymptotic level of accuracy for anticues remained well below that for procues, indicating that many older adults frequently failed to redirect their attention to the opposite location even when given ample time to do so.

In order to increase the reliability of the factorial cell means, we reduced the substantial error variance by pooling the two shortest SOAs, the two next shortest SOAs etc, so that the factor SOA was entered into the statistical analyses with four levels. The data from the neutral cue condition were analyzed separately by means of a two-way ANOVA with age group as between subjects factor and SOA as within subjects factor. The staircase-tracking procedure was successful at equating both age groups in the neutral cue condition, as indicated by a non-significant main effect of age group, $F(1,30) < 1$. The slight increase in accuracy across SOAs was not significant, $F(3,90) = 1.4$, $p > .2$.

The main analysis of the discrimination accuracy data included accuracy scores in the procue and the anticue condition. The data from these conditions were

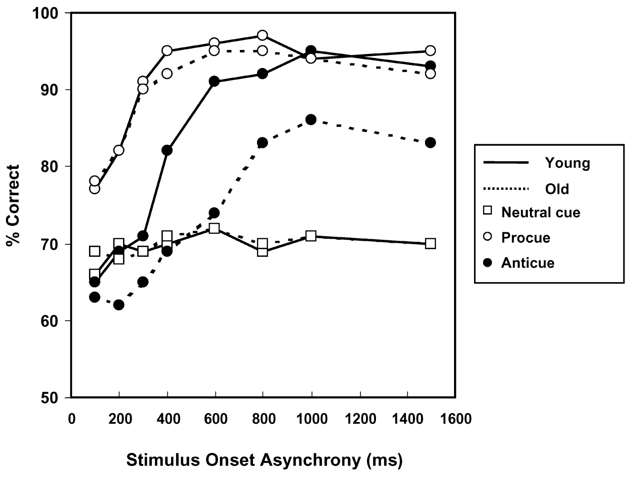

Fig. 2. Discrimination accuracy (%) as a function of cue condition and SOA for the younger and older age group in Experiment 1.

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[3] The estimated variance of the proportion of correct manual responses for each SOA was $(p * (1 - p))/n$, where p is the probability of a correct response, and n is the number of trials. Because p increased with SOA we needed fewer trials at the long SOAs than at the short SOAs in order to obtain a similarly reliable estimate of the percentage correct responses.

submitted to a three-way ANOVA with age group as between subjects factor and SOA and cue condition as within subjects factors. Taken across the two cue conditions the young adults were more accurate than the older adults, $F(1,30) = 21.1$, $p < .001$, indicating that the former group shifted their attention more efficiently in response to informative cues. As expected, accuracy was significantly lower in the anticue condition than in the procue condition, $F(1,30) = 75.1$, $p < .001$, and, importantly, this effect of cue condition was more pronounced for the older adults than for the young adults, $F(1,30) = 9.9$, $p < .005$. The factor SOA showed a significant main effect, $F(3,90) = 103.4$, $p < .001$, and entered in a reliable interaction with cue condition, $F(3,90) = 20.1$, $p < .001$, reflecting a slower rise in accuracy in the anticue condition. Indeed, the initial drop and modest increase of the anticue function of older adults resulted in a significant three-way interaction, $F(3,90) = 3.6$, $p < .03$.

2.3. Discussion

The results from Experiment 1 suggest a close relationship between age and antisaccade performance. Compared to the younger adults, the group of healthy, highly educated, older adults needed considerably more time to override the prepotent response activated by the cue. Interestingly, even when the SOA was increased up to 1.5 s, there remained a substantial asymptotic cost, suggesting that many older adults failed to initiate a voluntary (corrective) antisaccade on a proportion of the trials. What would cause such failures to anticipate the target?

At this point, we are confronted with an important discrepancy between the present results and results from two cross-sectional lifespan studies of pro- and antisaccade performance (Fischer, Biscaldi, & Gezeck, 1997; Munoz, Broughton, Goldring, & Armstrong, 1998). Both of these studies found an approximately linear increase of antisaccade latencies between the age of 20 and 75. However, a similar increase was reported for prosaccade latencies, suggesting that the age differences in antisaccade latencies should be attributed to aspecific perceptuomotor deficits rather than to a compromised ability to handle conflict.[4] The antisaccade error rates confirm this notion. In Munoz et al., the error rates were the same across the adult lifespan. The data from Fischer et al. show a modest, positive correlation between adult age and proportion of antisaccade errors, but the oldest group (age 55–75, $N = 15$) deviated from this pattern and performed much like the youngest adults. In neither study can this age invariance be attributed to a floor effect. Moreover, it is unlikely that the discrepancy between our results and these previous studies is related to our choice of subjects. All of our subjects were highly educated, and their mean age corresponded with that of the oldest subject groups in Fischer et al. and Munoz et al. Lack of motivation can also be ruled out as an alternative interpretation for the poor antisaccade performance of our group of older adults. Apart from the fact that, as usual, the older adults made the impression of being highly motivated, the finding that their prosaccade performance matched that of the younger adults is incompatible with motivational problems.

Although the paradigm used by Fischer et al. (1997) and Munoz et al. (1998) and our antisaccade paradigm are usually treated as logically and functionally equivalent, we believe that differences in task design and instructions may well account for the variability in findings. The most salient difference in task design between our study and the studies by Fischer et al. and Munoz et al. is that their design did not include a target identification task. That is, instead of being replaced by a target stimulus, the cue remained visible for 1 s, after which the trial ended. Subjects were simply required to respond to the cue with a prosaccade or antisaccade. Importantly, because this was their only task goal, subjects were explicitly instructed to produce a fast and accurate saccade on each trial. Note that in our experiment, subjects were not explicitly instructed to do so. The requirement to make saccades was strictly implicit in the instruction to make active use of any informative cue to improve choice performance. Above, we have reviewed evidence suggesting that explicit prompts (including instruction) may be beneficial to the triggering of intended behaviors (e.g., Duncan et al., 1996). Therefore, it is possible that the use of explicit instructions is one of the factors responsible for the absence of age differences in previous antisaccade studies.

Evidence for the importance of explicit instructions was obtained through comparison of the present results with the results from an experiment published elsewhere (Nieuwenhuis et al., 2000; Experiment 1). This experiment used virtually the same design and procedure but now the younger and older subjects were explicitly told to make active use of the cue by means of a saccade toward the target location. In addition, to increase the subjectively perceived necessity to make eye movements, the visual angle between fixation and each possible target location was increased to approximately 10° (compared with 4° in the present experiment).[5] Fig. 3A shows the discrimination accuracy data from

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[4] Recall that our experimental measures are not contaminated by age differences in perceptuomotor speed.

[5] Although saccades were required to discriminate the target and were consistently generated at either target eccentricity (4° and 10°), the phenomenological experience of subjects is that saccades are less necessary with smaller eccentricities.

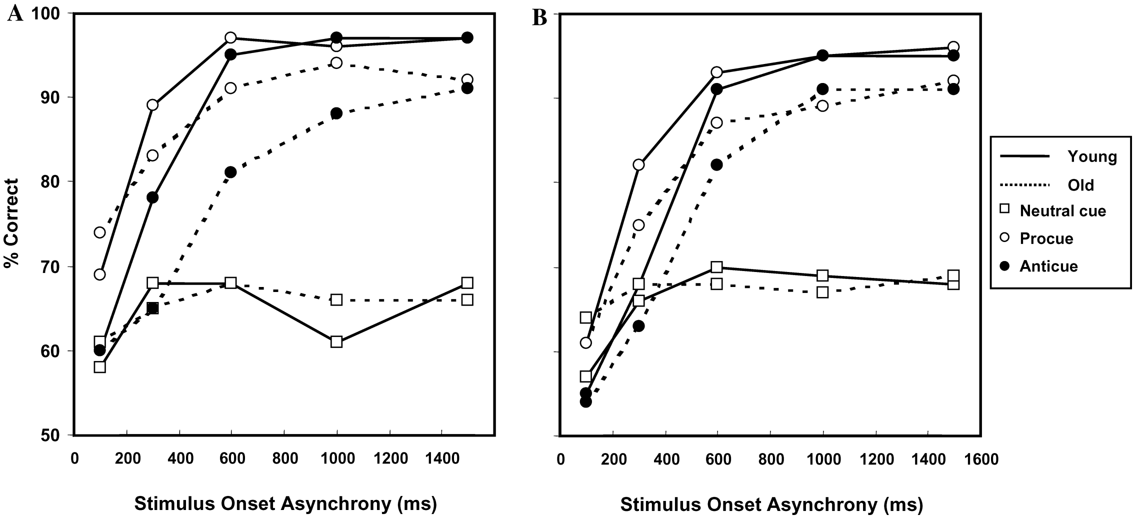

Fig. 3. Discrimination accuracy (%) as a function of cue condition and SOA for the younger and older age groups in Nieuwenhuis et al., 2000. (A) Experiment 1. Younger adults, N = 18, *M* age = 20.3, range 18–25; older adults, N = 18, *M* age = 68.9, range 59–80. (B) Experiment 2. Younger adults, N = 16, *M* age = 21.1, range 18–25; older adults, N = 16, *M* age = 68.6, range 61–79.

Nieuwenhuis et al. The results were very similar to those of the present experiment, with one important exception: the substantial difference between asymptotic levels of accuracy in the procue and anticue condition that was found for older adults in the present experiment, was now entirely absent. Thus, explicitly prompting subjects to make saccades was successful in the sense that it remedied the purported occasional failures by the older adults to initiate an endogenous antisaccade, but it did not seem to have affected the speed with which older adults were able to initiate antisaccades.

Inspection of the eye movement recordings reported by Nieuwenhuis et al. (2000, Experiment 1) suggested a reason for the age differences in the speed of initiating antisaccades. For many older adults, there was a strong relationship between SOA and the onset latency of antisaccades, such that longer SOAs were associated with slower antisaccades. A similar relationship was not observed in the procue condition. It seems that in the anticue condition, many older subjects adopted a strategy in which they attempted to exploit the onset of the target stimulus itself to trigger the antisaccade, and reserved endogenous initiation only for those instances in which the target did not appear promptly after the cue. Importantly, none of the younger subjects showed evidence of such a strategy.

At first sight, this strategy would seem counterproductive; in order to maximize their chances of correctly perceiving the facial expression, subjects should initiate the requisite saccade without delay. However, the perceptual impression of the facial expression at short SOAs, and especially in the anticue condition, was quite dim at best, resulting in the subjective experience of having to guess. Subjectively, therefore, the deleterious effects on the quality of perceptual judgment of briefly delaying the endogenous initiation of the antisaccade in waiting for the face stimulus may not have been obvious. With respect to the other, and in this experiment also prominent, goal, of making a correct antisaccade, the strategy must be deemed adaptive and clever, with older subjects apparently exploiting the external support provided by the triggering properties of the face stimulus itself to help them achieve that goal with greatly reduced effort.

An experiment (Nieuwenhuis et al., 2000, Experiment 2) was devised to test these conjectures. The experiment was identical to Experiment 1 from that study, with one important exception. To neutralize the unique exogenous qualities of the target stimulus, the target was now accompanied by three distractors (identical to the target face, but without a mouth) that were presented in the three remaining possible locations. This adjustment of the target display necessitated fully endogenous initiation of the required saccade. The mean discrimination accuracy data from this experiment are shown in Fig. 3B. The results show that, in contrast to Experiment 1 from the present study and the first experiment from Nieuwenhuis et al. (2000), age differences in the antisaccade condition were rather small and not any larger than age differences in the prosaccade condition. (This observation was supported by an additional between-experiments analysis, which yielded a significant three-way interaction of experiment, age group, and cue condition, $F(1,64) = 4.1$, $p < .05$.) The eye-movement recordings indicated that this reduction of age differences in discrimination accuracy was caused by markedly decreased age differences in antisaccade speed, especially at the longer SOAs. Thus, endogenous control of the oculomotor system in the antisaccade task seems to be little affected by age, because when the possibility of antisaccades being exogenously controlled was minimized, similar age effects on discrimination accuracy were obtained for prosaccades and antisaccades. This finding illustrates the previously forwarded view (De Jong et al., 1999) that in conflict tasks a purported bias against strict focusing of attention may only be overcome when such focusing is necessary in order to attain and maintain adequate task performance.

The experiments of Nieuwenhuis et al. (2000) seem to bridge most but not all of the gap between the findings reported in Experiment 1 and the studies by Fischer et al. (1997) and Munoz et al. (1998): unlike Fischer et al. and Munoz et al., Nieuwenhuis et al. (Experiment 2) found significant specific age differences in the proportion of direction errors and in the antisaccade SRTs. This suggests that oculomotor performance may be somewhat more sensitive to effects of age and goal neglect than discrimination accuracy. In the Fischer/Munoz paradigm, the explicit and only goal is to make a fast and correct saccade. In contrast, in the Nieuwenhuis paradigm, the main goal is to correctly identify the target and the generation of anticipatory saccades is only instrumental in enhancing the likelihood of achieving that goal. Put differently, the goal to make a saccade is the primary goal in the Fisher/Munoz paradigm, but only a subordinate goal in the Nieuwenhuis paradigm. Importantly, there is some evidence suggesting that goal activation failures are most likely when attention must be allocated in the service of multiple task demands (Baddeley, Della Sala, Papagno, & Spinnler, 1997; Duncan et al., 1996; Roberts et al., 1994). Further, it seems plausible to assume that goal neglect should first affect the subordinate requirement to make a swift saccade, especially since, as discussed above, the deleterious effects of neglecting this requirement on discrimination accuracy may not have been very obvious to subjects. Therefore, we propose that the need to meet multiple task demands may be an important determinant of between-task variability in the antisaccade task domain. Interestingly, the only other study investigating age-related effects on antisaccade performance that also included a target identification task, found clear age differences in the proportion of direction errors (Butler, Zacks, & Henderson, 1999).[6] Furthermore, as the present results suggest, the capability to keep multiple goals active is positively influenced by enhancing the saliency of actions associated with subordinate goals by means of instructions or manipulations of the necessity of such actions.

To summarize the results, we have discussed the effects on oculomotor performance of various factors that have previously been identified as mediating goal neglect in other task domains. Manipulation of these factors was argued to give rise to a continuum of antisaccade tasks that differ with respect to the saliency of the requirement to make a fast and accurate instrumental saccade. Interestingly, such manipulations had little effect on oculomotor performance in young adults; in contrast, they considerably affected such performance in older high-functioning adults. Thus, the results would seem to indicate a marked degree of goal neglect in older adults, consistent with previously reported results from other task domains (Duncan et al., 1996; West, 1999). Importantly, our results also highlight several factors that may be employed in order to ameliorate such goal neglect in older adults.

Given the close link between goal neglect, *g*, and frontal lobe functioning (Duncan, 1995), it is perhaps not surprising that older adults display goal neglect. First, for many tasks there is little effect of age on performance once age-related changes in fluid intelligence (i.e., *g*) have been partialed out (Rabbitt, 1993). Recall that Duncan and colleagues have proposed that *g* may in large part reflect the efficiency of a general goal activation process. And second, it has often been suggested that frontal dysfunction contributes substantially to the cognitive deficits of the elderly (West, 1996). Given the central role assigned to the frontal lobes in goal activation and goal maintenance (Duncan, 1995), it is possible, and consistent with the evidence presented here, that most of this contribution is mediated by goal neglect.

In the next sections of this paper, we will build upon the initial insights gained from these studies of goal neglect in normal aging and demonstrate how they can be extended to account for the distinctive pattern of executive capabilities and deficits in schizophrenia and obsessive-compulsive disorder.

3. Experiment 2: Schizophrenia

The general observation that persons with frontal lobe dysfunctioning may demonstrate generalized neuropsychological impairment without any clear selective executive deficit is perhaps best illustrated by schizophrenia patients, although it must be stressed that brain dysfunction in these patients is not confined to the frontal lobes (Buchsbaum, 1994). A recent, comprehensive review (Heinrichs & Zakzanis, 1998) of schizophrenic performance on a wide range of neuropsychological tests including those thought to measure executive function concluded that '...the evidence suggests that any selective deficits in functions... are relative and exist against a background of general dysfunction'' (p. 437). We know of no specific attempts to establish empirically whether this general dysfunction may be attributed to a

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[6] Butler et al. (1999) reported the absence of a specific age difference in the onset latency of antisaccades. However, this finding is likely to be an artifact of their task design (see Nieuwenhuis et al., 2000; for a discussion).

broad goal activation deficit. However, a possible relationship is suggested by Cohen and Servan-Schreiber's (1992) influential theoretical account of cognitive and biological disturbances in schizophrenia. These authors presented a set of formally related connectionist models that simulate normal and schizophrenic performance in three seemingly very different tasks. Model simulations showed that behavioral deficits of schizophrenics in each of these tasks can be modeled through the adjustment of one and the same model parameter in a model component corresponding to prefrontal cortex. Importantly, this adjustment was functionally interpreted as a degradation of the internal representation of contextual information, of which task requirements were proposed to be an important example. In each of the tasks this led to an increased probability of dominant but inappropriate response tendencies taking control over action. The possibility of interpreting goal activation and goal neglect within the connectionist approach of Cohen and Servan-Schreiber is further discussed in Section 5.

In line with the notion of generalized neuropsychological impairments in schizophrenia, the many studies that have examined schizophrenic performance on the antisaccade task have consistently reported an increased proportion of antisaccade errors in patients compared with controls (Broerse, Crawford, & Den Boer, 2001; Everling & Fischer, 1998). In addition, most studies have reported patients to exhibit increased antisaccade onset latencies in the context of normal prosaccade performance (Broerse et al., 2001), indicating that impairments in antisaccade performance are not due to a general oculomotor deficit. Importantly, with no exception these studies have used the most basic version of the antisaccade task, that is, the version in which making a swift saccade is the primary and only task. Thus, unlike older adults, schizophrenia patients experience difficulties even when the task provides the opportunity to fully focus on the requirement to make an antisaccade. From the above outlined goal activation perspective on antisaccade tasks, we reasoned that if schizophrenia is characterized by a severely deficient goal activation function, then schizophrenic performance should be extremely impaired in the version of the antisaccade task used in Experiment 1, in which instructions only mention the target discrimination task and do not explicitly refer to the need for making instrumental saccades. Put differently, severe goal neglect in schizophrenia should have particularly detrimental effects on oculomotor performance when the goal of making a saccade is only a subordinate goal. This issue was addressed in Experiment 2. Knowing that abnormalities in antisaccade performance are already present at the onset of schizophrenia (Hutton et al., 1998), we compared a group of first-episode schizophrenia patients with a group of healthy control subjects on the task used in Experiment 1.

3.1. Method

3.1.1. Subjects

This experiment included 12 patients (five women, *M* age = 28.1, *SD* = 8.5, range 20–48), who had recently experienced a first psychotic episode according to DSM-IV criteria (American Psychiatric Association, 1994). The diagnosis was based on a structured interview (SCAN, Wing et al., 1990). All patients were treated with novel antipsychotics (either olanzapine, risperidone or quetiapine), which were administered in a dose within the common therapeutical range. Treatment duration was at least six weeks. Exclusion criteria were (i) severe mental retardation; (ii) systemic or neurological illness; (iii) head injury; (iv) medication treatment other than antipsychotics; (v) severe tardive dyskinesia; and (vi) alcohol or substance abuse. Average education was at high school level. Since the Dutch educational system differentiates already after primary school, a coding system other than years of education was chosen. We coded the level of education ranging from 1 (primary school) to 5 (university or graduate school). The mean of the patient group was 3.7 (*SD* = .9). A control group of 24 healthy volunteers (16 women, *M* age = 29.0, *SD* = 7.5, range 18–44) were recruited from the local community and were matched to the patient group according to age and education. Exclusion criteria were (i) first degree relatives with severe psychiatric disease; (ii) severe mental retardation; (iii) systemic or neurological illness; (iv) head injury; and (v) alcohol or substance abuse. Average education was at high school level (*M* = 3.6, *SD* = .7). All subjects provided informed consent.

3.1.2. Stimuli, design, and procedure

Stimuli, design, and procedure were the same as in Experiment 1 with the following exceptions. Subjects received 144 practice trials before entering the experimental phase. Each set in the ABBA design included three blocks of trials. The first of every three blocks consisted of 18 trials, all of which were discarded, as in Experiment 1. The second and third block consisted of 54 trials each. The number of SOAs was reduced to three (200, 600, or 1400 ms, 18 trials per block with each SOA), which we expected would be sufficient to capture the dynamics of the function relating SOA to discrimination accuracy. Mean target duration was 165 ms for the schizophrenia group and 118 ms for the control group, $F(1,34) = 7.6$, $p < .01$. The experiment involved one session of approximately 45 min.

3.2. Results and discussion

Fig. 4 shows mean discrimination accuracy data for patients and their matched controls. The data can be summarized as follows. First, the two subject groups showed very similar performance at the 200-ms SOA

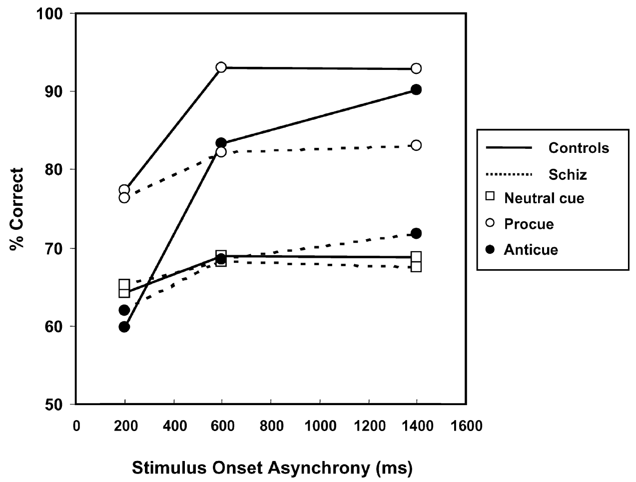

Fig. 4. Discrimination accuracy (%) as a function of cue condition and SOA for the schizophrenia group and control group in Experiment 2.

in both experimental cue conditions. Because this SOA is too short to allow for a substantial contribution to choice performance of voluntarily controlled eye movements, any cuing effect is most likely due to automatic capture of the eyes by the abrupt onset cue (Kramer, Hahn, Irwin, & Theeuwes, 1999). The results suggest that this tendency is preserved in our schizophrenia patients. Second, even when given ample time, the patients hardly took benefit from the opportunity to improve their performance through use of the cue, despite being carefully instructed to do so. Indeed, the patients' data indicate a similar reduction in asymptotic performance in the pro- and anticue conditions, suggesting that failures to use the cue to anticipate the target location were equally distributed across these two conditions. In contrast, the controls performed much like the young adults in Experiment 1 and managed to attain near-ceiling performance in both conditions within 1.5 s. It is worth emphasizing that the difference in performance between patients and controls cannot be attributed to differences in perceptuomotor speed because the neutral condition controlled for such differences.

The same statistical analyses were performed as in Experiment 1. The staircase tracking procedure was successful at equating both subject groups in the neutral condition, as indicated by a non-significant main effect of subject group, $F < 1$. The main analysis, involving the procue and anticue condition, confirmed that the effects of cue condition and SOA, and their interaction, were all highly significant, $p < .001$. Overall, the controls performed more accurately than the patients, $F(1,34) = 12.2$, $p = .001$, and showed a greater increase of accuracy with increasing SOA, $F(2,68) = 20.4$, $p < .001$. The greater SOA effect for controls was more evident in the anticue condition than in the procue condition, as indicated by a significant three-way interaction, $F(2,68) = 3.8$, $p < .05$. The interaction of subject group and cue condition was not significant, $F(1,34) = 2.1$, $p = .16$.

Experiment 2 suggests that, at least in the context of antisaccade tasks, excessive goal neglect can be witnessed at the onset of the clinical manifestations of schizophrenia. Although schizophrenia patients, despite being severely impaired on the antisaccade task, show normal performance on the "easy" version of the prosaccade task, in which saccades are explicitly required, this was not the case in the present, "difficult" task version, in which the goal to make saccades was subordinate to the discrimination of targets. In fact, the patients' data suggest that the voluntary component of their prosaccade performance was similarly impaired as the voluntary component of their antisaccade performance, as indicated by a rather weak improvement of target discrimination accuracy despite ample time to do so. This relative inability to incorporate the generation of anticipatory saccades within the overall task plan of optimizing choice performance can, in all probability, be attributed to the combined effects of the factors that distinguish the "difficult" version of the pro- and antisaccade task from the "easy" version: the absence of explicit instructions, the possibility of adopting a suboptimal performance mode as enabled by the support from the exogenous target onset, and the subordinate nature of the saccade component of the task.

Above, we have assumed that goal neglect affects the endogenous saccade component rather than the visual discrimination component of the tasks. This assumption seems justified, because our finding that the two groups reached equivalent accuracy levels at the shortest SOA is hard to reconcile with the notion of goal neglect affecting visual discrimination. Accordingly, Duncan et al. (1996, Experiment 3) found that the order in which task requirements were specified to the subject at the start of the experimental session, had a clear impact on which task component tended to be neglected. More specifically, a task requirement was more likely to be neglected when several other requirements had already been specified and activated. Note that in our experiments subjects first received extensive practice with the neutral condition. Only after the practice phase were subjects instructed about and exposed to the requirement to generate anticipatory saccades in response to the cue. It would be interesting to know to what extent the saccade component and visual discrimination component would be neglected if subjects first received practice with a pure saccade task (i.e., without a discrimination component), and were only then instructed about the need to discriminate stimuli at the target location.

4. Experiment 3: Obsessive-compulsive disorder

Experiments 1 and 2 suggest a clear susceptibility to goal neglect of older, high-functioning adults and of first-episode schizophrenia patients. At the level of the frontal lobes, both aging (Phillips & Della Sala, 1996) and schizophrenia (e.g., Goldman-Rakic, 1994) have often been characterized by biological disturbances of lateral prefrontal cortex. In a recent review of functional neuroimaging studies, Duncan and Owen (2000) showed that lateral prefrontal cortex and dorsal anterior cingulate cortex are consistently recruited by a wide range of different cognitive demands, whereas most of medial and orbital prefrontal cortex is largely insensitive to these demands. These and other results (Duncan et al., 2000) suggest that *g* may reflect the efficiency of a relatively specific frontal circuit, and raise the possibility that severe goal activation deficits may be restricted to populations with dysfunction in lateral prefrontal cortex.

To assess this hypothesis, Experiment 3 examined a group of patients with obsessive-compulsive disorder (OCD). OCD is characterized by severe and recurrent obsessional thoughts and compulsive behaviors, even though these thoughts and behaviors are regarded as inappropriate by the patient. OCD patients have been shown to be impaired on measures of visuospatial memory, cognitive set shifting and other, though predominantly non-verbal cognitive functions (for a review, see Wilson, 1998). Importantly, their neuropathology is well known to involve orbitomedial regions of the prefrontal cortex along with several subcortical areas (e.g., Swedo et al., 1989). Therefore, we predicted little or no impairment in the "difficult" version of the antisaccade task.

4.1. Method

4.1.1. Subjects

This experiment included 23 patients (16 women, *M* age = 32.3, *SD* = 9.3, range 19–52) with obsessive-compulsive disorder meeting the DSM-IV criteria (American Psychiatric Association, 1994) for the disorder. OCD symptoms were assessed with the Yale Brown Obsessive Compulsive Scale (Y-BOCS, Goodman et al., 1989; *M* = 24.0, *SD* = 5.7). Patients were drug-free for at least 4 weeks prior to testing. Exclusion criteria were (i) severe mental retardation; (ii) major depression and/or anxiety disorders; (iii) history of a psychotic episode; (iv) systemic or neurological illness; (v) head injury; and (vi) alcohol or substance abuse. Average education was at high school level (*M* = 3.2, *SD* = .9). The OCD patients were compared with the same control group as in Experiment 2 and were matched to this group according to age, sex, and education. In addition, both groups were administered the Raven Standard Progressive Matrices test as a measure of fluid intelligence. No difference in estimated intelligence levels was found between groups (OCD, *M* = 112.5, *SD* = 10.9; controls, *M* = 116.0, *SD* = 13.5; $t = 9.6$, $p = .35$). Other characteristics of the control group are described in the 'subjects' section of Experiment 2. All subjects provided informed consent.

4.1.2. Stimuli, design, and procedure

Stimuli, design, and procedure were the same as in Experiment 2. Mean target duration was 128 ms for the OCD group and 118 ms for the control group, $F(1,45) = 1.2$, $p = .27$.

4.2. Results and discussion

Fig. 5 shows mean discrimination accuracy data for the OCD patients and the control group. It is immediately clear that the two groups displayed strikingly similar performance in all conditions. The OCD patients were a bit less accurate at the longest SOA, but this was the case in both the procue and anticue condition. Though speculative, it is possible that the increased tendency to doubt and control the outcome of their actions, here induced by a relatively long interval of nothing happening on the screen, occasionally led OCD patients to check whether the target had already appeared in one of the three non-selected locations. If, on these occasions, the target appeared in the initially attended location after all, this would hamper target identification.

The same statistical analyses were performed as in the previous experiments. The staircase tracking procedure was successful at equating both subject groups in the neutral condition, as indicated by a non-significant main effect of subject group, $F < 1$. The main analysis confirmed that, as in the previous experiments, the effects of cue condition and SOA, and their interaction, were all highly significant, $p < .001$. Most importantly, the main effect of subject group and the interaction terms including this between subjects factor were all far from significant: subject group, $F(1,45) = .2$, $p = .70$; subject group × cue condition, $F(1,45) = .003$, $p = .96$; subject

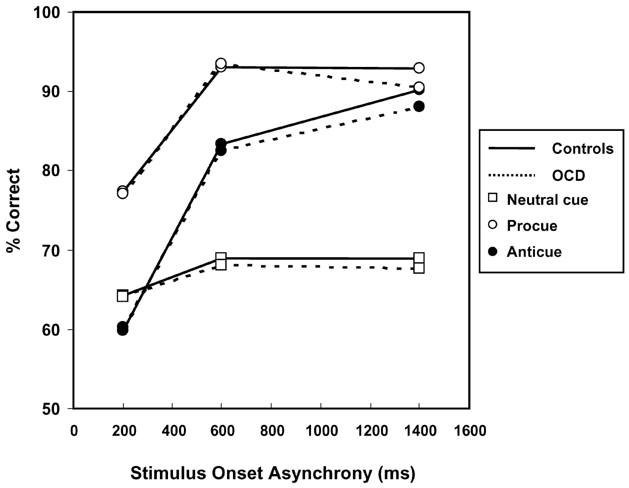

Fig. 5. Discrimination accuracy (%) as a function of cue condition and SOA for the obsessive-compulsive disorder group and control group in Experiment 3. Note that the same control group was used as in Experiment 2.

group × SOA, $F(2,90) = .7$, $p = .47$; three-way interaction, $F(2,90) = .1$, $p = .88$.

The data showed fully intact performance of OCD patients on the "difficult" version of the antisaccade task. From our goal activation perspective on antisaccade tasks, it follows that OCD patients should also demonstrate normal performance on the "easy" version of the antisaccade task. To our knowledge, there are four published studies reporting OCD performance on antisaccade tasks, all of which have used the "easy" task version. Two of these studies (Maruff, Purcell, Tyler, Pantelis, & Curry, 1999; McDowell & Clementz, 1997) report equivalent error rates in the antisaccade condition for OCD patients and controls. Furthermore, Maruff et al. (1999) report a reliable but relatively small (approximately 35 ms) reduction in antisaccade speed in OCD patients, whereas prosaccade speed is fully unaffected. McDowell and Clementz did not include a prosaccade control condition, which prevents interpretation of group differences in antisaccade speed. Two other studies (Rosenberg, Dick, O'Hearn, & Sweeney, 1997; Tien, Pearlson, Machlin, Bylsma, & Hoehnsaric, 1992) report an overall impairment in antisaccade performance in OCD patients, but these studies used insufficient numbers of trials (for a discussion of these methodological shortcomings, see Maruff et al., 1999; McDowell & Clementz, 1997), which cast serious doubt on the reliability of their findings. Thus, although the evidence is scant, OCD patients' performance on the "easy" version of the antisaccade seems indeed, to a large extent, unimpaired. Together, these findings are consistent with the hypothesis that severe goal neglect is specifically characteristic of neuropsychological populations with dysfunction of lateral prefrontal cortex.

5. General discussion

We have presented a relatively new theoretical perspective (De Jong et al., 1999; Duncan, 1995; Duncan et al., 1996), according to which executive dysfunction is characterized not as a consistent and replicable pattern of cognitive limitations, but rather as failures to fully or consistently focus attention on task demands, even though these demands can, in principle, be met. Evidence for such disregard of task demands, or goal neglect, can be obtained through examination of the effects of variations in attentional focus. We have illustrated this approach for the antisaccade task, which, like other conflict tasks (De Jong et al., 1999), is highly sensitive to goal activation failures. As stated by Roberts et al. (1994): "…successful [antisaccade] performance seems dependent on maintaining a high enough level of activation of the relevant self-instructions to make an eye movement to the opposite side at the moment the cue is presented" (p. 391)". Our study suggests that the goal activation process is mediated by instructions, environmental structure, and concurrent task requirements, all of which induce systematic variation in attentional focus. The importance of such factors has previously been emphasized in the context of prospective memory tasks (Duncan et al., 1996), and other conflict tasks (De Jong, 2001; De Jong et al., 1999). The results also support the conclusion that a susceptibility to goal neglect is characteristic of healthy older adults and, to a larger extent, of schizophrenia patients, but not of individuals with OCD.

To our knowledge, other theoretical frameworks for explaining existing dysfunction make no predictions regarding the varying performance profiles (of for instance older adults and schizophrenia patients) across the versions of the saccade tasks compared here. Here we focus on inhibitory deficit theories, since deficient top–down inhibition of reflexive eye movements is a particular prominent feature in verbal models trying to account for antisaccade performance deficits. It is important to point out that some of our procedures to enhance the saliency of the requirement to execute instrumental saccades (i.e., presenting the target at a more peripheral position, and the use of distractors accompanying the target) also enhanced the objective difficulty of the primary discrimination task. From a limited inhibitory capacity perspective, one would therefore expect that these manipulations should, if anything, enhance purported manifestations of inhibitory failure, instead of reducing or eliminating such manifestations as the present results indicate. The appropriateness of explaining antisaccade performance deficits in terms of inhibitory deficits is further called into question by recently proposed computational models of saccadic control. These models can account for many oculomotor phenomena, including reflexive saccade errors and the specific slowing of antisaccades, without the need to incorporate top–down inhibitory connections (Kimberg & Farah, 2000; Trappenberg, Dorris, Munoz, & Klein, 2001). Consistent with the goal activation account, these models suggest that prefrontal cortex sustains a representation of the task goal to produce an endogenous antisaccade, which biases processing in posterior areas (like the superior colliculus; Trappenberg et al., 2001) that tend to generate a saccade toward the target (see Miller & Cohen, 2001; for a general review of studies of prefrontal cortex consistent with this view). Weakening of the connections between prefrontal and posterior areas reduces this bias and leads to the observed antisaccade deficits (Kimberg & Farah, 2000). These models also suggest a parsimonious account of the finding that antisaccade performance is impaired when subjects have a concurrent working memory load (Roberts et al., 1994). Rather than merely saying that working memory load interferes with inhibitory processes, the goal activation account suggests that working memory load interferes with the active memory representation of the goal to make antisaccades (cf. Kane & Engle, 2003).

Finally, although we believe that goal neglect is a central element of executive dysfunction in the antisaccade task and other conflict tasks, we acknowledge that individuals' performance may well suffer from other types of limitations. A coarse task analysis suggests that, compared to the prosaccade task, performance on the antisaccade task must require the operation of several additional component processes, each of which might be disrupted. For instance, one may ask whether the poor performance of schizophrenia patients on the "easy" version of the antisaccade task (Broerse et al., 2001; Everling & Fischer, 1998) is diagnostic of a catastrophic goal activation deficit (i.e., pertaining even to situations that promote effective mobilization of attention), or rather due to additional cognitive limitations. Further research is needed to distinguish between these possibilities.

5.1. Methodological implications

Our studies and literature review illustrate the potential problems with the common approach of selecting a specific task, or version of a task, as an operationalization of a theoretical construct or mental ability, such as when a task is thought to measure inhibitory ability (cf. Rabbitt, 1997). For instance, some authors have reported clear age differences in the control of antisaccades (Butler et al., 1999; Experiment 1 from this study), whereas others (Fischer et al., 1997; Munoz et al., 1998), using slightly different task versions, have reported no such differences. Obviously, as relevant conclusions in this example would be critically dependent on which specific task version has been employed, the choice of task becomes a major issue that should be decided on principled grounds and not based on incidental preferences of investigators. We suggest a different, more principled approach. In this approach, several task versions are employed. The different versions share a subset of goals –with each goal corresponding to a distinct aspect of overall task performance– but differ in the nature of the overall goal network and, more specifically, in the prominence of the shared subset of goals in this network. In this paper, we have studied the influence of the saliency of the requirement to execute saccades, hypothesizing that enhancing this saliency would promote goal activation and goal maintenance and thus help prevent goal neglect. The results for age effects on saccadic performance nicely confirmed this hypothesis.

A major benefit of this methodological approach can be appreciated by considering the different profiles of success and failure across the various task versions for the different groups examined in this study. For instance, only performance in the antisaccade condition in the "difficult" version of the task was found to discriminate between healthy older adults and OCD patients. Also, prosaccade performance in the "easy" version of the task does not discriminate between patients with schizophrenia and other groups such as healthy older adults and OCD patients, whereas prosaccade performance in the "difficult" version clearly distinguished between these groups. In general, then, the ability or power to distinguish between different populations with known or suspected frontal-lobe dysfunctioning may well be critically dependent on having available profiles of performance across task versions.

A central assumption underlying this approach is that people's strategies for goal setting and goal maintenance can be influenced by manipulations of the saliency of task requirements. It is important to emphasize the methodological point that such manipulations should be applied preferably at a between-subjects level. Several previous studies using a within-subjects design have found a marked lack of flexibility in adjusting strategies in response to changing instructions or task requirements that other studies, using a between-subjects design, have generally found to result in robust changes in strategy (De Jong, 2000; Los, 1996; Strayer & Kramer, 1994). These findings suggest that differences in performance between various task versions, which differ with respect to saliency of task requirements, may be greatly reduced in the context of within-subjects design. This important methodological point deserves further examination.

5.2. Links with neuroscience and computational modeling

Neuroimaging reviews suggest that lateral prefrontal cortex and dorsal anterior cingulate cortex are key components of a frontal circuit that is necessary for dealing with a wide range of task demands (Duncan & Owen, 2000; Duncan et al., 2000). Although more direct evidence is needed, it may prove useful to conceive of this frontal circuit as implementing a general goal activation function. According to this conception, severe goal activation failures should be specifically characteristic of populations with damage or dysfunction in this frontal circuit. This perspective receives support from our observation of goal neglect in older age and schizophrenia, both of which are characterized by dysfunction of lateral prefrontal cortex. In contrast, patients with OCD, which involves other frontal regions, and patients with parietal lesions (Duncan et al., 1996) show no evidence of goal neglect. Interestingly, although many cortical regions are involved in antisaccade task performance, an increased number of antisaccade errors is specifically seen after lesions of lateral prefrontal cortex or anterior cingulate cortex, but not after lesions of the supplementary eye fields, frontal eye fields, posterior or temporal cortex (for review, see Everling & Fischer, 1998). As noted by Duncan and colleagues (e.g., Duncan et al., 1997), other regions of prefrontal cortex appear to have rather domain-specific functions that are considered not to be characteristically "executive" in nature. A striking example of the effects of lateral prefrontal cortex damage on goal activation in the antisaccade task was reported by Walker and colleagues (Walker, Husain, Hodgson, Harrison, & Kennard, 1998). They presented a case study of a patient with a right lateral PFC lesion who, despite perfect verbal knowledge of the response required on each antisaccade trial, made 100% direction errors, regardless of required saccade direction.

Goal activation and goal neglect are still rather poorly defined concepts. Therefore, in order to establish their construct validity, we need not only develop new and refine existing empirical techniques for uncovering the phenomena that these concepts refer to; ultimately, we need to formalize the concept of goal activation and describe in more detail how goal neglect can arise. For instance, how can we account for the fluctuations in focused attention that underlie manifestations of goal neglect in conflict tasks? An intriguing possibility is offered by a recent theoretical study (Botvinick, Braver, Barch, Carter, & Cohen, 2001), building forth on the connectionist work by Cohen and colleagues (e.g., Cohen, Dunbar, & McClelland, 1990; Cohen & Servan-Schreiber, 1992). Botvinick et al. propose that mobilization of control processes may be accomplished in part through monitoring for response conflicts in information processing. When conflict, characterized by the concurrent activation of mutually incompatible response channels, is detected by the conflict monitoring system, attention is more tightly focused on the relevant stimuli or stimulus-response mappings to reduce conflict on future occasions. Using connectionist simulations, Botvinick et al. show that a direct feedback loop connecting a conflict monitoring system with an attentional control system provides a unifying explanation for the effect of the relative proportion of non-corresponding trials on the Stroop effect (e.g., Logan & Zbrodoff, 1979), and a set of other, seemingly different "strategic" behavioral phenomena. Botvinick et al.'s work also illustrates that, in the context of conflict tasks,[7] problems with the consistency of control allocation may originate in dysfunction of either one of these systems or their connection. These findings suggest that the integration of computational modeling, cognitive psychology, and neuroscience may eventually lead to a more precise understanding of goal activation failures.

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[7] For suggestions how similar principles may be applied to prospective memory failures, see Cohen and O'Reilly (1996).

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