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An examination of the nature of attentional deficits in patients with Parkinson's disease: Evidence from a spatial orienting task

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Abstract

Endogenous and exogenous shifts of attention were examined in nondemented patients with Parkinson's disease (PD). In the endogenous condition, an arrow was used to cue participants' attention to the possible location of an impending target, whereas in the exogenous condition, a brightened box was used to cue attention. Cues were either valid (i.e., the target appeared in the cued location) or invalid (i.e., the target appeared in a noncued location). The time between cue onset and target onset (stimulus onset asynchrony or SOA) was varied in each condition. The results indicated that PD patients were not differentially impaired in shifting attention at the shorter SOAs relative to normal controls. However, at longer SOAs, the PD patients demonstrated less of an effect from cueing than did the normal control participants. PD patients' differential effect from cueing was evident in both exogenous and endogenous conditions. These results suggest that PD patients may experience a rapid decay of attentional inhibition and do not support the notion that a decrement in processing resources underlies their attentional deficits. Moreover, these findings further support the notion that the basal ganglia may play an important role in attentional functions. (*JINS*, 1997, *3*, 337–347.)

Keywords: Attention, Parkinson's disease

INTRODUCTION

Although it is well accepted that cognitive impairment can be an integral component of Parkinson's disease (PD), the nature and range of this impairment is not well understood. In recent years, investigators have attempted to account for PD patients' cognitive impairments using a single unifying neurobehavioral theory (Karayanidis, 1989; Brown & Marsden, 1990; Taylor et al., 1990; Dubois et al., 1991). One prominent theory, developed by Brown and Marsden (1990), holds that PD patients' cognitive impairment is directly related to a decrement in cognitive "resources" that are necessary to perform a given task. Their theory is based on Norman and Shallice's cognitive model of attention (cited in Shallice, 1988, pp. 328–352), which posits a supervisory attention system (SAS) that is responsible for the modulation of lower cognitive operations, particularly under novel conditions or when automatic responding cannot be used to perform a task. When the capacity of the SAS is exceeded by a given task, a decrement in performance will be observed. According to Brown and Marsden, PD results in a decrease in the processing resources within the SAS, and as a result, these patients are more likely to demonstrate impairment as the processing demands of any given task increase.

Several converging lines of evidence provide support for the idea that the cognitive deficits associated with PD are due to a reduction in their processing resources. For example, a number of studies have indicated that PD patients demonstrate greater impairment on memory tasks that are more effortful as compared to memory tasks that are less demanding (Weingartner et al., 1984; Breen, 1993; Cooper & Sagar, 1993; Buytenhuijs et al., 1994). PD patients have also been shown to be more impaired on each of two tasks performed

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simultaneously than when the identical tasks are performed separately, suggesting that the dual task performance exceeded PD patients' reduced processing resources (Horstink et al., 1990; Brown & Marsden, 1991; Brown et al., 1993; Dalrymple-Alford et al., 1993). In addition, several studies have demonstrated that PD patients are more impaired on tasks that require the use of resource demanding internal cueing mechanisms than on tasks that use external cues that place relatively low demands on processing resources (Cools et al., 1984; Brown & Marsden, 1988; Georgiou et al., 1994).

From a neuroanatomical point of view, it has been suggested that damage to the frontal lobes will result in a deficit in the SAS (Shallice, 1988), and Brown and Marsden argue that the depletion of the processing resources of PD patients is related to such frontal dysfunction. It is now widely accepted that there are several functionally segregated circuits that reciprocally connect the basal ganglia with the thalamus and the cortex (Alexander et al., 1986). A number of investigators, including Brown and Marsden, have implied that damage at any point within this circuit can lead to a similar pattern of cognitive impairment (Brown & Marsden, 1990; Cummings, 1993). Thus, the frontal dysfunction in PD is thought to occur secondarily to the loss of dopaminergic innervation of the basal ganglia, and the resulting disruption of these frontostriatal circuits. Numerous neuropsychological studies have implicated frontal lobe dysfunction in the cognitive impairment of PD patients and suggest that this dysfunction may be the single neuropathological correlate of their deficits. For example, Bondi et al. (1993) found that PD patients' impairment on a variety of measures of visual spatial cognition were related to frontal dysfunction, and were not visual spatial deficits *per se*. Stam and colleagues (1993) found that PD patients' impaired performances on certain neuropsychological tests were associated with a disturbance in an event-related potential believed to be invoked by frontal structures during attentional processing, and Grossman et al. (1992) found that a decrease in resting blood flow in the medial aspects of the frontal lobes in PD patients was positively associated with their poor performance on an attention-demanding sentence processing task.

In contrast to the evidence supporting Brown and Marsden's theory, a few studies, which have directly tested the processing resources account, have not provided support. For example, V.J. Brown et al. (1993) compared the performances of PD patients and normal controls on a choice reaction time task in which cues prompting either a left or a right key press varied in the nature of the intrinsic information they provided about the required response. In a spatially compatible condition, the cue consisted of a solid box on the right (indicating that a right response should be made) or left (indicating that a left response should be made); in a compatible symbolic condition, the cue consisted of a centrally presented arrow pointing to the right (indicating a right response) or left (indicating a left response); and in an arbitrary symbolic condition, the cue consisted of a centrally presented box (indicating a right response) or circle (indicating a left response). Because the arbitrary symbolic condition required the processing and utilizing of internal cues, it was hypothesized that if PD patients have a processing resource deficit, they should be differentially impaired in that condition as compared to the compatible symbolic or spatially compatible conditions. In contrast to the processing resources theory, however, V.J. Brown et al. (1993) found that the PD patients were differentially impaired in the spatially compatible condition as compared to the two other conditions.

A recent study by Downes and colleagues (Downes et al., 1993) also failed to support the reduced processing resources account of PD patients' cognitive deficits. These investigators had PD patients and control participants rapidly generate words from either a letter category or a semantic category, generate words while alternating between two different letters or two different semantic categories, or generate words while alternating between a letter and a semantic category. On half of the trials, the participants were provided with visual cues that indicated the current letter or category, and in the other half no cues were provided. The results indicated that the PD patients were impaired when required to alternate between a letter and a semantic category but not when required to produce words from a single letter or semantic category, or to alternate within letter or semantic categories. Most importantly, the observed deficit did not improve when the participants were provided with visual external cues. Downes et al. (1993) argued that their results did not support the notion that PD patients have a depletion in their cognitive resources because (1) the patients were not impaired in all of the alternating conditions, even though all of these conditions should have been more resource demanding than the single category condition; and (2) the presentation of visual cues, which should have reduced processing demands, did not lead to improved performance in the condition in which subjects had to alternate between a letter and a category. In contrast, Downes et al. (1993) explained their results in terms of a deficit in inhibitory mechanisms. That is, when generating a word beginning with a specific letter, the PD patients were unable to inhibit the previous response set of producing a word from a specific semantic category, or *vice versa*.

The idea that PD patients have a deficit in inhibitory mechanisms may also explain the results of a recent study (Maddox et al., 1996), which showed that PD patients were impaired on a perceptual decision task that required them to attend selectively to one stimulus component while ignoring another, but not when they had to integrate the two stimulus components or when only one of the stimulus components was presented. The PD patients may have been unable to inhibit the processing of the extraneous visual feature. Similarly, an inability to inhibit shifting their attention across hierarchical levels may explain the PD patients' impairment on a task in which subjects were presented with global–local stimuli (e.g., a large "1" made up of small "3"s) and asked to indicate whether they saw a "1" or a "2" at either of the levels (Filoteo et al., 1992, 1995). On consecutive

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trials, the target could either appear at the same level (e.g., the target could appear at the global level on two consecutive trials) or could change levels (e.g., the target could appear at the global level on one trial and then at the local level on the next trial). The PD patients took less time than controls to identify the target on the second of two consecutive trials when the target changed levels, whereas they took more time when the target remained at the same level. Although these results were initially interpreted as a deficit in maintaining attention (in that the PD patients' attention may have rapidly disengaged from the previously attended global-local level), this pattern could also indicate that PD patients are unable to inhibit the movement of their attention away from the previously attended level.

Taken together, these latter studies suggest that PD patients may demonstrate a specific impairment in the ability to inhibit the movement of their attention from one cognitive process to another, and this can be observed on tests of verbal fluency (e.g., Downes et al., 1993), selective attention (e.g., Maddox et al., 1996), or shifting attention between different levels of hierarchical stimuli (e.g., Filoteo et al., 1992, 1995). Such a deficit in PD patients would also be expected to be observed whenever task demands require subjects to engage attentional mechanisms on a particular stimulus attribute or cognitive operation and maintain this attentional engagement over a period of time. An impairment in inhibiting an attentional disengagement could possibly have accounted for the pattern of PD patients' performances in the studies described above.

In view of the controversy surrounding the basis of PD patients' attention deficits, the purpose of this present study was to contrast two accounts of their attentional impairment: (1) Brown and Marsden's theory that PD patients have reduced processing resources, and (2) the notion that PD patients' attentional deficits are best characterized as an impairment in inhibitory processes. Because Brown and Marsden's theory predicts that PD patients should be more impaired on tasks that require the use of internal cues than when external cues can be used to direct their behavior, the present study used an orienting of attention paradigm (Posner, 1980; Posner et al., 1980) which allows both internal and external cueing mechanisms to be examined. In this paradigm, subjects are presented with a visual cue that directs their attention to a specific location within the visual field. Following a variable interval, a target is presented at one of four spatial locations, and the participants press a button as soon as they detect the target (see Figure 1). The cue can either be valid in the sense that it correctly directs the locus of attention to the location at which the target appears, or it can be invalid because it directs attention to a location other than that of the impending target. Studies with normals have indicated that response times are much lower when the cue is valid than when it is invalid (Posner, 1980; Posner et al., 1980). This *validity effect* is believed to be due to participants having shifted their attention to the spatial location that was indicated by the cue: on valid trials participants shift their attention to the location where the target is going to appear and are thereby much quicker at detecting the target. In contrast, on invalid trials, they take longer to identify the target because they shift their attention to an incorrect location and must disengage their attention from that location and move it to the correct target location.

The advantage of using this task is that the nature of the visual cue can be manipulated in a manner that allows one to examine internal and external attentional mechanisms. In this study, we used two types of cues: (1) an endogenous or symbolic cue, which consisted of a centrally presented arrow; and (2) an exogenous or spatial cue, which consisted of a brightening box at one of the four spatial locations. Although these two types of cues are efficient at directing attention within the visual field, it has become increasingly clear that they have different properties. Jonides (1981) and Rafal and Henik (1994) have specified several important differences between endogenous and exogenous attentional cues in normal individuals. First, the efficiency at which attention is moved based on the two cue types appears to differ in that normals are much quicker to detect a target following exogenous cues as compared to endogenous cues. This is believed to be due to the fact that the exogenous cues elicit more of an automatic shift of attention, whereas endogenous cues (e.g., arrow cues) require participants to translate the meaning of the cue in order to use that information to shift attention. Second, shifts of attention following endogenous cues can be interrupted by a secondary task, whereas exogenous cues do not appear to be as affected. This indicates that shifts of attention following endogenous cues require more processing resources than shifts of attention following exogenous cues. Third, people can ignore endogenous cues when instructed to do so, which subsequently leads to diminished cueing effects, whereas they cannot ignore exogenous cues. Fourth, normals exhibit the *inhibition of return* phenomenon at longer cue–target intervals when exogenous cues are used, but do not under endogenous cueing conditions. Inhibition of return refers to slower responding to targets following valid cues than invalid cues and is believed to be due to the active inhibition of the return of attention to a previously attended location (Posner & Cohen, 1984).

The characteristic properties of endogenous and exogenous cues can be used to argue that these two cue types place a different degree of demand on internal attentional mechanisms. Specifically, it appears that endogenous cues (i.e., the arrow cue) place more demands on internal attentional mechanisms, whereas exogenous cues place less of an emphasis on this attentional system. If this is the case, then we should be able to utilize this paradigm in order to examine whether PD patients' attentional deficits are better characterized as a reduction in processing resources or an impairment in inhibitory attentional mechanisms. If PD patients exhibit a decrease in their processing resources, we would predict that their ability to shift attention within the visual field would be disproportionately affected when endogenous cues are used relative to exogenous cues. In contrast, if PD patients' attentional impairments are best

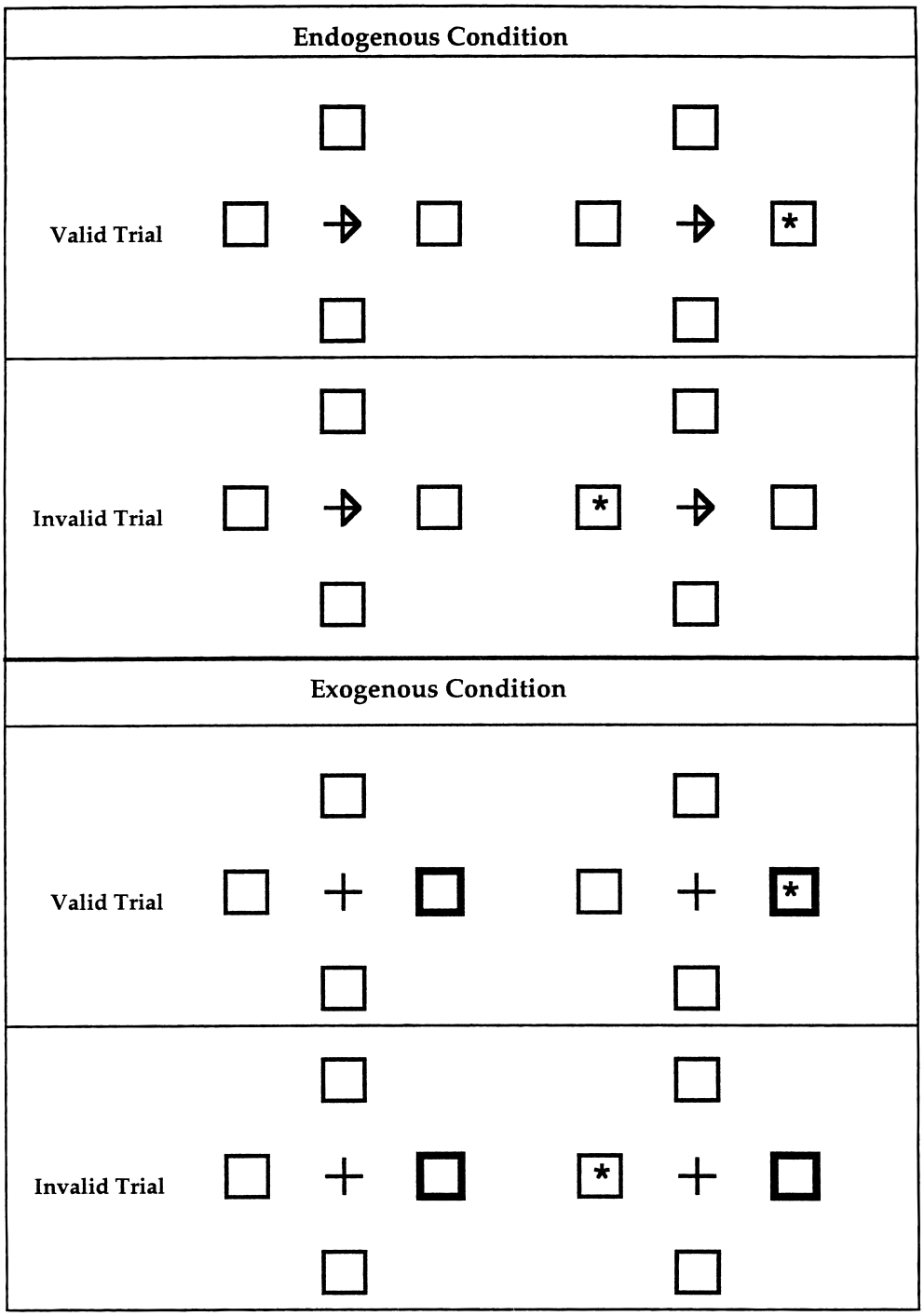

Fig. 1. Examples of valid and invalid trials for the endogenous and the exogenous conditions.

characterized as a deficit in inhibitory processes, we would expect these patients to demonstrate equivalent levels of impairment in shifting attention following the two cue types. More specifically, based on our previous findings that PD patients tended to disengage attention more rapidly from a previously attended location (Filoteo et al., 1992, 1995), we expected that the PD patients would demonstrate less of a validity effect following *both* endogenous and exogenous cues.

METHODS

Research Participants

Seventeen patients with idiopathic PD (12 men and 5 women) and 17 normal controls (12 men and 5 women) participated in this study. All participants were right-handed. The PD patients were recruited from the Movement Disorders Clinic at the University of California, San Diego. The diagnosis of

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PD was made by a senior staff neurologist (C.W.S.) based on the presence of at least one of the three cardinal features of PD (i.e., tremor, rigidity, bradykinesia). PD patients were excluded from the study if they had a history of stroke, head injury (loss of consciousness for more than 5 min), alcoholism (4 or more drinks per day for more than 1 year), or any other neurological condition. Fifteen of the PD patients were on dopaminergic replacement therapy, 1 was on both dopaminergic and anticholinergic therapy, and 1 patient was not taking any medication. Eighty-nine percent of the patients reported tremor as their predominant symptom. Using Hoehn and Yahr's (1967) staging of PD, four patients were in stage I, seven in stage II, four in stage III, and two in stage IV. The mean length of illness for the patients was 10.65 years ($SD = 8.31$).

The normal control (NC) participants were recruited from the community. Exclusion criteria included a history of neurological disease, head injury, alcoholism, or serious psychiatric illness. The inclusion and exclusion of potential NC participants was made by the first author (J.V.F.) and was based on an informal interview and questionnaire. The NC participants were included in this study if their age and education matched those of the PD patients. Table 1 shows the mean age, years of education, and scores on the Dementia Rating Scale (DRS: Mattis, 1976). The PD patients did not differ from the normal controls in terms of mean age ($p > .05$) or years of education ($p > .05$). In addition, there was not a significant difference between the PD patients and the NC subjects in their scores on the DRS ($p > .05$), indicating that, as a group, these PD patients were nondemented.

Orienting of Attention Task

Each participant was administered two different orienting conditions: the endogenous condition and the exogenous condition. In each condition, the subjects were asked to fixate on a central cross and were presented with visual targets which consisted of a single asterisk. The target would appear in one of four boxes which were displayed above, below, to the right, and to the left of the central cross (see Figure 1). The central cross was 1.0 × 1.0 cm and the boxes were 2.0 × 2.0 cm. The boxes on the left and the right of the cross were 8.0 cm apart from their inner most positions and the boxes above and below the cross were 8.7 cm apart from their inner most positions. The target (asterisk) was 1.2 cm in diameter. Prior to the presentation of the target, a cue would appear, which would provide probabilistic information pertaining to the location of the impending target (see below). In the endogenous condition, the cue consisted of an arrow that appeared at the central fixation point and pointed to one of the four boxes, whereas in the exogenous condition, the cue consisted of the brightening of one of the four boxes (see Figure 1). The arrow cue was 2.3 cm in width and the brightening box was an enlargement of the box to 2.0 × 2.0 cm and a small change in luminance. Both conditions were presented to participants using an IBM PC and a monochrome monitor. Responses were made on a response box that interfaced with the computer and recorded participants' reaction times.

Each trial preceded as follows: For the first trial, the boxes and the central cross would appear on the screen (and would remain on the screen for the remaining trials in that condition); second, a cue would appear on the screen (the nature of which depended on the condition) and remained on the screen until the participant responded; third, following one of four variable cue–target intervals (stimulus onset asynchrony or SOA: 50, 150, 250, 1,000 ms) a target would appear in one of the four boxes; finally, the participant would respond by pressing a button as soon as they detected the target in one of the four boxes. Each participant was asked to respond with their dominant hand. The dependent measure for both conditions was the latency to detect the target.

Table 1. Demographic information and Dementia Rating Scale scores of the Parkinson's patients and normal controls

	Participant group			
	Parkinson's patients		Normal controls	
	M	(*SD*)	*M*	(*SD*)
Age (years)	63.88	(7.54)	67.35	(10.22)
Education (years)	15.23	(2.93)	15.76	(2.17)
Dementia Rating Scale score	139.41	(3.10)	141.24	(2.02)

Procedure

The participants were administered the endogenous and the exogenous conditions on the same day. The order of the two conditions was counterbalanced across participants. The participants were tested in a quiet room. The distance from the participant to the monitor was approximately 45 cm. The patients were asked to remain on their regular schedule of medications on the day of testing. Each participant's vision was normal or corrected to normal.

The endogenous condition consisted of 18 practice trials and 250 experimental trials, whereas the exogenous condition consisted of 18 practice trials and 260 experimental trials. The four SOAs were presented equally in each of the two conditions. In the endogenous condition, the arrow would validly cue the location of the target on 80% of the trials (i.e., on 80% of the trials the cue would indicate the correct location of the asterisk), and in the exogenous condition, the brightening box would validly cue the location of the target 50% of the time. The percentage of valid trials was selected in order to maximize the endogenous and exogenous features of each of the two conditions. An 80% validity value when arrows were used as the cues would ensure that expectancy (which can be considered a more internal

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attentional mechanism) was maximal. In contrast, a 50% validity value when boxes were used as the cues would place even less emphasis on internal attentional mechanisms (such as expectancy) and more on external mechanisms. Figure 1 depicts examples of valid and invalid cues for the two conditions.

Analysis

Because the main focus of the study was to contrast subjects' performances on the endogenous and exogenous conditions, we decided not to collapse across SOAs but to compare participants' performances on the endogenous and exogenous conditions separately for each of the four SOAs. The data were analyzed in this way because we included a 1,000-ms SOA in both conditions and the inhibition of return effect (i.e., a slower reaction time following valid cues than following invalid cues) typically occurs only at longer SOAs in the exogenous cueing condition. Thus, any important group differences at the 1,000-ms SOA might be obscured in an overall analysis of variance (ANOVA), which included SOA as a between-group factor.

Reaction times were included in the analysis if they were greater than 200 ms (in order to exclude anticipatory reaction times) and less than 2,000 ms (in order to exclude long reaction times). The percentage of anticipatory responses and long reaction times for each group was less than 1 percent of the total number of responses and did not differ significantly between the two groups. Median reaction times for the four SOAs were analyzed using an ANOVA where group (PD *vs*. NC) served as a between-group factor, and cue validity (valid trials *vs*. invalid trials) and condition (exogenous condition *vs*. endogenous condition) served as within-group factors. Although data collected from exogenous and endogenous cueing tasks are typically analyzed separately, we decided to examine performances in these two tasks within the same ANOVA because the main point of the study was to directly contrast internal and external attentional mechanisms. We felt that the best manner in which to accomplish this was to directly compare performances in the two cueing conditions.

RESULTS

50-ms SOA

The mean of the participants' median reaction times on the 50-ms SOA trials are presented in Figure 2a. An ANOVA indicated that the group factor was not significant ($p > .05$), suggesting that, overall, the reaction times of the PD and the NC groups were not significantly different. The cue validity main effect was significant [$F(1,32) = 76.68$, $p < .001$] due to the fact that reaction times in detecting the target following valid cues were much faster than following an invalid cue. The condition main effect was also significant [$F(1,32) = 7.36$, $p < .05$], indicating that reaction times were faster in the exogenous condition than in the endogenous condition. The Group × Cue Validity, Group × Condition, and Group × Cue Validity × Condition interactions were not significant ($p > .05$). There was also no significant interaction of Cue Validity × Condition ($p > .05$).

150-ms SOA

The mean of the participants' median reaction times on the 150-ms SOA trials are presented in Figure 2b. An ANOVA revealed that the main effects of Group and Condition were not significant ($p > .05$). The effect of cue validity was significant [$F(1,32) = 51.57$, $p < .001$], which can be attributed to participants' reaction times in the valid condition being significantly faster than in the invalid condition. However, this significant main effect was qualified by a significant interaction of Cue Validity × Condition [$F(1,32) = 4.80$, $p < .05$]. An inspection of Figure 2b indicates that the difference between reaction times for valid and invalid cues appeared to be greater in the exogenous condition than in the endogenous condition. The group factor did not enter into any two-way interactions with condition or cue validity ($p > .05$ for both contrasts) nor did it enter into a significant three-way interaction with condition and cue validity ($p > .05$).

250-ms SOA

The results from the trials with 250-ms SOAs are shown in Figure 2c. An ANOVA indicated that the main effects of group and condition were not significant ($p > .05$). The main effect of cue validity was significant [$F(1,32) = 80.63$, $p < .001$] indicating that reaction times were faster on valid than invalid trials. A significant Cue Validity × Condition interaction [$F(1,32)$, $p < .001$], however, indicated that the difference between valid and invalid trials was much greater in the endogenous condition than in the exogenous condition, a finding which is opposite to that found in trials with a 150-ms SOA. The group factor did not enter into any two-way interactions with condition or cue validity ($p > .05$ for both contrasts) nor did it enter into a significant three-way interaction with condition and cue validity ($p > .05$).

1,000-ms SOA

The mean of the participants' median reaction times for trials with 1,000-ms SOAs are shown in Figure 2d. An ANOVA indicated that the group main effect was not significant ($p > .05$), but there were significant main effects for both the condition [$F(1,32) = 8.16$, $p < .01$] and the cue validity factors [$F(1,32) = 28.94$, $p < .001$]. There was no significant interaction of Group × Cue Validity ($p > .05$). However, there was a significant interaction of Condition × Cue Validity [$F(1,32) = 84.16$, $p < .001$], which was qualified by a significant Group × Condition × Cue Validity interaction [$F(1,32) = 8.61$, $p < .01$].

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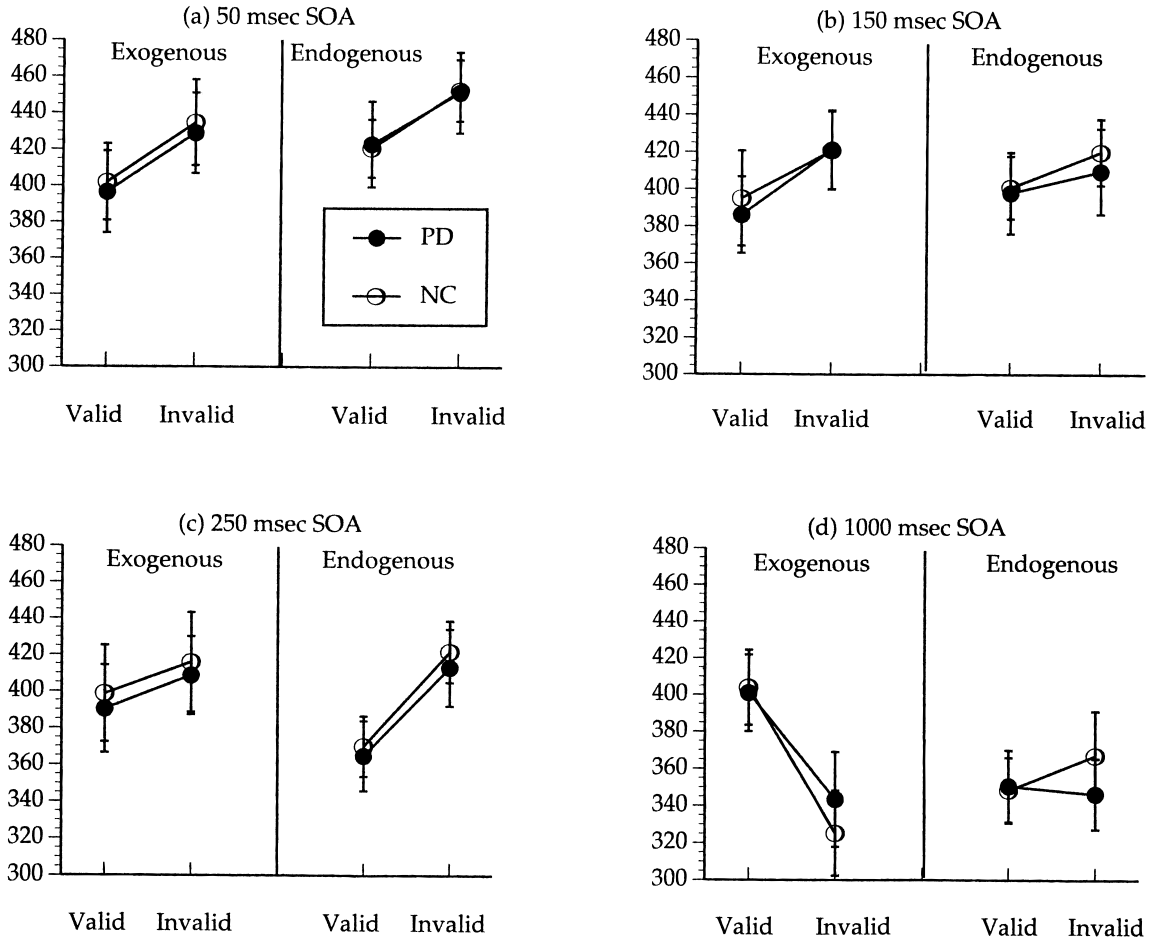

Fig. 2. Mean of median reaction times for Parkinson's patients and normal controls for trials with (a) 50-ms SOA, (b) 150-ms SOA, (c) 250-ms SOA, and (d) 1,000-ms SOA as a function of condition and cue validity. Error bars are in standard errors of the mean.

Several important aspects of the three-way interaction can be seen in Figure 2d. First, collapsed across groups, the difference between valid and invalid trials (i.e., the validity effect) appears to be different in the exogenous and the endogenous condition. Specifically, an inhibition of return effect was observed in the exogenous condition, with reaction times being much slower following valid trials than invalid trials. In the endogenous condition, in contrast, overall reaction times appeared to be somewhat faster on valid than the invalid trials, a finding that was also observed in both the endogenous and exogenous conditions with all of the shorter SOAs. The magnitude of these effects differed, however, for the PD and NC participants. To further examine this three-way interaction, difference scores were computed for each participant in both the endogenous and the exogenous conditions by subtracting the reaction time on valid trials from the reaction time on invalid trials. These difference scores, shown in Figure 3, indicate that the inhibition of return effect for the PD patients were less than those of the NC participants in the exogenous condition, as was the validity effect in the endogenous condition. Planned comparisons of their difference scores using one-tailed t tests revealed that the PD patients exhibited a significantly smaller inhibition of return effect than the NC participants in the exogenous condition [$t(32) = 1.99$, $p = .028$], and a marginally significantly smaller validity effect in the endogenous condition [$t(32) = 1.50$, $p = .07$].

Relationship Between Stage of Disease and Orienting Performance

In order to examine the possible relationship between stage of the disease and attentional performance, patients' Hoehn and Yahr ratings were correlated with their reaction time difference scores for the 1,000-ms SOA in the endogenous and exogenous conditions. The results of these correlations indicated that there was not a significant relationship between patients' stage of the disease and their difference scores in either the endogenous condition [$r(17) = .23$, $p > .20$], or the exogenous condition [$r(17) = .24$, $p > .20$]. Thus, the pattern of attentional deficits does not appear to be associated with the severity of the PD patients' motor disability.

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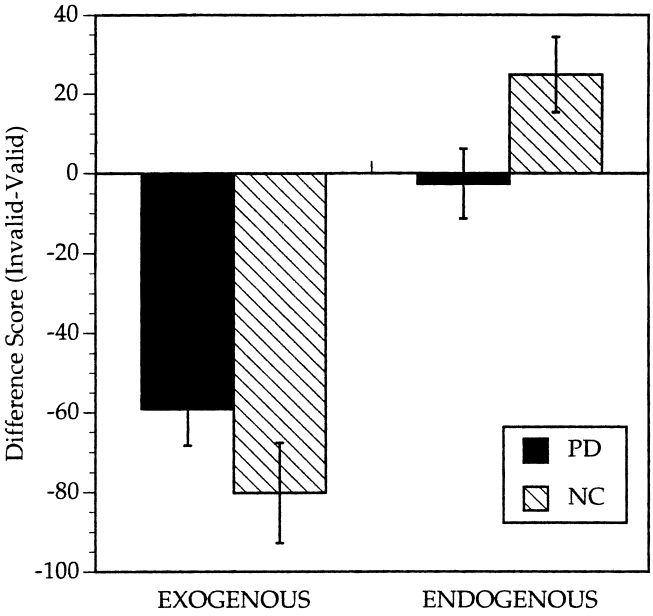

Fig. 3. Mean validity effects for Parkinson's patients and normal controls in the exogenous and endogenous conditions for trials with 1,000-ms SOA. Error bars are in standard errors of the mean.

DISCUSSION

An examination of the PD and NC groups' performances on the orienting of attention task with short SOAs revealed that both groups demonstrated the typical validity effects in which they were faster at detecting targets preceded by a valid cue than an invalid cue. Furthermore, the magnitude of these effects were virtually equivalent for the 50-, 150-, and 250-ms SOAs. These results are consistent with previous studies by Yamada and colleagues (Yamada et al., 1990) and Bennet and colleagues (Bennet et al., 1995) who found that PD patients were not impaired on endogenous attentional shifting tasks that utilized 100-ms and 600-ms SOAs, respectively. In contrast, the difference between the PD patients' reaction times in detecting targets on the valid and invalid trials at the 1,000-ms SOA was less than the difference for the NC subjects, and this reduction in the difference scores was evident in *both* the endogenous and exogenous cueing conditions (see also Wright et al., 1990).

The finding that PD patients are impaired in both the exogenous and endogenous conditions at the 1,000-ms SOA is not consistent with Brown and Marsden's (1990) theory that PD patients have diminished processing resources. Based on this theory, PD patients would be expected to be impaired in the endogenous condition but not the exogenous condition, because shifts of attention following endogenous cues require more attentional capacity than do attentional shifts following exogenous cues (see Jonides, 1981; Rafal & Henik, 1994). In contrast, the present results can be accounted for by the notion that PD patients' attentional deficits are due to impaired inhibitory processes. This interpretation must be constrained, however, by the fact that the PD patients were only impaired at the 1,000-ms SOA, and that the reduction in their inhibition of return and validity effect at this SOA was primarily attributable to their performance with invalid cues.

With regard to the first constraint, the finding that PD patients were not impaired at the shorter SOAs suggests that they have a normal buildup of inhibition. Clearly, if a deficit in the initial development of inhibition were present, the PD patients would most likely have shown decrements in their performances at the shorter SOAs. The finding that PD patients were only impaired at the longer SOA suggests that the locus of their attentional deficits may be in maintaining inhibition over an extended (yet relatively brief) period of time. That is, PD patients may have a more rapid decay of inhibition than normal control participants. This possibility is supported by several previous studies that have also shown that PD patients have deficits in shifting attention following longer, but not shorter, cue-target intervals (Wright et al., 1990; Yamada et al., 1990; Bennet et al., 1995).

With regard to the second constraint, the PD patients' attentional impairments at the longer SOA in the endogenous condition appear to be due to a reduction of the validity effect specifically related to a lack of increase in reaction times on the invalid trials. Similarly, the reduction of inhibition of return in the exogenous condition appears to be related to a smaller reduction in reaction times following invalid cues for PD patients than for controls. Wright et al. (1990) also reported a decreased validity effect with endogenous cues that was due to a lack of increase in PD patients' reaction times following invalid cues (i.e., the lack of reaction time cost), and attributed this impairment in the patients' ability to maintain attention. However, if PD patients' deficits on invalid trials could be explained by a general deficit in maintaining attention, one would also have expected to see a deficit following valid cues. That is, an inability to maintain attention at a cued location should also affect their ability to take advantage of the target appearing in the cued location and lead to longer reaction times following valid cues. Because PD patients' reaction times were normal following valid cues in the present study, a general deficit in maintaining attention cannot account for their deficits.

Rather than a deficit in maintaining attention, the present results are consistent with the possibility that PD patients suffer a rapid decay of inhibition that usually serves to bias subjects from shifting attention to an uncued location in the endogenous condition, and in returning their attention to the cued location in the exogenous condition. Specifically, in the endogenous condition, inhibition may build up at the uncued location and bias the individual from moving attention to that location. If this inhibition decays much more rapidly for PD patients than for controls, the patients would be more efficient in detecting a target at the unattended location than the controls and show less of an increase in reaction time following invalid cues. In the exogenous condition, the inhibition of return effect may be due to a buildup of inhibition at the cued location that biases subjects from returning their attention to that location after it has been re-

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moved. If PD patients experience a rapid decay of this inhibition, they would be more efficient than normals at returning their attention to the cued location.

The notion that PD patients experience a rapid decay of inhibition is only tentative, but such a theory enables us to make specific predictions about the conditions under which PD patients will demonstrate attentional impairment. For example, if PD patients experience a rapid decay of inhibition for unattended locations, they may be expected to shown a smaller than normal negative priming effect. The negative priming effect occurs in selective attention tasks with objects and spatial locations and refers to increased difficulty in identifying a target that had served as a distracter stimulus on the previous trial, presumably because of a buildup of inhibition when the stimulus was a distracter (see Neill et al., 1995). Consistent with the notion that PD patients have a rapid decay of inhibition for unattended locations or objects, a previous study found that these patients do not demonstrate the same magnitude of negative priming for objects as normal subjects (Downes et al., 1991) and preliminary data from our laboratory also suggests that PD patients show less negative priming for spatial locations (Filoteo, 1996).

Although our findings suggest that PD patients' impairment in orienting attention may be due to a deficit in inhibitory processes and not depleted cognitive processing resources, several important issues must be addressed. First, it may be that the task we used did not directly assess internal attentional mechanisms, and the cognitive requirements in the endogenous condition never fully exceeded the attentional capacity of the PD patients. Thus, no differential impairment in the endogenous and exogenous conditions could be observed. This explanation is unlikely, however, given that previous studies that have shown that the endogenous condition involves internal attentional mechanisms (see above). Second, although deficits in inhibitory processes may account for PD patients' impaired performance on the orienting task in the present study, this is not to say that inhibitory deficits can account for all of PD patients' cognitive deficits. On the contrary, basal ganglia dysfunction can result in a variety of deficits, many of which do not appear to be related to inhibitory dysfunction (Butters et al., 1985; Heindel et al., 1989). We only argue that inhibitory deficits may account for impaired performance on attentional measures (such as the one in this study) and that the cognitive resources theory of Brown and Marsden may not account for *all* of the cognitive impairments observed in PD patients. Third, the explanation that PD patients' impairments on this task may be attributed to a deficit in inhibitory processes may not generalize to all patients with this disease. The patients used in this study were nondemented and it is possible that if demented PD patients were evaluated on the orienting task they might demonstrate a pattern more consistent with Brown and Marsden's theory.

Another important issue that must be considered when interpreting the findings of the present study is the possible influence of visuospatial deficits on PD patients' performances on the orienting task. It is well known that PD patients can demonstrate impaired performance on tasks of visuospatial functioning (see Levin, 1990), and given the spatial nature of the attentional task, it is possible that the pattern of the PD patients' results may be due to visuospatial impairment. Unfortunately, we did not examine visuospatial functioning in our patients at the time they were administered the spatial orienting task, so we are unable to provide independent evidence that the patients' attentional performance is not associated with visuospatial dysfunction. However, the finding that PD patients were only impaired at the 1,000-ms SOA and on invalid trials argues against the notion that visuospatial dysfunction accounted for their pattern of performance, because such dysfunction should not be specific to a certain SOA or the validity of the cue. If visuospatial deficits could readily account for the results, such effects should be evident under all SOAs and on both valid and invalid trials. As such, the pattern of deficits observed in this study is more consistent with a rapid decay of inhibition.

The results of this study are consistent with several lines of research that indicate that the basal ganglia may be directly involved in inhibitory attentional functions. For example, Hassler (1978) has argued that the role of the putamen is to "focus the attention, the emotional participation and the excitability on one single event by simultaneously suppressing and fading out all other happenings and motivational objects" (p. 188). More recent reviews have also implicated the basal ganglia in the sensory (Krauthamer et al., 1987) and response selection (Robbins & Brown, 1990) processes in selective attention tasks, and recent positron emission tomography studies indicate that the basal ganglia are activated during selective attention tasks in which the subject must attend to one particular stimulus attribute and inhibit the processing of the other attributes (Corbetta et al., 1991). The results of the present study also suggest that the basal ganglia may play an important role in inhibitory processes, particularly in maintaining inhibition at unattended spatial locations over extended periods of time (i.e., 1,000-ms).

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