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Cognitive speed in nondemented Parkinson's disease

MARCIA C. SMITH,[1]* WILLIAM P. GOLDMAN,[2] KEVIN W. JANER,[1] JACK D. BATY,[3] AND JOHN C. MORRIS[4]

[1]Department of Psychology, Washington University, St. Louis, MO
[2]Department of Neurology and the Alzheimer's Disease Research Center, Washington University, St. Louis, MO
[3]Division of Biostatistics and the Alzheimer's Disease Research Center, Washington University, St. Louis, MO
[4]Departments of Neurology and Pathology and the Alzheimer's Disease Research Center, Washington University, St. Louis, MO

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Abstract

Studies of speed of cognitive processing in Parkinson's disease (PD) have yielded mixed results. This may relate in part to a differential effect on cognitive speed by the type of information to be processed. In the present study, we compared medication fasted, nondemented individuals with mild idiopathic PD ($N = 26$) with age-matched controls ($N = 12$) on a test requiring easy and hard same–different discriminations for verbal, quantitative, and spatial information, as well as on a traditional memory scanning paradigm. A voice-activated relay rather than a key press was used to eliminate the need for limb and finger movements. Simple reaction time and movement time were also measured in a task requiring subjects to move a hand held stylus to a designated target. The PD group performed as fast as the control group across all tasks except movement time. Thus, in our paradigm, the presence of PD alone does not predict cognitive slowing in the presence of motor slowing. (*JINS*, 1998, *4*, 584–592.)

Keywords: Parkinson's disease, Bradyphrenia, Cognitive speed

INTRODUCTION

One of the characteristic symptoms of Parkinson's disease (PD) is a slowness of movement or bradykinesia attributed to dysfunction of the basal ganglia. It remains controversial if this slowing is purely motoric or is also accompanied by slowing of cognitive processes or bradyphrenia. While bradyphrenia is suggested as being specific to subcortical pathology (Pate & Margolin, 1994), it has not been reliably obtained in PD patients—particularly in those without a coexisting dementia.

In a review of this topic, Revonsuo et al. (1993) noted that the concept of bradyphrenia has been operationalized in many ways. Prior studies have suggested that cognitive slowing in PD is associated with impairment of concentration (Rogers et al., 1986), with deficits in monitoring stimulus–response compatibility (Cooper et al., 1994), and with deficits in attention and vigilance (Mayeux et al., 1987), although Taylor et al. (1986) maintained that bradyphrenia can only be defined in the presence of preserved attention. Other studies have suggested that bradyphrenia in PD does not exist. Rafal et al. (1984), for example, found no cognitive slowing on memory scanning, visual attention, and manual movement tasks. Helscher and Pinter (1993) likewise reported that patients on optimal dopaminergic medication showed no slowing of processing on a matrix test, which is considered a measure of abstract reasoning.

The difficulty in comparing studies of cognitive slowing in PD has been exacerbated by differences in participant selection, particularly regarding levels of general intellectual function, age, disease severity, and medication. Several recent studies have supported the notion that slowing is present only in PD patients with concomitant cognitive deterioration. Revonsuo et al. (1993) reported that a PD group with mild cognitive impairment had slowed "automatic" and "controlled" processing but no difference in motor programming speed. Specifically, this group was slower than a PD group with preserved cognitive capacities on a visual recognition task (including recognition of numbers, letters, and figures, analyzed together), suggesting a deficit in automatic processing speed. To measure controlled processing speed, they administered easy and hard arithmetic tasks, and, using a subtraction logic paradigm to calculate differences between tasks, again showed a deficit in the cognitively im-

Reprint requests to: John C. Morris, Department of Neurology, Washington University School of Medicine, 660 S. Euclid Avenue, Campus Box 8111, St. Louis, MO 63110.

*Marcia C. Smith is now at the University of Portsmouth, Department of Psychology, Portsmouth, UK.

paired PD group. Similarly, Pate and Margolin (1994) compared results from simple and choice reaction time tasks and argued that PD individuals with questionable dementia showed disproportionate cognitive slowing.

Most of the studies assessing cognitive speed have used only PD patients on optimal dopaminergic medication. In one study that specifically addressed medication effects (Rafal et al., 1984), overall reaction time increased when participants were undermedicated, but no disproportionate slowing of cognitive processing was found. Pillon et al. (1989), although claiming that PD patients showed cognitive slowing on a test of identifying superimposed images, reported that speed on this test did not improve after administration of levodopa, whereas motor symptoms did. In contrast to the studies mentioned, Malapani et al. (1994) found an effect of medication. In their study, recently diagnosed patients who had not received medication were slowed in choice reaction time compared with patients taking their standard dose of medication. Furthermore, patients taking medications were compared with themselves during maximal and minimal clinical benefit of the medications. Results indicated that choice reaction time was slowed during the state of minimal clinical benefit.

Studies also differ in the type of tasks used to assess cognitive speed. Such task differences could account for the divergent findings in the literature. One task that has often been used as a measure of cognitive speed is the Sternberg paradigm (1975), which measures speed of scanning of short term memory, independent of motor slowness. Examinees are given variable amounts of information to process, but the motor response remains the same. Previous studies of PD using this paradigm, however, have also been inconclusive. Wilson et al. (1980) found that an older subgroup of PD patients (over age 65 years) showed disproportionately longer scanning time (which, according to the paradigm, would be evidence of cognitive slowing). No difference was found between the younger subgroup (age 64 years and under) and controls. Researchers have attempted to replicate this finding with no success. No evidence of cognitive slowing was found on the memory scanning task in older PD participants by Howard et al. (1994). Ransmayr et al. (1990) used the same paradigm on medication fasted PD patients and found no evidence of cognitive slowing. Furthermore, while Ransmayr et al. found no correlation between cognitive slowing and age, they showed that individuals who had longer disease duration (over 4 years) showed more cognitive slowing than subjects more recently diagnosed. The study by Rafal et al. (1984) mentioned previously specifically contradicts these findings. They claimed there was no evidence that speed of cognition was decreased even in patients with longer duration of disease.

There are methodological limitations to each of these replications that must be addressed before it is certain that nondemented PD patients are not impaired on the memory scanning paradigm. Rafal et al. (1984) did not include an elderly control group in their experiment and included questionably demented individuals in their PD sample. Ransmayr et al. (1990) selected a subsample of patients for analyses based on reaction time and set size correlations. Thus, their sample was not random and representative of nondemented PD patients. Howard et al. (1994) did not control for the effects of antiparkinsonian medication fluctuations, which have been shown to influence cognitive speed (Malapani et al., 1994). Thus, the memory scanning paradigm remains to be tested on well characterized nondemented, medication fasted PD patients.

A limitation of prior studies of cognitive slowing is that only patterns of global slowing (i.e., slowing that is independent of the type of information being processed) have been investigated. One exception is a study by Davidson and Knight (1995) in which speed of mental rotation and speed of semantic reasoning was measured in separate tasks. There was no difference between PD patients and controls on either task. It is important to investigate different cognitive domains because disease states may produce content-specific slowing. For example, Nebes and Madden (1988) reported that individuals with dementia of the Alzheimer type show disproportionate slowing on verbal tests compared with healthy elderly controls, specifically on lexical decision and sentence completion tasks. PD has been associated with a variety of neuropsychological impairments, including spatial dysfunction (Mortimer et al., 1982), reduced verbal fluency (Gurd & Ward, 1989), and slowness in arithmetic processing (Revonsuo et al., 1993). It is surprising, therefore, that few studies have compared speed of processing among the different cognitive domains.

The primary goals of the present study were as follows:

1. To examine slowing of cognitive processes for various types of information (verbal, quantitative, and spatial) using a same–different discrimination task in patients with PD. Disproportionate slowing of the PD group on hard compared with easy tasks, within the same content area, would be evidence of cognitive slowing in that area (Group $\times$ Task $\times$ Difficulty interaction), whereas overall cognitive slowing in comparison with controls would be evidenced by a Group $\times$ Difficulty interaction.

2. To investigate whether slowing of memory scanning occurs in PD patients in comparison with age-matched controls, using a traditional memory scanning paradigm. A difference between groups in the slope of the line connecting reaction times for different set sizes would be evidence for a difference in cognitive processing speed.

3. To investigate central processing time with a task having minimal cognitive demands and to examine a relatively pure measure of motor output speed in patients with PD. A Fitts task (1954) was used in which examinees move a stylus to a target area as quickly as possible following an auditory signal. A difference between groups in simple reaction time would be evidence for a difference in cognitive processing speed while a difference between groups in movement time would be evidence for a difference in motor output speed.

To reduce differences due to participant selection, the present investigation was limited to nondemented idiopathic PD patients with relatively mild parkinsonism, who were compared with a group of healthy age-matched controls. We carefully characterized these participants using the Washington University Clinical Dementia Rating (CDR; Berg, 1988; Hughes et al., 1982; Morris, 1993). A CDR score of zero was required for all participants, to minimize the possibility of inclusion of individuals with unrecognized very mild dementia contaminating the sample. Although over one-third of otherwise healthy elderly persons demonstrate at least 1 extrapyramidal sign (Richards et al., 1993), we required that all participants in the healthy elderly control group be free of such findings as assessed by a standardized neurological examination and staged by the Hoehn and Yahr scale (1967), the Columbia scale (Yahr et al., 1969), and the Northwestern University Disability Scale (Canter et al., 1961). This requirement was used to minimize the possibility of subjects with incipient PD contaminating the healthy elderly control group. While such strict selection criteria may limit the generalizability of our findings, we believe that using such participant groups, rather than ones likely to be contaminated by preclinical or unrecognized mild disease, allows differences between truly healthy aging and PD to be revealed. To avoid dose–response variability of antiparkinsonian medications at the time of testing, all PD participants were fasted (no medication) for 12 hr before the testing. This served to make the PD group more homogenous with respect to antiparkinsonian drug effects on performance. We chose to examine PD participants in a medication fasted state as opposed to an optimal or a steady state because this is when the effect of medication on behavior would be minimal.

We predicted that well characterized nondemented individuals with mild idiopathic PD who were medication fasted would show motor slowing, as this is a cardinal sign of PD, but no additional cognitive slowing on the same–different discrimination task, the memory scanning task, or the simple reaction time task in comparison with well characterized age-matched controls screened for extrapyramidal signs.

METHODS

Participant Selection

Individuals in the PD ($N = 26$; 19 men, 7 women) and control ($N = 12$; 6 men, 6 women) groups were selected from the participant registry of the Memory and Aging Project (MAP) of the Alzheimer's Disease Research Center at Washington University. Groups were matched for mean age, education, and socioeconomic status as measured by the Hollingshead two-factor index (Hollingshead, 1957). Participants were classified according to well defined diagnostic criteria (Berg et al., 1982; Morris et al., 1988, 1991). Semistructured interviews with the participant and a collateral source (usually a close relative) and a standardized neurological examination of the participant are conducted annually by MAP physicians who rate the presence or absence of dementia and, when present, its severity by means of the CDR. The CDR assesses cognitive functioning in six domains: memory, orientation, judgment and problem solving, community affairs, home and hobby, and personal care. Based on these six scores and without reference to psychometric performance, a global CDR score is assigned in which CDR zero indicates *no dementia* and CDR 0.5, 1, 2, and 3 indicate *questionable*, *mild*, *moderate*, and *severe dementia*, respectively. All participants met criteria for no dementia, corresponding to CDR zero. The reliability of the CDR has been established (Burke et al., 1988).

The clinical diagnosis of PD was confirmed during the MAP assessment when two or more extrapyramidal signs (bradykinesia, cogwheel rigidity, resting tremor) were present on examination in the absence in the previous 6 months of medications with potential extrapyramidal side effects. Gait and postural reflex abnormalities were not included as criteria for PD diagnosis because these symptoms are common in normal elderly populations (de Rijk et al., 1997; Morris et al., 1987). All PD participants were diagnosed as having idiopathic PD.

Exclusionary criteria included the presence of other neurological, medical, and psychiatric disorders (including depression) with the potential to impair cognition as assessed by medical history and clinical interviews (Berg et al., 1982). In addition, participants who displayed clinical impairment in hearing, visual acuity, or language were excluded from enrollment.

The cognitive portion of the Blessed Dementia Scale (BDS/C; Blessed et al., 1968) and the Short Blessed Test (SBT; Katzman et al., 1983), both based on the clinical interview with the patient, were administered as measures of global cognitive function.

Motor Measures

To assess the presence and severity of parkinsonian motor symptoms, participants received the following clinical rating scales:

1. Hoehn and Yahr (1967) stage, a five-stage measure of overall motor disability ranging from Stage I (unilateral disease) to Stage V (confinement to a bed or wheelchair).

2. Columbia Scale (Yahr et al., 1969), a series of scales measuring rigidity, tremor, bradykinesia, gait disturbance, and postural stability. All scales ranged from zero to 4—higher scores indicate greater impairment. Tremor and rigidity were scored for the head and the four limbs separately and are presented as an average of these five measures.

3. Northwestern University Disability Scale (Canter et al., 1961), a series of scales measuring walking, dressing, hygiene, feeding, eating, and speech. One scale score is derived ranging from zero to 50. We coded the items such that higher scores indicate greater impairment.

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Table 1. Demographic characteristics and measures of global cognitive function by group

	PD ($N = 26$)	Control ($N = 12$)
Variable	*M* (*SD*)	*M* (*SD*)
Age (years)	69.5 (5.9)	71.3 (7.2)
Education (years)	14.3 (3.2)	14.4 (3.5)
Socioeconomic status	2.6 (1.2)	2.4 (1.2)
BDS/C	0.3 (0.4)	0.2 (0.3)
SBT	1.1 (1.4)	0.5 (0.9)

Note. BDS/C = Blessed Dementia Scale/Cognitive. SBT = Short Blessed Test.

Healthy elderly control participants were included only if they displayed no extrapyramidal signs during the standardized neurological examination, met criteria for Hoehn and Yahr Stage zero (no disability), and scored zero on the Columbia Scale and the Northwestern University Disability Scale.

Participant Characteristics

Demographic characteristics and measures of global cognitive function are presented in Table 1. No significant differences were found between the groups based on age, education, socioeconomic status, or global dementia ratings (BDS/C and SBT).

Table 2 displays the scale scores measuring the presence and severity of parkinsonian motor symptoms. According to Hoehn and Yahr (1967) criteria, most of the PD participants were classified as Stage II ($N = 16$; bilateral involvement), with 3 participants classified as Stage I (unilateral involvement), and 7 classified as Stage III (mild gait disturbance). Means from the other scale scores indicate that the motor impairments in the PD group were mild.

Table 2. Scores on the scales measuring the presence and severity of parkinsonian motor symptoms by group

Variable	PD	Control
Hoehn and Yahr stage		
I	3	0
II	16	0
III	7	0
IV	0	0
V	0	0
Columbia Scale		
Rigidity	1.0 (0.6)	0 (0.0)
Tremor	0.6 (0.5)	0 (0.0)
Bradykinesia	1.6 (0.8)	0 (0.0)
Gait disturbance	1.0 (0.5)	0 (0.0)
Postural stability	0.5 (0.6)	0 (0.0)
NUDS	7.0 (4.4)	0 (0.0)

Note. NUDS = Northwestern University Disability Scale. *SD*s are shown within parentheses.

Cognitive and Motor Speed Measures

Same–different task

This task was a modification of Levine et al. (1987) same–different reaction time task, which was developed to measure cognitive speed in children. Six series of stimuli covering three content areas were presented: verbal, quantitative, and spatial. Within each content area, one task was designed to be relatively easy, and a second task was designed to be relatively hard. For each item, the participant was required to make a same–different discrimination.

The blocks of tests were presented in random order on a color monitor. Each participant received four practice items with feedback for each series. Eighteen test items were then presented with no feedback. The interstimulus interval of 1,750 ms included a 1,000-ms blank pause followed by a 750-ms fixation star. The tasks were self-paced in that the next stimulus would not appear until after the participant responded to the previous stimulus. To eliminate the need for limb or finger movements, reaction time was measured with a voice-activated relay rather than a key press. The participants were encouraged to respond carefully but quickly.

The tasks were as follows:

1. *Easy verbal:* The participant saw two three-letter words and said if they were the same words or were different words (e.g., "let" and "let"; "bat" and "car"). This task could be performed using perceptual information alone. In this and the next series, the words were drawn from the most common 1,000 words in Thorndike and Lorge's (1944) list of 30,000 words.
2. *Hard verbal:* The participant saw two words and said if the meanings of the words were the same or different (e.g., "small" and "little"; "down" and "up"). The words were two to six letters in length. All stimuli in which the correct response was "different" were antonyms. This task required semantic knowledge of the words and could not be performed using only perceptual information.
3. *Easy quantitative:* The participant said whether two sets of geometric figures contained the same number of parts, regardless of their orientation on the screen. Figure orientation was varied randomly, meaning that for some trials orientation was identical.
4. *Hard quantitative:* Pairs of single-digit arithmetic problems were presented, including addition, subtraction, and multiplication. The answers were all single-digit positive integers. The participant performed the arithmetic operation for both items and stated whether the result was the same or different.
5. *Easy spatial:* Two geometric figures were presented, which were either identical in form or different, with no difference in spatial orientation. The person said whether the two figures were the same or different.
6. *Hard spatial:* Two geometric figures were presented, which were identical in form. The figures were pre-

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sented either in the same orientation or in different orientations (e.g., one figure was a rotated version or a mirror image of the other). The participant said whether or not the two figures were in the same spatial orientation.

Sternberg task

A version of the memory scanning task developed by Sternberg (1975) was used. Participants were instructed that a row of single-digit numbers would appear on the monitor. One, two, or four digits ranging from *1* to *9* were presented at a self-paced rate. The participants were instructed to say "okay" when they thought they had adequately memorized the array. The array was removed, and a warning sign, "Get ready for probes" appeared at the top of the screen for 2,250 ms, followed by a fixation point for 800 ms in the center of the screen. The probe number then appeared in the center of the screen until the participant responded. Reaction time for these tests was measured with a voice-activated relay. Participants indicated whether the probe was one of the numbers included in the memory set, by saying "yes" or "no." The monitor then went blank for 2 s, while the experimenter entered the response on a keyboard. Participants received one practice block with 10 probe trials. The practice was followed by nine task blocks (three of each array set size), with 16 probe trials per block. For each block there was only one presentation of the array. This is the fixed set version of the Sternberg task. In half of the trials the probe number was in the original array (probe present), and in half of the trials the probe number was not in the original array (probe absent). For the probe present condition, the position of the stimulus probe in the array for Set Sizes 2 and 4 was counterbalanced across all positions. All participants received the same arrays and probes; the order of blocks and trials was randomized for each person.

Fitts task

A Fitts task (1954) was used to measure simple reaction time and movement time. Unlike the other tasks discussed previously, the Fitts task requires a manual response. Participants held a stylus in the dominant hand and rested the stylus on a start area. Upon receiving a verbal "ready" signal immediately followed by an auditory tone, participants moved the stylus as quickly as possible from the start position to a designated target. There were four different targets 60 cm from the start position: 3.8, 2.5, 1.9, and 1.2 cm in diameter. The task was presented in blocks by target size from the largest to the smallest target. There were 10 trials for each target. Simple reaction time was the duration between the auditory tone and removal of the stylus from the start position. Movement time was the duration to move the stylus to the target once the stylus was removed from the start position.

Procedure

The cognitive and motor speed measures described were given as part of two comprehensive batteries. In one session, participants received the same–different task followed by the Sternberg paradigm. In another session, the Fitts task was administered. The individuals with PD were tested in a medication fasted state (i.e., after foregoing their normal morning dose of dopamine replacement medication) in both sessions. Clinical interview data are reported from the assessment time immediately before same–different, Sternberg, and Fitts testing, within a window of approximately 3 months. Due to time constraints, 1 control participant did not perform the same–different paradigm, 1 (different) control participant did not perform the Sternberg task, and 1 (different) control participant did not perform the Fitts task. All PD participants completed the same–different paradigm, 5 PD participants did not perform the Sternberg task, and 3 of these 5 PD participants did not perform the Fitts task. All analyses were conducted using computerized statistical software (SAS 6.11; SAS Institute Inc., Cary, NC). An alpha level of .05 was used for all statistical tests. The data were log-transformed to reduce positive skewness. Analyses using raw rather than log-transformed scores showed an identical pattern. Raw scores are presented in the tables to illustrate the relationships.

All assessment procedures and means for obtaining informed consent were approved by the Institutional Review Board of Washington University School of Medicine.

RESULTS

Same–Different Task Results

Median reaction times across trials for each participant under each stimulus condition were calculated, and the means of these medians were computed for each group. Trials for which reaction times were greater than 10 s (seven trials, or 0.1% of trials) or less than 300 ms (26 trials or 0.7% of trials) were removed from further analyses, as the participants most likely were not responding according to the directions on these items.

A mixed analysis of variance was used to investigate the effects of group (2), task (3), and difficulty level (2) on median reaction time. Task and level of difficulty were within-participants variables, and diagnostic group was a between-participants variable. Hypotheses regarding cognitive slowing in PD were addressed by testing the Group × Difficulty and Group × Task × Difficulty interactions. Analyses based only on correct trials yielded the same pattern of results as analyses based on all trials; therefore, the following results are reported only for correct trials.

Main effects of task [$F(2,70) = 64.75$, $p < .0001$], difficulty [$F(1,35) = 176.16$, $p < .0001$], and a Task × Difficulty interaction [$F(2,70) = 42.04$, $p < .0001$], were found. Both groups showed the expected pattern of performance for speed of processing, in that easy tasks were performed significantly more quickly than the paired hard tasks. No Group × Task × Difficulty interaction or main effect of group were found. The means are shown in Table 3. Because the scores for the PD group were as good as those of controls,

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Table 3. Mean of median raw score reaction time in ms and percent errors on same–different tasks by group

	PD		Control	
Task	Reaction time *M* (*SD*)	% Errors *M* (*SD*)	Reaction time *M* (*SD*)	% Errors *M* (*SD*)
Verbal				
Easy	1239 (520)	2 (4)	1124 (182)	3 (4)
Hard	1577 (487)	4 (7)	1507 (347)	4 (6)
Quantitative				
Easy	1198 (237)	7 (10)	1302 (174)	3 (7)
Hard	2358 (1047)	10 (9)	2569 (796)	7 (8)
Spatial				
Easy	1044 (207)	4 (5)	1040 (135)	3 (5)
Hard	1299 (408)	7 (10)	1251 (230)	7 (14)

the lack of statistically significant differences between groups does not appear to be due to a lack of power.

Error rates

The percentage of errors for each task by group are shown in Table 3. No effect of group was found. A main effect of task [$F(2,70) = 4.18$, $p < .05$], and a Task × Difficulty interaction [$F(2,70) = 6.53$, $p < .01$], were significant. As shown in Table 3, error rates for both groups were highest on the hard quantitative task, and were below 10% for all other tasks.

Sternberg Task Results

Trials for which reaction times were greater than 10 s (1 trial, or < 0.1% of trials) or less than 300 ms (27 trials, or 0.3% of trials) were removed from further analyses. Table 4 shows the mean of median reaction times and error rates as a function of group, set size (one, two, or four digits), and probe (present or absent).

A mixed analysis of variance with reaction time as the dependent measure revealed no main effect of group, and no Group × Set Size, Group × Probe, or Group × Set Size × Probe interactions. Both groups showed a pattern of significantly greater reaction time for larger set size [$F(2,192) = 72.81$, $p < .0001$], and greater reaction time when the probe was absent [$F(1,192) = 57.30$, $p < .0001$]. In addition, a Set Size × Probe interaction was found [$F(2,192) = 9.60$, $p < .001$]. This interaction appeared to be due primarily to a disproportionately greater benefit of stimulus presence for the Set Size 1 condition. Again, the fact that the scores of the PD group were as good as those of controls suggests that the lack of statistical significance was not due simply to low power.

Intercept and slope analyses

Intercept and slope values were computed between reaction times and set size for each participant for probe present and absent conditions. Separate analyses were conducted for intercept and slope values. The memory set size by decision time functions in both probe conditions were highly linear

Table 4. Mean of median raw score reaction time in ms and percent errors on Sternberg task by set size, probe, and group

	PD		Control	
Set size	Reaction time *M* (*SD*)	% Errors *M* (*SD*)	Reaction time *M* (*SD*)	% Errors *M* (*SD*)
Probe present				
1	627 (146)	4 (12)	610 (75)	1 (2)
2	696 (144)	3 (6)	713 (110)	0 (1)
4	838 (206)	6 (13)	829 (118)	1 (3)
Probe absent				
1	709 (165)	5 (10)	754 (145)	1 (2)
2	758 (204)	4 (9)	804 (147)	3 (4)
4	893 (232)	13 (15)	899 (200)	7 (6)

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($r > .9$) for all except 1 control and 2 PD participants in the probe present condition and 1 control and 1 PD participant in the probe absent condition. Statistical analyses on intercept values revealed a main effect of probe [$F(1,30) = 83.25$, $p < .0001$], as well as a Group × Probe interaction [$F(1,30) = 5.75$, $p < .05$], with no main effect of group (see Table 5). Higher intercepts reflecting slower reaction times were found for the probe absent condition than for the probe present condition. The Group × Probe interaction appeared to be due to the surprisingly faster performance of the PD group compared with controls for the probe absent condition. As can be seen in Table 4, however, the PD group was faster only for Set Sizes 1 and 2, whereas their performance for Set Size 4 was similar to that of the control group.

The slope values are considered a measure of the speed of scanning memory, with higher values representing slower speed. The slope data is also shown in Table 5. Statistical analyses showed a main effect of probe [$F(1,30) = 13.36$, $p < .001$], such that scanning speed was slower in the probe present condition compared with the probe absent condition. No group effect and no Group × Probe interaction were found. A probe absent–probe present slope ratio of 1.0 suggests that participants examine all stimuli in the set before responding (serial exhaustive scan), whereas a ratio of 2.0 suggests that they respond as soon as a match is found (serial self-terminating scan). The relation between slope values for probe present and absent slope values was under 1.0 for both groups (PD = .88, control = .68), suggesting that both groups used a serial exhaustive scan strategy.

Error rates

Both groups were correct on over 90% of the trials under all conditions. Overall, the control group showed a 2% error rate, and the PD group showed a 6% error rate. A significant effect of set size was present [$F(2,60) = 10.08$, $p < .001$], with more errors in Set Size 4. No main effect of group or Group × Set Size interaction was present. A main effect of probe [$F(1,60) = 20.90$, $p < .0001$], was shown with fewer errors in the probe present condition. In addition, a Set Size × Probe interaction was found [$F(2,60) = 11.59$, $p < .0001$], apparently because both groups had higher error rates in the probe absent condition when the set size was four. See Table 4 for a summary of these findings.

Table 5. Mean intercept and slope values of raw score reaction time in ms on Sternberg task by probe and group

Index	PD *M* (*SD*)	Control *M* (*SD*)
Probe present		
Intercept	556 (162)	552 (95)
Slope	70 (55)	71 (30)
Probe absent		
Intercept	642 (212)	707 (128)
Slope	62 (64)	48 (33)

Fitts Task Results

Reaction times were analyzed as median times of the 10 trials at each target size. The data were analyzed collapsed across target size because target size was not counterbalanced. The means are presented in Table 6. No effect of group was found for simple reaction time, and a main effect of group was found for movement time [$F(1,32) = 6.02$, $p < .05$].

DISCUSSION

Nondemented individuals with mild PD showed no cognitive slowing compared with a healthy elderly control group on a verbal, quantitative, or spatial same–different discrimination task, on a memory scanning task, and on a simple reaction time task. As expected however, the PD group did show motor slowing on a movement time task. The error rates of the PD group were comparable to those of the controls. Thus, there is no evidence of PD patients showing a tradeoff between accuracy and speed. We also examined the data set for outliers and found no indication that a subgroup of PD patients performed abnormally slowly across tasks. Not only did the PD group fail to show cognitive slowing, the overall speed of response of the PD group was as fast as that of controls. The only motor response required on two of the three tasks was saying "yes" or "no." By requiring a verbal response instead of a manual response, the motor slowness in limb and finger movements characteristic of patients with PD is less likely to contribute to the task performance. Such motor slowness may have contributed to the overall slowing found in previous reports.

The findings from the Fitts task replicate and extend our research (Goldman et al., 1998) where we found intact simple reaction time and impaired movement time in nondemented PD participants. The difference in the present study is that control participants were screened on a range of measures for extrapyramidal signs in order to minimize the possibility of including participants with incipient PD in the control group.

It is possible that differences in selection criteria may contribute to differences in the results from our study compared with those in the literature. The participants in this

Table 6. Mean of median raw score reaction time in ms on Fitts task by group

Task	PD *M* (*SD*)	Control *M* (*SD*)
Simple reaction time	235 (51)	249 (37)
Movement time	769 (247)	601 (114)

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study were in relatively early stages of PD. Individuals with longer disease duration and greater PD severity are more impaired on cognitive speed tasks (Cooper et al., 1994; Ransmayr et al., 1990). It remains to be seen if patients with more severe disease would exhibit cognitive slowing on the tasks we employed. Our PD group excluded participants with even minor "age-related" cognitive decline, and thus minimized contamination by preclinical dementia that may confound other samples (Morris et al., 1996). The CDR is sensitive to very mild cognitive impairments, an advantage over measures such as the Mini-Mental State Exam (Folstein et al., 1975) or similar brief tests that are confounded by effects of age, education, and ethnic status (Mungas et al., 1996) and are insensitive to early stage dementia in well educated individuals (Butler et al., 1996). Inclusion of participants with unrecognized very mild dementia could increase the mean cognitive processing speed of a PD group as a whole.

Our results are consistent with prior studies (Davidson & Knight, 1995; Helscher & Pinter, 1993; Howard et al., 1994; Rafal et al., 1984; Ransmayr et al., 1990) suggesting that the presence of PD alone does not predict cognitive slowing in the presence of motor slowing. This research extends previous findings to established measures of cognitive speed in the literature by showing that cognitive speed remains intact across different cognitive operations, even when participants are tested in a medication fasted condition and the control group is screened for extrapyramidal signs. This research also indicates that cognitive speed remains intact across a range of cognitive demands within and between tasks. It is still unknown whether PD participants of the types previously reported to show cognitive slowing (e.g., overt dementia) would show a differential slowing of cognitive processing depending on the type of information processed.

The limitations of the tasks used in this study (as well as in most prior studies of cognitive slowing) must also be addressed. Both the same–different task and the Sternberg task are structured, forced-choice tasks. It is possible that subtle cognitive slowing in PD participants is most likely to occur on multiple choice tasks where more complex sequential or parallel processing of information would be required (Malapani et al., 1994).

Finally, the present results are based on comparisons with age-matched controls. Prior studies have shown that cognitive slowing occurs with aging in healthy populations (Cerella, 1985; Myerson et al., 1990). Thus, the present findings show only that PD does not produce slowing in addition to slowing associated with normal aging.

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