TEMPORAL ORDERING AND SHORT-TERM MEMORY DEFICITS IN PARKINSON’S DISEASE

by H. J. SAGAR\(^1,2,3\), E. V. SULLIVAN\(^1,2,3\)*, J. D. E. GABRIELI\(^1,2\), S. CORKIN\(^1,2\) and J. H. GROWDON\(^2,3\)

(From the \(^1\)Department of Brain and Cognitive Sciences and the \(^2\)Clinical Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts, and \(^3\)Department of Neurology, Massachusetts General Hospital, Boston, Massachusetts, USA)

SUMMARY

Previous studies of remote memory function have indicated a dissociability between memory for the content and date of past events and suggested selective deficits of dating capacity in Parkinson’s disease (PD). The present study examined the hypothesis that poor dating in PD is linked to a specific deficit in temporal contextual memory which also affects new learning. Patients with PD and patients with Alzheimer’s disease (AD) were compared in their ability to perform tasks of content recognition and recency discrimination of words presented sequentially. Compared with AD patients, PD patients were disproportionately impaired in recency discrimination relative to content recognition. When performance was analysed as a function of retention interval, AD patients showed impairment in both tasks at all intervals. PD patients, by contrast, showed deficits in content recognition at the short stimulus-test intervals only, possibly reflecting the clinical phenomenon of bradyphrenia. These results suggest that recency discrimination deficits and impaired short-term memory processing are specific cognitive deficits in PD that may be linked to subcortical deafferentation of the frontal lobes.

INTRODUCTION

In a previous study (Sagar et al., 1985a, 1988) we showed that patients with Parkinson’s disease (PD) were impaired in their capacity to date past public events despite preserved ability to recognize those events; this deficit was greater than occurred in Alzheimer’s disease (AD). We postulated that dating past events may require cognitive mechanisms distinct from those involved in the recognition of content of those events and that in PD the former process may be selectively disrupted.

The ability to date past historical events is a complex one including rote learning and reconstructive memory (Friedman and Wilkins, 1985). It is probable, however,
that part of this reconstructive process involves judgements of recency between the
event to be dated and highly salient personal events of high memorability for which
the date is known as a fact (Loftus and Marburger, 1983). In normal subjects
(Hasher and Zacks, 1979), amnesic patients (Huppert and Piercy, 1976; Hirst and
Volpe, 1982; Sagar et al., 1984; Mayes et al., 1985; Meudell et al., 1985) and epileptic
patients treated with focal cortical excision (Milner, 1971, 1974; Corsi, 1972) the
ability to make judgements of recency in new learning was dissociable from the
capacity to recognize previous events, suggesting that recognition memory and
recency discrimination are served by independent cognitive processes.

Thus, to the extent that the ability to date past public events involves judgements
of recency, we predicted that patients with PD would show a deficit in recency
discrimination when content recognition memory was intact. Accordingly, we
examined recognition memory and recency discrimination in patients with PD.
Results in PD were compared with those in AD so as to establish the nonspecific
effects of dementia; performance was measured at several retention intervals so as to
compare the course of forgetting of the different functions.

METHODS

Subjects

The subjects were 15 patients with PD, 15 patients with AD and 15 healthy control subjects (Table
1). The patients were drawn from the Memory Disorders Unit and the Movement Disorders Unit at
the Massachusetts General Hospital. The diagnosis of AD was based on strict inclusion and exclusion
criteria (McKhann et al., 1984; Khachaturian, 1985). The diagnosis of PD was based upon the
presence of 2 of the 3 clinical criteria of akinesia, rigidity and rest tremor, and a positive response to
antiparkinsonian medication. None of the patients had a past history of stroke or any abnormal
neurological signs other than those of PD. The PD patients were not selected by any behavioural
criteria. At the time of testing, all PD patients were treated with antiparkinsonian medication, in the
majority of cases a levodopa preparation. All AD and PD patients were ambulant and free from
psychiatric disease. Neither patient group was treated with any primarily psychoactive medication.
The groups were matched for age and years of education but the PD group had a higher male: female
sex ratio than the other two groups. The PD group had a longer mean duration of illness ($P < 0.01$),

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>Education (yrs)</th>
<th>Duration of disease (yrs)</th>
<th>Blessed Dementia Scale score*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>63.1</td>
<td>13.7</td>
<td>Not</td>
<td>0.3</td>
</tr>
<tr>
<td>(7 M, 8 F)</td>
<td>(54–77)</td>
<td>(10–19)</td>
<td>applicable</td>
<td>(0–2)</td>
</tr>
<tr>
<td>Parkinsonian</td>
<td>62.5</td>
<td>15.4</td>
<td>6.0</td>
<td>3.0</td>
</tr>
<tr>
<td>(13 M, 2 F)</td>
<td>(39–80)</td>
<td>(8–20)</td>
<td>(1–13)</td>
<td>(0–12)</td>
</tr>
<tr>
<td>Alzheimer</td>
<td>63.5</td>
<td>14.9</td>
<td>3.2</td>
<td>8.6</td>
</tr>
<tr>
<td>(7 M, 8 F)</td>
<td>(53–76)</td>
<td>(12–20)</td>
<td>(2–7)</td>
<td>(5–16)</td>
</tr>
</tbody>
</table>

* Memory and orientation section. M = male; F = female.
but was less demented as judged by performance on the memory and orientation section of the Blessed Dementia Scale (BDS) (Blessed et al., 1968). Three of the 15 PD patients were clinically demented according to criteria of the Diagnostic and Statistical Manual of Mental Disorders of the American Psychiatric Association (DSM III).

Procedure

The Verbal Temporal Ordering (VTO) Test, modified from Hirst and Volpe (1982), consisted of a series of 493 nouns which were displayed on a computer screen at a rate of one every 2 s. Each word contained 4, 5 or 6 letters and had a frequency rating in the English language of 25 times per million or more (Kucera and Francis, 1967). At random intervals throughout the display, one of two types of item appeared on the screen: content recognition tests contained a previously presented word and a foil; recency discrimination tests contained 2 previously presented words. The test questions ‘Which of these words have you seen on this test?’ or ‘Which of these words did you see more recently?’ appeared at the top of the screen and were also spoken by the examiner. The two alternative answers subsequently appeared side-by-side underneath the question on the screen.

The test questions appeared at various intervals after stimulus presentation. The duration of each stimulus-test interval was defined as the number of intervals between events where an event was either another stimulus word or a test question. For example, where a question immediately followed stimulus presentation, the stimulus-test interval was 1 and there were no intervening events; where a question was the third item after stimulus presentation, the stimulus-test interval was 3 and there were 2 intervening items that could be stimulus words or test questions relating to earlier stimulus words. The position of a content recognition question was defined by one such interval. Recency discrimination questions examined 2 previously presented words; the position of a recency discrimination question was therefore defined by two intervals, one corresponding to each word examined in the test.

For content recognition, the stimulus-test intervals were 1, 3, 6, 10, 15, 25, 50, 100 and 150; there were five exemplars at each position. For recency discrimination, all possible pairings of these stimulus-test intervals were used (1–3, 1–6, 1–10 ... 50–100, 50–150, 100–150); there were 5 exemplars for each pairing.

Test questions were presented in random order, subsequently modified to equalize the proportion of test questions and single-word stimuli within each stimulus-test interval. The 2 words presented as choice responses in each test of content recognition or recency discrimination were matched for word length and frequency. For each stimulus-test interval, the 5 exemplars of each type of test (content recognition or recency discrimination) were matched for word length and frequency to the list as a whole; content recognition and recency discrimination test responses were similarly matched to each other. In the two-choice tests, 50% of the correct responses appeared on the left half of the screen and 50% on the right half of the screen in random order.

During administration of the test, subjects were seated beside the examiner and in front of the screen. They were instructed to read each word aloud and to remember the words in their order of appearance. Subjects gave oral responses to the questions in unlimited time. The examiner entered the response into the computer at the same time as he instructed the subject ‘Keep on reading’. The registration of the response triggered the appearance of the next stimulus word.

Statistical analysis

Results were calculated separately for content recognition and recency discrimination as the mean percentage correct at each stimulus-test interval. For recency discrimination in some analyses, results were pooled for each position of the more recent stimulus and performance was assessed across stimulus-test intervals corresponding to the more recent stimuli of the pairs. Other analyses examined the effect on performance of increasing interstimulus intervals: for each position of the recent stimulus, the results were analysed according to the position of the more remote stimulus. Total percentage correct was the mean of the average performances at each stimulus-test interval.
Repeated measures analyses of variance (ANOVA) of Group (G) x Task (content or recency) (T) x Interval (I) were performed separately for the scores on the VTO test. Arc sin square root transformations were used to produce normal distributions of data with homogeneous variances. For statistical purposes, all stimulus-test intervals were examined separately. In graphic representations, however, results were pooled for intervals beyond the theoretical limit of short-term memory (i.e., intervals greater than 6) as 10, 15, 25 and 50, 100, 150 so as to eliminate irregularities in the forgetting curve that may have resulted from reduced numbers of data points at longer intervals. When ANOVA yielded significant differences among data sets, planned paired comparisons were performed using the Mann-Whitney U Test or the Wilcoxon Matched-Pairs Signed-Ranks Test (two-tailed unless otherwise stated).

**RESULTS**

*Total scores*

In all subject groups, recency discrimination was more difficult than content recognition (for VTO, \( F(1, 42) = 182.89, P < 0.001 \)). Significant differences emerged among groups, however, in their performance on content recognition and recency discrimination (Table 2) (for total scores across groups on the VTO test \( F(2, 42) = 11.08, P < 0.001 \)). The interaction G x T was significant (\( F(2, 42) = 3.32, P < 0.05 \)), indicating a difference among groups in their relative performance in content recognition and recency discrimination.

<table>
<thead>
<tr>
<th>Stimulus-test interval ( l )</th>
<th>1</th>
<th>3</th>
<th>6</th>
<th>10</th>
<th>15</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>Total</th>
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<tr>
<td>Content Control</td>
<td>100</td>
<td>96.0</td>
<td>85.3</td>
<td>74.7</td>
<td>88.0</td>
<td>77.3</td>
<td>72.2</td>
<td>64.0</td>
<td>81.6</td>
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</tr>
<tr>
<td></td>
<td>(0)</td>
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<td>(5.8)</td>
<td>(6.5)</td>
<td>(1.9)</td>
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<tr>
<td>PD</td>
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<td>85.3</td>
<td>85.3</td>
<td>76.0</td>
<td>81.3</td>
<td>72.0</td>
<td>66.7</td>
<td>73.7</td>
<td>58.7</td>
<td>75.8</td>
</tr>
<tr>
<td></td>
<td>(6.2)</td>
<td>(3.8)</td>
<td>(5.0)</td>
<td>(5.2)</td>
<td>(4.9)</td>
<td>(4.3)</td>
<td>(5.7)</td>
<td>(4.2)</td>
<td>(5.7)</td>
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<td>76.0</td>
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<td>56.7</td>
<td>69.3</td>
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<td>(4.3)</td>
<td>(4.6)</td>
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<td>(2.8)</td>
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<td>82.2</td>
<td>71.7</td>
<td>66.1</td>
<td>59.7</td>
<td>62.6</td>
<td>58.7</td>
<td>54.7</td>
<td>—</td>
<td>69.0</td>
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<tr>
<td></td>
<td>(0.9)</td>
<td>(2.5)</td>
<td>(1.8)</td>
<td>(2.5)</td>
<td>(2.9)</td>
<td>(3.4)</td>
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<tr>
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<td>(2.9)</td>
<td>(3.0)</td>
<td>(4.5)</td>
<td>(7.0)</td>
<td>—</td>
<td>(2.0)</td>
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</tbody>
</table>

* For recency discrimination, stimulus-test interval defines the position of the more recent item of the stimulus pairs. Results are expressed as mean percentage correct with the SEM in brackets.

Post hoc planned comparisons showed the G x T interaction to be due to a selective deficit in recency discrimination in the PD group. Thus PD patients did not differ from control subjects in content recognition (\( U = 74, P > 0.1 \)) but were impaired in recency discrimination (\( U = 45, P < 0.02 \)), whereas patients with AD
were impaired in both types of task (for content, $U = 38$, $P < 0.002$; for recency, $U = 28.5$, $P < 0.002$).

**Effect of stimulus-test interval**

In statistical analysis of content recognition, stimulus-test interval defined the position of the appropriate single stimulus item. For recency discrimination, in which 2 stimuli are used, the stimulus-test interval defined the position of the more recent item of the stimulus pairs.

In all groups, performance declined with increasing stimulus-test interval on the VTO test (Table 2, fig. 1; $F(7, 294) = 39.03$, $P < 0.001$); the interaction $T \times I$ was not significant. The subject groups differed, however, in the relationship between test performance and stimulus-test interval; thus the interaction $G \times I$ was significant ($F(14, 294) = 1.93$, $P = 0.02$). Mean scores for each interval are shown in Table 2 and for pooled intervals in fig. 1. Patients with AD showed performance inferior to that of control subjects in both content recognition and recency discrimination at all stimulus-test intervals (for content recognition, $U = 38$, $P < 0.002$; for recency discrimination, $U = 28.5$, $P < 0.002$). The forgetting curves of the AD group were in general parallel but inferior to those of the control group. The PD group, by contrast, showed a pattern of performance in which disproportionately severe deficits were seen at the shorter stimulus-test intervals. Content recognition by the PD group was inferior to that by the control group at stimulus-test intervals of one ($U = 60$, $P < 0.05$) and three ($U = 64.5$, $P < 0.05$) but not at longer intervals and, unlike the control and AD groups, there was no decrement in performance between stimulus-test intervals of 1 and 6 (for controls, $T = 0$, $P < 0.02$; for AD, $T = 1$, $P < 0.05$; for PD, n.s.). At a stimulus-test interval

![Figure 1](image-url)
of 1, the scores of the AD and PD groups did not differ although the PD group tended to inferior performance (PD 84%; AD 89%).

In recency discrimination, the groups as a whole did not differ significantly in the relationship of test performance to stimulus-test interval.

**Relationship to dementia and minimental state test scores**

Exclusion of the 3 PD patients who were demented by DSM III criteria did not alter the qualitative differences between groups. The scores for the remaining 12 PD patients expressed as mean percentage correct, with SD in brackets, were as follows: total content 78.5 (9.96), total recency 64.0 (5.96); content at stimulus-test intervals of 1, 90.0 (18.1); of 3, 86.7 (13.0); of 6, 90.0 (16.0); of 10–25, 73.9 (12.4); and of 50–150, 69.5 (10.1).

The groups were divided according to their score on the memory and information section of the Blessed Dementia Scale (BDS) on which normal control subjects scored a maximum of 2. The total PD group was divided into Group 1 with normal BDS scores (0–2) and Group 2 with abnormal BDS scores (3–12), which included the 3 PD patients who were demented according to DSM III criteria. The AD group was divided into a mildly demented subgroup that matched the PD Group 2 for BDS score (3–12) and a moderately demented subgroup (BDS > 12) for which no parallel existed among the PD patients, owing to the overall greater severity of dementia in AD.

Within patient groups, scores on content recognition and recency discrimination tended to be lower in subjects with higher BDS scores (fig. 2). The relationship between performance and BDS score was similar in the 2 patient groups for content recognition but differed for recency discrimination. For content recognition, the correlations between test score and BDS score were not significant in either group (for PD, r = -0.45; for AD, r = -0.30). For recency discrimination, however, PD patients with higher BDS scores achieved significantly lower scores on the VTO test (r = -0.84, P < 0.001). In AD, the correlation between recency discrimination performance and BDS score was not significant (r = -0.18).

When performance was analysed according to stimulus-test interval, the PD subgroups showed a qualitatively similar pattern of performance to the total PD group (fig. 2). In general, however, the results were no longer significant, possibly because of the smaller number of subjects in each subgroup. In content recognition, scores of PD Group 1 tended to be inferior to those of control subjects at stimulus-test intervals of 1 (U = 37.5) but not at longer intervals. At the shortest interval of 1, PD Group 1 patients produced results equivalent to those of the mildly demented AD group but, at longer intervals, tended to superior performance (U = 30.0–41.0). PD Group 2 tended to inferior performance to the mildly demented AD group at a stimulus-test interval of 1 (U = 29.5) but did not differ at longer intervals. In recency discrimination, PD Group 2 achieved scores inferior to the mildly demented AD group only at a stimulus-test interval of 1 (U = 21, P < 0.05, one-tailed). At this point, the performance of PD Group 2 matched that
of the more severely demented AD group, whereas the mildly demented AD group achieved scores equivalent to those of control subjects. At longer intervals, the scores of PD Group 2 did not differ from those of the mildly demented AD group but were superior to those of the moderately demented AD group.

**Fig. 2.** VTO test performance (mean ± SEM) across stimulus-test intervals related to the severity of dementia. For recency discrimination, stimulus-test interval defines the position of the more recent item of the stimulus pairs. In both tasks, more demented patients showed inferior performance but PD patients performed disproportionately poorly at short stimulus-test intervals. Control, n = 15 (○); PD, n = 8, BDS = 0-2 (□); PD, n = 7, BDS = 3-12 (◇); AD, n = 13, BDS = 3-12 (▲); AD, n = 2, BDS = 13+(▲).

**Interstimulus interval in recency discrimination**

The effect on recency discrimination of increasing intervals between items of the stimulus pair was analysed as follows. The position of the more recent of the two items was defined by its position relative to the test, that is, as 1, 3, 6, 10, . . . items prior to test; for each of these positions, an ANOVA was performed of Group × Interval × Test where Interval refers to the number of items between the more remote stimulus and test. There were significant effects on Interval for all positions of the more recent stimulus (for positions 1, 6 and 15, P < 0.001; for positions 3 and 10, P < 0.01). There were no significant G × I interactions. Thus in all groups, recency discrimination was better with longer intervals between items of a stimulus pair.

**DISCUSSION**

The purpose of this study was to examine the relationship between content recognition memory and recency discrimination in PD and AD as a function of the interval between stimulus and test. The main findings were (1) patients with AD were impaired in all tasks at all retention intervals; (2) unlike patients with AD, patients with PD had a deficit in verbal recency discrimination with preserved
recognition of stimulus content; and (3) patients with PD showed selective or disproportionate deficits in content recognition at the shortest stimulus-test intervals, unlike AD patients whose forgetting curves were below but parallel to those of control subjects at all stimulus-test intervals. These results suggest specific cognitive deficits in verbal recency discrimination and in short-term memory processing in PD.

These cognitive deficits occurred in a group of patients who were not preselected by any behavioural criterion and who were thus representative of a typical outpatient group of PD patients. Only 3 of the 15 cases were demented by DSM III criteria, a proportion representative of the PD population in general (Mortimer et al., 1985). The results cannot be attributed to the nonspecific effects of Alzheimer-type dementia because the qualitative nature of the findings is not altered by exclusion of these cases, even assuming that their dementia is of the Alzheimer type. More specifically, the findings of qualitatively different results in a control AD group essentially excludes this possibility. Equally, the results cannot be considered as artefacts resulting from the motor disorder or poor attentional skills because these deficits would tend to affect performance indiscriminately, whereas our results show selective deficits among cognitive processes examined under parallel conditions. Parkinson's disease and Alzheimer's disease share many cognitive deficits and, in some respects, differ quantitatively but not qualitatively (S. Corkin, J. H. Growden and M. J. Nissen, unpublished observations; Mayeux and Stern, 1983). In this study, however, poor temporal ordering and impaired short-term memory processing were features that distinguished both qualitatively and quantitatively the cognitive decline of PD from that of AD.

Verbal recency deficits in PD

Studies of normal subjects and patients with memory disorders have indicated that recency discrimination is not slavishly linked to content recognition. Evidence from normal subjects suggests that these two cognitive functions are dissociable and are affected differentially by alterations in the learning strategy (Hasher and Zacks, 1979). Thus performance on recognition memory tasks was better if subjects were given prior instructions to learn the test material (intentional or effortful learning) than if learning took place without instruction, as an incidental accompaniment to some other task, such as reading (incidental or automatic learning). Recency discrimination, by contrast, was not affected by a change from incidental to intentional learning. Studies of some amnesic patients have shown loss of temporal contextual memory in the absence of deficits in recognition memory; this loss has been postulated to form the basis of the amnesic syndrome (Huppert and Piercy, 1976; Hirst and Volpe, 1982; Schacter et al., 1984). Squire et al. (1981) have suggested that this pattern of performance in amnesia is a simple consequence of degraded normal memory because recency discrimination, being a more difficult task, is more susceptible to disruption by disease than is content recognition. Even when normal memory was degraded to the amnesic level, however, patients with
Korsakoff's syndrome still performed more poorly in recency discrimination than did a control group (Meudell et al., 1985). Moreover, in the severely amnesic patient, H.M., the reverse pattern occurred: H.M. showed preserved recency discrimination under conditions where recognition performance was at chance levels and in no circumstance was recency discrimination impaired when recognition memory was normal (Sagar et al., 1984). In studies of epileptic patients treated by focal cortical excision, Milner and colleagues have demonstrated dissociations of function dependent upon lesion site: frontal excisions are associated with impaired recency discrimination and intact recognition memory whereas temporal excisions are followed by recognition deficits but preserved recency discrimination (Milner, 1971, 1974; Corsi, 1972). Taken together, these observations suggest that content recognition and recency discrimination are, under certain circumstances, independent cognitive processes that may be selectively disrupted or manipulated.

In the present study, patients with PD showed recency discrimination deficits when content recognition was preserved. The interaction Group x Task was significant, indicating that the groups differed in their relative performance on the tasks of content recognition and recency discrimination. This interaction cannot be attributed to ceiling effects at short intervals on content recognition because, at short intervals, the difference between groups is greatest. Equally, the results cannot be due to floor effects in recency discrimination at long intervals because such effects would reduce rather than increase the interaction. Instead, the significant Group x Task interaction reflected the observations that content recognition by the PD group was as good overall as that of the control group but its recency performance was as poor as that of the AD patients, who were impaired on both tasks. Furthermore, recency discrimination in PD showed a different relationship to score on a minimental state test, the BDS, from either recency discrimination in AD or content recognition in either group. These observations suggest that recency discrimination in PD is also a specific deficit and not a simple consequence of impaired memory for content, although further studies will be needed to clarify this point.

In concurrent studies we have shown that, compared with AD patients, patients with PD have a disproportionately severe deficit in their ability to date past historical events when account is taken of their relatively preserved recognition of the content of these events; we have postulated frontal lobe dysfunction as the basis of the impairment (Sagar et al., 1985a; 1988). The present study demonstrated that PD patients also have verbal recency discrimination deficits in new learning despite preserved content recognition, suggesting that impaired dating capacity may be partly based upon an impaired ability to make temporal discriminations. Several studies suggest that recency discrimination is dependent upon the integrity of the frontal lobes, whereas recognition memory is served by structures in temporal and diencephalic regions (Milner, 1971, 1974; Corsi, 1972; Schacter et al., 1984; Mayes et al., 1985; Meudell et al., 1985). Although the recency discrimination deficit in PD cannot be established absolutely as a specific deficit, the results of our two studies
together suggest that patients with PD may have impaired dating capacity and poor temporal discrimination due to pathology in the frontal lobes or their connections. In further studies (Sullivan et al., 1985; Sagar, 1987), we have shown that, compared with AD patients, PD patients are selectively impaired in their capacity to arrange pictures in sequence so as to tell a logical story, a task that is also dependent upon frontal lobe function (McFie and Thompson, 1972). These observations indicate that impaired dating and recency discrimination in PD may form part of a broader deficit in cognitive sequencing as a result of dysfunction in the frontal lobes. In all these studies, the deficits in the PD group were disproportionately severe when compared with performance of an AD group, indicating that these cognitive deficits cannot be explained solely by the presence of Alzheimer-type cognitive impairment in PD.

**Deficits in short-term memory processing in PD**

Patients with PD were poor at content recognition and recency discrimination when tests of retention followed soon after presentation of the stimulus but showed less deficit or normal performance when the stimulus-test intervals were longer. This pattern was not seen in AD. The results cannot be explained by deficits in attention, perception or registration since an inadequately encoded stimulus would be poorly recognized whatever the stimulus-test interval. Equally, the findings cannot be due to factors, such as practice effects or improved attention, that may predictably improve performance as the testing proceeds, because the stimulus-test intervals were distributed randomly throughout the whole test. The special relationship of impairment to short stimulus-test intervals suggests that short-term memory processes in PD are impaired. We have considered two possible explanations for these results, bradyphrenia and inability to manipulate multiple items in PD.

**Bradyphrenia in PD.** The first hypothesis is that short-term memory processes in PD, although adequate, are slowed. Recognition tested during this period is poor because the material has been incompletely encoded but, after an interval, improves as registration increases. This cognitive slowing may be analogous to the slowing of movement or bradykinesia, which forms one of the cardinal motor signs of PD. Clinical descriptions have also drawn attention to hesitancy and slowing of cerebration in PD and, by analogy with motor function, have used the term bradyphrenia to catalogue these deficits (Naville, 1922). Wilson et al. (1980) have provided experimental support for this clinical concept by showing that scanning of short-term memory is slowed but accurate in PD and that the effects are not readily attributable to extreme reaction times. In another study (Rafal et al., 1984), in which patients acted as their own controls, speed of short-term memory scanning was shown to be independent of motor function although no absolute level of function could be established in the PD group because of the lack of normal control subjects. Taylor et al. (1986) studied a selected group of PD patients deemed nondemented on clinical evaluation and found evidence of bradyphrenia on a block-counting task on
which their accuracy was normal. Rogers et al. (1987) detected cognitive slowing on the digit-symbol substitution task in untreated PD patients; the deficit was related to structural brain disorder, mostly cerebral atrophy, on CT scans, and to the severity of associated depression. None of these studies incorporated a non-parkinsonian demented group to examine whether the pattern of performance in the PD group was different from the nonspecific effects of dementia. The results of our study are compatible with the notion that short-term memory processing is slowed but accurate in PD. An explanation based on slowing of cognitive processes would predict that PD patients would perform poorly on any memory task soon after registration of information, whether testing be conducted in recall or recognition format.

Hypothesis: inability to manipulate multiple items in PD. The second possible explanation of the short-term memory deficit lies in dysfunction of a higher-order memory system, based upon the frontal lobes, that is capable of manipulating, discriminating and comparing independent memoranda (Warrington and Weiskrantz, 1982; Baddeley, 1985; Warrington, 1985; Baddeley and Wilson, 1986). Deficits in this cognitive mediational system were proposed as the basis of the selective dating impairment in our studies of remote memory function in PD (Sagar et al., 1985a, 1988). Such a system could serve recency discrimination and cognitive sequencing tasks, which PD patients also perform poorly (Sullivan et al., 1985; Sagar, 1987; Sagar and Sullivan, 1988) and may be operative in manipulating multiple items of any nature, whether mnemonic or nonmnemonic. Dysfunction of the same system could underlie the clinical phenomenon of bradyphrenia if certain assumptions are fulfilled: (1) that at the short but not long stimulus-test intervals, stimuli are within a short-term memory store; (2) that the foils, being common nouns, form part of the subjects' long-term memory store; and (3) that comparison of memoranda across stores is more difficult than within the same store. If these conditions are fulfilled, then impoverished performance may be most marked at short stimulus-test intervals owing to the particular incapacity in discriminating, in a two-choice recognition task, between stimuli in different memory stores. Such a model would not require slowing of cognitive processes but the deficits would nevertheless be manifest clinically as slowness in producing accurate responses.

In so far as discrimination between stimuli in different memory stores demands shifting of attention from one cognitive process to another, the impairment may be related to deficits on other tasks in which subjects make attentional shifts between multiple items. Specifically, patients with PD show difficulty in altering cognitive attitude in response to changing environmental demand, a process known as 'set-shifting' (Lees and Smith, 1983; Cools et al., 1984). Although this term is traditionally applied to attentional shifting between different stimulus characteristics, similar attentional shifts may also take place between different cognitive processes. Although speculative, these considerations suggest that the results of this study may be explained by dysfunction of processes that are also
involved in classical set-shifting. Both the cognitive mediational system and processes serving set-shifting are considered to depend on integrity of the frontal lobes, raising the possibility that bradyphrenia may also arise from frontal lobe dysfunction. This hypothesis predicts that patients with PD would show a general impairment in performing multiple tasks simultaneously, a deficit that may extend to mnemonic and nonmnemonic cognitive processes and may also involve motor control.

The lack of similar findings in AD indicates that the short-term memory deficits of the PD group are not attributable simply to nonspecific effects of Alzheimer-type dementia. Rather, the results of this study support the concept of bradyphrenia as a specific clinical finding in PD, although the underlying cognitive deficits need not involve prolonged processing time.

Frontal lobe dysfunction in PD

A number of cognitive deficits have been claimed to be characteristic of PD (Sagar, 1985; Growdon and Corkin, 1986; Sagar and Sullivan, 1988). The impaired capacities include visuospatial function (Boller et al., 1984); motor sequencing and predictive behaviour (Flowers, 1978; Stern et al., 1983), dating capacity (Sagar et al., 1985a, 1988), verbal recency discrimination (Sagar et al., 1985b, this study), cognitive sequencing (Sullivan et al., 1985; Sagar, 1987; Sagar and Sullivan, 1988) and processes underlying the clinical phenomenon of bradyphrenia (Naville, 1922; Wilson et al., 1980; Sagar et al., 1985b, this study). Many of these deficits can be attributed to frontal lobe dysfunction. Other workers have provided evidence of impairment in patients with PD on tests traditionally associated with frontal lobe function including release from proactive interference (Tweedy et al., 1982), double simultaneous motor acts (Schwab et al., 1954) and the Wisconsin Card Sorting Test (Lees and Smith, 1983). These observations suggest that frontal lobe dysfunction may form a large contribution to the aetiology of cognitive impairment in PD. For some of these deficits, the lack of equivalent findings in AD indicates that the frontal lobe pathology must be quantitatively or qualitatively different from that in AD. Normal brain has a richness of subcortical-cortical interconnections that are disrupted in both AD and PD. Although multiple neurotransmitter systems are affected in both diseases, PD differs from AD in the extent of loss of dopaminergic subcortical-cortical projections (Thierry et al., 1978). In PD, the cholinergic deficits are usually milder than in AD (Perry et al., 1985). Loss of noradrenergic cells of the locus coeruleus occurs in both diseases (Bondareff et al., 1982; Hornykiewicz, 1982). Cholinergic, dopaminergic and noradrenergic neurons project to the frontal cortex (reviewed by Sagar and Sullivan, 1988). Differential involvement of these subcortical-cortical neurotransmitter systems in AD and PD may account for the differing patterns of cognitive impairment in the two diseases and explain the selective loss of frontal lobe function in PD.
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