MEMORY FOR TEMPORAL ORDER AND CONDITIONAL ASSOCIATIVE-LEARNING IN PATIENTS WITH PARKINSON’S DISEASE

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Abstract—The performance of Parkinson’s patients was compared to that of normal controls on memory for temporal order and conditional associative-learning tasks, each of which is sensitive to frontal-lobe dysfunction. Memory for temporal order involved reconstructing the presentation order of each of a series of drawings, words and designs. Recognition of similar stimuli was also examined. Parkinson’s patients exhibited poor memory for the relative temporal relations between stimuli, though no group differences were observed in the number of stimuli placed in the correct position. Recognition was intact in the Parkinson’s patients, and an absence of correlation between performance on the recognition and temporal order tasks indicates that the poor memory for temporal order is not simply a function of degraded memory for the individual stimuli. The conditional associative-learning task required subjects to learn, either by trial-and-error or with immediate correction, numbers paired with drawings, designs or spatial locations. Parkinson’s patients were impaired only when learning by trial-and-error was required. Results suggest that the strategic retrieval processes involved in both memory for temporal order and learning conditional associations by trial-and-error depend on the integrity of the fronto-striatal system, which is known to be affected in Parkinson’s disease.

INTRODUCTION

Studies of the neuropathology of Parkinson’s disease have revealed neuronal loss and dopamine depletion in the substantia nigra and striatum [22, 28]. These structures lie along reciprocal pathways between association cortices and the frontal lobes [2, 8]. The functional integrity of the frontal lobes may therefore be at risk in Parkinson’s patients. Some support for this conjecture comes from recent neuropsychological studies of Parkinson’s patients which have revealed a pattern of selective impairment of cognitive abilities dependent upon the frontal lobes [38, 39]. For example, the performance of Parkinson’s patients is impaired on the Wisconsin Card Sorting test [6, 12, 15, 18, 38, 39], a self-ordered pointing task [12], and cognitive puzzles such as the “Tower of Hanoi” that require abilities mediated by the frontal lobes [26, 33]. In contrast to the impairment on tests sensitive to frontal-lobe dysfunction, performance is generally intact on tests dependent on more posterior regions of the brain. General intelligence is intact [15, 18, 19, 38, 39] and visuospatial deficits are observed only on tests involving actual or planned motor responses [4, 11].

It might be expected, therefore, that in patients with Parkinson’s disease, memory deficits will be observed only on those tests that are sensitive to frontal-lobe dysfunction. The results of a number of studies are generally consistent with this prediction. Recognition is intact in nondemented Parkinson’s patients [9, 18, 38], as is performance on many recall tasks [15,
38, 39] with the exception of those that require organization or other strategic processes [13, 21, 38, 42]. Impaired performance has been reported on certain memory tests, including conditional associative-learning [6, 12], temporal dating of public and personal events [31] and recency discrimination [32]. Performance on these latter memory tests is also compromised following frontal-lobe lesions [24, 30]. Several authors have argued that the frontal lobes play a critical role in memory temporal information [10, 25, 34, 37]. Poor temporal dating and recency discrimination may reflect deficits in the retrieval of specific temporal information associated with an event. One might also expect that the ability to reconstruct temporal order may be impaired following frontal-lobe lesions. Such a deficit would be predicted not only from the impaired recall of temporal information but also from the difficulties in sequencing hand and face movements experienced by frontal patients [14, 16]. Some recent work suggests that patients with frontal-lobe dysfunction do experience difficulty reconstructing the order of previously presented words [35]. We might expect similar temporal ordering difficulties in Parkinson's patients.

Impairment on a conditional associative-learning task, a task that is sensitive to frontal-lobe damage [30], has been reported in some Parkinson's patients, but not in others [6, 12]. PETRIDES [30] proposed that the impaired performance of frontal patients on this task arises from an inability to select from a group of responses the appropriate response to a given stimulus, perhaps as a result of interference. Another possibility is that the deficit arises from an inability to learn by trial-and-error, as is typically required on this task. Patients with frontal-lobe lesions have difficulty in learning by trial-and-error and in benefiting from error feedback [7, 17, 23]. Although it is not clear whether the same processes underlie trial-and-error learning and the retrieval of temporal information, it is possible that an inability to monitor and distinguish between temporally distinct events underlies the impaired performance of frontal patients on both tasks. If a deficit in trial-and-error learning underlies the poor performance of frontal patients on the conditional associative-learning task, then immediate correction feedback should reduce the deficit. On the other hand, if an inability to select the correct response from a set of responses underlies the deficit, impairment should be evident even with immediate correction feedback.

In order to investigate further the performance of Parkinson's patients on tests of memory and learning sensitive to frontal dysfunction, two tasks were developed. Memory for the temporal order of sequentially presented items was assessed by requiring subjects to reconstruct the order in which a series of items occurred. A recognition task was also administered in a format similar to that of the temporal order task in order to establish whether poor memory for the order is independent of recognition of the individual items. The second task involved a modification of PETRIDES' conditional associative-learning test [30]. Two different learning conditions were included, one involving learning by trial-and-error, and the other, learning with correction feedback. It was hypothesized that Parkinson's patients would perform more poorly than matched control subjects on both the memory for temporal order and the conditional associative-learning tasks as a result of the fronto-striatal dysfunction.

METHOD

Subjects

Twenty individuals with Parkinson's disease, 14 males and 6 females, were recruited as outpatients from three metropolitan hospitals. Parkinson's disease had been diagnosed in each patient by a neurologist, and there was no history of other neurological illness or injury in any patient. The mean duration of illness was 6.6 years (SD = 4.45).
and ranged from 1 to 22 years. Seven patients had motor symptoms primarily in the left side of the body, six had predominantly right-sided motor symptoms, and seven had bilateral motor symptoms. All but one patient was treated with a levodopa preparation; one patient was also treated with an anticholinergic medication and another was unmedicated, but the performance of these two patients was not different or outstanding. The Mattis Dementia Rating Scale [20] was administered to patients who had not received the test within the last year, and only individuals who scored higher than 135, indicating that they were not demented, were included in the study. Errors occurred on measures of conceptualization and occasionally attention and initiation but items on the memory tests were seldom missed. The mean age of the patients was 68.45 years (SD = 5.69). The patients had an average of 15.25 years of education (SD = 2.63), and the mean score on the Mill-Hill Vocabulary test was 15.2 out of 20 (SD = 2.8). All patients were predominantly right-handed.

A control group was recruited through the elderly volunteer subject pool at Erindale College, University of Toronto. Control subjects were matched with Parkinson's patients with respect to sex, age (mean = 68.70), education (mean = 13.75), and score on the Mill-Hill Vocabulary test (mean = 16.65). All elderly controls were in good health and without a previous history of neurological illness or injury.

Materials

Memory for temporal order and recognition tasks. The temporal order task required subjects to reconstruct from memory the order of presentation of a series of stimuli. Three versions of this task were administered; in one version representational drawings were used as stimuli, a second version included abstract words, and the third version consisted of abstract designs. The representational drawings consisted of line drawings of familiar objects taken from those collected by Snodgrass and Vanderwart [36]. Abstract words were drawn from the list compiled by Pauvio et al. [29] and included only those words with concreteness scores below 3.60. Abstract designs were taken from those assembled by Vanderplas and Garvin [40]. All stimuli were mounted on 4 x 6 in. blue index cards. For each of the three versions of this task, three sets of nine stimuli were constructed; one set was presented for recall of temporal order, a second set was presented for recognition, and a third set served as distractors in the recognition task. The three sets of stimuli were assigned to these conditions in a random order and counterbalanced within each group as far as possible, given the restrictions imposed by group size.

Conditional associative-learning task. This task involved learning a set of stimulus–response pairs under each of two learning conditions. Three versions of this task were administered. Stimuli in one version consisted of representational line drawings, in another version, of abstract designs, and the third version, of spatial locations. Stimulus material for this latter task involved six black circles of 2 in. dia. mounted in an irregular spatial array on a 9 x 12 in. white board. This board was presented in one orientation for the first learning condition and was rotated 180° for the second learning condition. Representational drawings were again selected from Snodgrass and Vanderwart [36], and abstract designs from Vanderplas and Garvin [40], though none of these stimuli overlapped with those employed in the temporal order task. All stimuli were mounted on 3 x 5 in. white index cards. For both the line drawings and the abstract designs, two sets of six stimuli were generated; one set of stimuli was assigned to each of the two learning conditions in a random, counterbalanced order.

Procedure

Each subject first performed the memory for temporal order task. Stimuli were presented to the subject at the rate of one every 3 sec, and the subject was instructed to try to remember the order in which the stimuli appeared. On each of the verbal versions of the task, the subject was also instructed to name each object or read each word aloud, in order to ensure that they had correctly perceived the stimulus. Following the presentation of the final card, there was a distracting task to prevent rehearsal of the material. The duration of the distracting activity was established for each stimulus type in pilot testing so that performance on the recognition task fell between chance and ceiling levels. For the representational drawings, the distracting task lasted 3 min and required the subject to label each of a series of drawings as “man-made” or “part of nature”. For the abstract words, the distracting activity lasted 2 min and involved labelling each of a series of words as either concrete or abstract. For the abstract designs, the distracting task lasted 30 sec and involved cancelling each of three symbols from random strings of symbols. Subjects were familiarized with the distracting tasks at the outset of the study so that the delay period would not be filled with task instructions. Following the distracting activity, the subject was presented with a parallel set of cards consisting of the original stimuli in a pseudo-random order, with the restriction that no stimulus appear in its original position or that it immediately follow the same stimulus it succeeded in the initial presentation. The subject's task was to rearrange the stimuli according to the original order of presentation, and each subject was given as much time as necessary to complete this task.

The delayed recognition task was administered next. The order of presentation of the three stimulus types corresponded to that of the memory for the temporal order task. The subject was shown nine stimuli at the rate of one every 3 sec, followed by the same distracting tasks as previously described. The subject was then presented with a series of 18 cards consisting of the nine target stimuli just presented and nine new stimuli which had not been seen previously, randomly interspersed between the target stimuli. For each stimulus, the subject indicated whether or not it had been seen previously.

Each subject then received the trial-and-error and the correction forms of the conditional associative-learning
task. On both forms, each stimulus was associated with one number between 1 and 6. The subject was told that the task was to learn which number in this set of numbers was associated with each of the six stimuli. Each trial was initiated by the presentation of a stimulus. Stimuli were presented in a pseudo-random order with the restriction that each stimulus appear once in each block of six trials, and that no stimulus be presented twice consecutively. On the trial-and-error form of this task, the subject guessed which number was associated with the stimulus, and feedback was given by the experimenter. If the response was correct, the next trial was initiated. If the response was incorrect, another response was required until the correct number was chosen. Only one error was scored for an incorrect trial, regardless of the number of incorrect responses given on that trial. This process was repeated until three consecutive blocks of six trials were completed without error or until 20 blocks of trials were completed. On the correction form of this task, the subject was initially shown each stimulus and told the number with which it was associated. Following this familiarization period, the first trial was initiated by the presentation of a stimulus, and the subject was required to respond with a number between 1 and 6. If the correct response was given, the next trial was initiated. If the incorrect response was given, the subject was told the correct response and one error was scored. This procedure was repeated until three consecutive blocks of six trials were completed without error or 20 blocks of trials were completed. Both forms of the task were performed with representational line drawings, abstract designs and spatial locations. The six conditions were administered in a random order, counterbalanced to the greatest extent possible within the restrictions imposed by group size.

Scoring

On the temporal order task, a rank-order correlation was calculated between the positions of the stimuli on presentation and on recall. This measure reflects the degree to which the presentation order has been preserved. Four other measures were also recorded; (1) the number of stimuli placed in the correct position, (2) the number of intact pairs of items recalled; credit was given for correctly placing the first stimulus and the last stimulus, and for any sequence of two stimuli corresponding to a contiguous pair of stimuli in the original presentation, (3) an absolute deviation score, derived by calculating the distance between each stimulus’ presentation and recall position and summing these scores across the nine stimuli to form an overall absolute deviation score, (4) a relative deviation score, derived by summing the distance between each stimulus’ presentation position and the presentation positions of the stimuli placed before and after it on recall; these scores are then summed across the nine stimuli to produce one overall relative deviation score.

Three measures are reported for the recognition task; the number of previously presented stimuli correctly recognized (hits), the number of new stimuli falsely identified as having been previously seen (false positive errors), and a corrected recognition score, calculated by subtracting the number of false positive errors from the number of hits.

Scores for the conditional associative-learning task included the number of blocks of trials required to learn the associations and the number of trials on which an error was made. For the trial-and-error condition, the number of errors produced after the first block of trials was recorded, since the initial block of trials involves the first exposure to the pairs, and any correct responses would simply reflect a chance occurrence. Similarly, the number of blocks of trials recorded for the trial-and-error condition excludes the initial block of trials.

RESULTS

For each task, an analysis of variance was performed for every dependent measure; group was a between-subject factor and all other variables were within-subject factors. The Student–Newman–Keuls Multiple Range Test was used to assess post-hoc comparisons.

Memory for temporal order

2 × 3 (group × stimulus) analyses of variance yielded significant group by stimulus interactions for three of the five dependent measures. As illustrated in Fig. 1, the significant group by stimulus interaction for the rank-order correlation scores \( F(2, 76) = 4.57, P < 0.02 \) reflects poorer performance by the Parkinson’s patients with the words \( (P < 0.01) \), but no difference between the groups with the drawings or the designs. A similar pattern of results was obtained with the absolute deviation scores \( F(2, 76) = 4.34, P < 0.02 \). A significant interaction was also obtained for the relative deviation scores \( F(2, 76) = 7.52, P < 0.005 \); as indicated in Fig. 2, the Parkinson’s patients performed more poorly than the matched control subjects with the drawings and the words \( (P < 0.05) \), though differences between the groups with the designs did not reach significance. There were no group
Fig. 1. Mean rank-order correlation scores on the memory for temporal order task as a function of stimulus type and subject group.

Fig. 2. Mean relative deviation scores on the memory for temporal order task as a function of stimulus type and subject group.

differences in the number of stimuli placed in the correct position \[ F(1, 38) = 3.73, \text{ ns} \] or the number of intact pairs recalled \[ F(1, 38) = 3.16, \text{ ns} \].

**Recognition**

Most Parkinson's and control subjects performed the recognition test at or near ceiling levels when the stimuli were representational drawings, though the scores for the words and the designs fell between ceiling and chance levels (see Table 1). Cell variances were not homogeneous for the number of hits and a logarithmic transformation of these scores was performed. False errors and corrected recognition scores (hits minus false positive errors) did not require transformation.

For each of the three dependent measures, a \( 2 \times 3 \) (group \( \times \) stimulus) analysis of variance was performed. There were no differences between the Parkinson's patients and the controls on any measure. Neither the main effect of group nor the group by stimulus interaction reached significance, with an \( F \)-ratio of less than 1.0 in every instance.
Table 1. Recognition scores (hits—false positive errors) by group and stimulus

<table>
<thead>
<tr>
<th></th>
<th>Parkinson’s patients</th>
<th>Matched controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Drawings</td>
<td>8.50 (0.95)</td>
<td>8.80 (0.52)</td>
</tr>
<tr>
<td>Words</td>
<td>6.80 (1.51)</td>
<td>6.90 (2.02)</td>
</tr>
<tr>
<td>Designs</td>
<td>3.50 (1.70)</td>
<td>3.75 (1.48)</td>
</tr>
</tbody>
</table>

Note: maximum score = 9, chance performance = 0.

Conditional associative-learning

One of the Parkinson’s patients was unable to complete all the versions of this task due to time constraints, and the partial data for this subject are not included in the analysis. Of the remaining 19 Parkinson’s patients, five were unable to complete at least one of the six conditions of the task due to high levels of frustration at being unable to perform the task. In these instances, error scores were prorated over the remainder of the test and the maximum number of blocks of trials (20) was assigned. All of the matched control subjects were able to complete all conditions of the task. Logarithmic transformations were performed on the number of errors and the number of blocks of trials in order to stabilize cell variances.

A $2 \times 2 \times 3$ (group x feedback type x stimulus) analysis of variance for the error scores yielded a significant group by feedback type interaction [$F(1, 37) = 7.56$, $P < 0.005$]. As illustrated in Fig. 3, the Parkinson’s patients performed more poorly than the control subjects on trial-and-error learning ($P < 0.01$), but differences between the groups were not significant when correction feedback was provided. A similar pattern of results was obtained for the number of blocks of trials required to reach criterion [$F(1, 37) = 11.43$, $P < 0.001$], with significant differences between the groups only in the trial-and-error learning condition ($P < 0.01$). Neither the main effect of group nor the interaction between group and any factor other than feedback type reached significance ($F < 1.0$ for all other interactions).

![Fig. 3. Subject group by feedback type interaction on the conditional associative-learning task.](image)

Relationship between tasks

Since the temporal order (TO) and conditional associative-learning (CAL) tasks each depend on the integrity of the frontal lobes, performance of the Parkinson’s patients on these two tasks should be correlated. In contrast, performance on the recognition task and the two
frontal memory tasks should not be related, since recognition is not typically affected by frontal dysfunction and is likely mediated by other brain structures. For the control subjects, there is no reason to expect that performance on the tasks would be correlated, since the tasks share little in common in intact subjects. In order to examine the relationships between performance on these tasks, correlations were computed separately for the Parkinson's patients and control subjects. These correlations were computed with the drawings only, since these stimuli were common to all tasks, and since some group differences were obtained with these stimuli.

Although the results of the correlational analysis are somewhat variable, they are generally consistent with our predictions. The performance of the Parkinson's patients on the trial-and-error form of the CAL task was highly correlated with the relative deviation score on the TO task \((r = 0.59\) to \(0.61, Ps < 0.01\)), and moderately correlated with the rank-order correlation, absolute deviation and number of intact pairs scores \((r = 0.42\) to \(0.55, Ps < 0.055\)). The number of stimuli in the correct position did not correlate with CAL performance \((r < 0.23\). In contrast to the significant correlations between the TO and CAL tasks, performance of the Parkinson's patients on the recognition task did not correlate with any measure on the TO \((r < 0.38\) or CAL \((r < 0.16)\) tasks. Thus, for the Parkinson's patients, performance on the TO task and the trial-and-error form of the CAL task were well correlated, but performance on these tasks was not related to performance on the recognition task or the correction form of the CAL task.

A different pattern of correlations was obtained for the matched control subjects. None of the correlations between the TO and the CAL tasks reached significance \((r < 0.23)\). Recognition of the drawings did not correlate with performance on the TO task \((r < 0.21\) but was modestly correlated with performance on the correction form of the CAL task \((r = 0.45\) to \(0.48, Ps < 0.05)\).

**DISCUSSION**

It was anticipated that patients with Parkinson's disease would experience more difficulty than matched control subjects on the memory for the temporal order task and on the conditional associative-learning task due to fronto-striatal disruption arising from lesions in the basal ganglia. Results of the present study are consistent with this hypothesis.

On the memory for temporal order task, the Parkinson's patients performed more poorly than the matched control subjects on some dependent measures but not on others. Specifically, group differences were obtained on the deviation and the rank-order correlation scores but not on the number of stimuli placed correctly or the number of intact pairs recalled.

There are several possible interpretations of this pattern of results. One possibility is that the deviation measures are more sensitive indicators of memory for temporal order. Some recent findings from our own laboratory suggest that this explanation is unlikely. When elderly and young subjects are compared on this same task, the elderly perform more poorly than the young on the number of stimuli placed correctly and the number of intact pairs recalled but not on the deviation or the rank-order correlation scores \([41]\). Thus, no single measure can be considered to be the most sensitive in all cases. Our experiments suggest that the sensitivity of a measure depends on the different processes and brain structures involved in aging and in Parkinson's disease \([1, 3, 5]\).

A second possible interpretation of the differential pattern of results across the measures is
that it may reflect differences in the sensitivity of the various measures to different cognitive processes involved in reconstructing order. Both associative and strategic retrieval processes are likely involved in the reconstruction of temporal order. Associative processes are those in which retrieval is relatively automatic and is mediated by local cues with direct relationships to the target. The number of stimuli recalled in the correct position may reflect the efficiency of these processes. Strategic processes, on the other hand, are largely self-initiated and involve organization, estimation and formation of relational judgements. Rank-order correlations and the deviation scores may be more sensitive to the efficiency of these processes. Not only do these measures of temporal order differ in the degree to which they reflect different cognitive processes, but the processes themselves are likely mediated by different areas of the brain. For example, MOSCOVITCH [27] has argued that strategic processes are dependent upon the integrity of the frontal lobes, whereas associative processes are mediated by the mesial temporal lobes and related structures. The finding that Parkinson's patients are selectively impaired on measures reflecting strategic processes is thus consistent with the fronto-striatal dysfunction in this group.*

Different patterns of results were also obtained on the temporal order task with different types of stimuli. Parkinson's patients performed more poorly than matched control subjects when the stimuli consisted of words and, to a lesser extent, drawings, but no group differences were observed with designs. An absence of group differences with the designs can be understood in terms of the recognition data. Although both groups performed at above chance levels on the design recognition task, recognition of the designs was generally poor and may well have contributed to the diminished performance of both subject groups on the temporal order task. With the drawings and the words, which were well recognized by both groups, differences were obtained between groups on the temporal order task.

It is important to note that the Parkinson's and control subjects did not differ in their ability to recognize the stimuli. Furthermore, performance with the drawings on the recognition and memory for temporal order tasks was not correlated. These findings suggest that the poor memory for temporal order exhibited by Parkinson's patients does not reflect a generally degraded memory for the stimuli themselves. Moreover, the finding in our laboratory of a different pattern of results in the elderly [41], who do experience a mild memory decline relative to the young, suggests that a general memory problem does not underlie the current pattern of results.

These results on the temporal order task supplement previous findings of poor memory for temporal information in Parkinson's patients. SAGAR et al. demonstrated diminished recency discrimination [32] and temporal dating ability [31] in these patients. The tasks employed in these studies required the retrieval of specific temporal information associated with a public event, or the formulation of a relational judgement between two previously seen stimuli. The current results extend these findings by demonstrating that the Parkinson's patients cannot reconstruct the order in which a series of stimuli occur, a task that likely involves not only the retrieval of item-specific temporal information, but also involves estimation and sequencing of the general temporal framework of a series of events.

As anticipated, the Parkinson's patients also performed significantly more poorly than the control subjects on the conditional associative-learning task, but only when learning by

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*If we consider that strategic processes make great demands on attentional or cognitive processes, our results can be interpreted as consistent with the hypothesis that "attentional" deficits underlie the impairment observed in Parkinson's patients on a variety of tests [21].
trial-and-error was required. These results are consistent with previous reports of impaired conditional associative-learning in some Parkinson’s patients [6, 12].

As previously mentioned, Petrides [30] proposed that the deficit in frontal-lobection patients on the conditional associative-learning task arises from an inability to select from a group of responses the appropriate response to a given stimulus. The present results suggest, however, that in Parkinson’s patients with fron-to-striatal disruption, it is the requirement of learning by trial-and-error that is critical in producing this impairment. It will be important to establish whether a similar pattern of performance is evident in patients with circumscribed frontal-lobe lesions. The finding of intact performance of Parkinson’s patients with immediate correction is not surprising, given the similarity of such a task to paired-associate learning tasks, on which Parkinson’s patients are generally unimpaired [38, 39]. Impaired learning by trial-and-error may reflect the greater demand on strategic processes in this condition, such as organizing and monitoring responses. In this respect, the deficits in temporal order memory and trial-and-error conditional associative-learning may be related to each other.

We had originally hypothesized that Parkinson’s patients would perform more poorly on the memory for the temporal order task and on the conditional associative-learning task, particularly with trial-and-error learning, because of the damage to the basal ganglia and resultant fronto-striatal dysfunction. Evidence that these tasks are sensitive to fronto-lobe dysfunction comes from several sources. In addition to the data linking memory for temporal order with the frontal lobes [10, 25, 34, 37], a temporal ordering task very similar to that employed in the present study has been shown to be sensitive to fronto-lobe lesions by Shimamura et al. [35]. The present study employed fewer stimuli per trial and investigated different types of stimulus material, but these differences should not change the sensitivity of the task to fronto-lobe dysfunction. A task similar to the conditional associative-learning task with trial-and-error learning has also been associated with fronto-lobe lesions [30], though different types of stimuli were employed in the present study. Thus, the sensitivity of the tasks in the present study to fronto-lobe dysfunction is well established. Impaired performance by Parkinson’s patients is consistent with fronto-lobe disruption. Future research might clarify these relationships by examining correlations between performance on these tasks and on other tests of fronto-lobe function.

Evidence for a common neural basis for the memory for temporal order and conditional associative-learning tasks would be a pattern of high correlation between the temporal order task and the trial-and-error form of the conditional associative-learning tasks, and low correlations between each of these tasks and the recognition task. Indeed, there was a significant correlation between the temporal order and the trial-and-error form of the conditional associative-learning tasks with the drawings, and low correlations were obtained between each of these tasks and the recognition task. While consistent with the hypothesis of a common neural basis for the deficit on both tasks, we cannot rule out alternative explanations. Although significant, the correlations between the temporal order and conditional associative-learning tasks were not as high as might be anticipated if performance on these two tasks is mediated by the same areas of the brain. It is possible that different areas of the frontal lobe are critical for the performance of each task and that these areas are affected to different degrees in individual patients. It may also be that although the tasks involve some similar processes, additional differences in the processes required by each task and the brain regions mediating them may diminish the correlations.

These provisions notwithstanding, the results of the present study are consistent with the
hypothesis that frontal-lobe function is compromised in patients with Parkinson's disease. At least some of the memory and learning disturbances experienced by these patients likely arise from this frontal dysfunction. Specifically, memory for temporal order is poor and may reflect reduced efficiency of the strategic processes required by such tasks. Conditional associative-learning difficulties appear to be restricted to tasks requiring learning by trial-and-error, and can also be understood in term of the strategic demands of the task.

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