Comparison of Patients with Alzheimer's and Parkinson's Disease on Different Explicit and Implicit Tests of Memory

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Summary: Memory was tested explicitly (directly) and implicitly (indirectly) in nondemented (NDPD) and demented (DPD) patients with Parkinson's disease, mild Alzheimer's patients (AD), and normal controls. Memory for geometrically transformed sentences (mirror-reading) was tested explicitly by recognition and implicitly by measuring reading times. Memory for words was tested explicitly by graphemic cued recall and implicitly by word-stem completion. Patients with AD and DPD were impaired on all explicit tests. NDPD patients were only mildly impaired on recognition. By contrast, performance was normal in all groups on two implicit tests: mirror-reading of nonrepeated sentences and word-stem completion. This was not the case for mirror-reading of repeated sentences, which probably involved both implicit and explicit components on which patients with AD and DPD were impaired. It is concluded that patients with mild AD and DPD can perform normally on non-motor implicit tests of procedural (skill learning) and perceptually based item-specific memory, even though their performance on comparable explicit tests is severely impaired. Key Words: Neuropsychological tests—Alzheimer's disease—Parkinson's disease—Demented—Nondemented. NNBN 7:185–193, 1994

Evidence has accumulated in recent years for a dissociation between performance on two types of memory tests, "explicit" and "implicit" (1–3). Explicit tests of memory involve conscious recollection of past experiences and is typically tested by recall and recognition (4). Implicit tests of memory do not require the subject to reflect on the past. Instead, retention of past experience is measured by changes in performance with practice (4). Thus, improvement in cognitive or motor skills with practice, or enhanced perceptual identification of previously seen material, can occur without the subject recognizing or recalling the experience or the material. For example, the very same words that the subject may not remember studying may be perceived better (5) or read more quickly (6) than words that were not previously studied. The conscious recollection of new information as assessed by tests of recall or recognition can be severely impaired following localized damage to limbic system structures such as the hippocampus (7, 8), the mammillary bodies (9), and dorsomedial nucleus of the thalamus (10). Patients with such lesions, however, may perform normally on implicit tests of memory (11–14).

The structures mediating the performance on implicit memory tests have yet to be identified with cer-
tainty, although a number of candidates have been proposed. Two principle ones are the neostriatum, especially the caudate nucleus (15–18), and the posterior association cortex (13, 19–22). The structures that are implicated seem to depend on the type of implicit test that is used.

It is possible to distinguish between at least two types of implicit tests, each of which may be mediated by different neural structures (21, 22). One type involves learning skills or rules, what some would term acquisition of procedural memory, which requires extensive practice. Examples of this type of test are learning to read spatially transformed script (14, 39), improving on a pursuit rotor test, mirror-writing test, or serial reaction time tests (16, 17, 23–25), and acquiring implicit rules involving puzzles such as the Tower of Hanoi (18, 26). Because performance on these implicit tests, but not on their explicit counterpart, is impaired in Huntington’s disease and sometimes in Parkinson’s disease (16, 17, 27–30), investigators have suggested that they are mediated by the neostriatal system (see below for more detailed discussion).

A second type of implicit test involves acquisition of item-specific, usually perceptual, information for which a single exposure to the target is often sufficient for retention. For example, the probability of identifying visually degraded words (5, 31) or generating them from a three-letter cue (word-stem completion) (1) increases after only a single presentation of the item. This facilitation in performance is known as the repetition priming effect and it, too, is independent of performance on explicit memory tests for the same information. Patients with neostriatal lesions, as well as amnesic patients with hippocampal/limbic system damage, perform normally on these implicit tests, indicating that these structures are not the critical ones. The prime candidate seems to be the posterior neocortex, which, some theorists have suggested, is involved in storing perceptual stimulus information (13, 19–22, 35).

To the extent that the posterior neocortex is affected in patients with Alzheimer’s disease (AD), repetition priming effects should be reduced. At this time the evidence is inconsistent. Some investigators have reported a deficit (32–35), whereas others have found no difference in repetition priming effects between patients with AD and normal control subjects (35–39, 52).

A number of factors may be responsible for the inconsistencies, including severity of dementia (30), methodological differences among the various experiments, and whether repetition priming tests were primarily perceptual or conceptual. Visual perceptual tests are likely mediated by posterior neocortical structures, such as striate and prestriate cortex that are relatively preserved in AD, whereas conceptual tests may involve association cortex, which is affected in the temporal and parietal lobes by AD (16, 17, 21, 22, 34).

The purpose of this study is to compare the performance of patients with Parkinson’s disease and AD on the two types of implicit tests of memory, skill learning (procedural memory), and item-specific acquisition (repetition priming). The two tests we chose were reading spatially transformed script and word-stem completion. Learning to read spatially transformed script has both a skill-learning and item-specific acquisition component, whereas word-stem completion involves only the latter. The item-specific component of both tests is primarily perceptual, although conceptual variables are sometimes found to have a small, but reliable, effect on performance (40).

Based on the above hypotheses, it was predicted that patients with Parkinson’s disease would perform normally on item-specific acquisition but not on skill learning. Patients with AD were expected to be impaired at skill learning and to be only slightly deficient, if at all, on item-specific acquisition.

Performance on the explicit counterpart on both tests was also assessed. Patients with AD were expected to be impaired on all tests, whereas Parkinson’s patients without dementia were expected to perform well. We could not make any firm predictions regarding Parkinson’s patients with dementia.

SUBJECTS AND METHODS

Subjects

A total of 55 subjects gave informed consent to participate in the study: 23 were normal elderly individuals without evidence of central nervous system disease (NC), 16 had idiopathic Parkinson’s disease without dementia (NDP; 12 males, 4 females), 9 had Parkinson’s disease with dementia (DPD; 7 males, 2 females), and 7 were diagnosed as having AD (4 males, 3 females) (Table 1). None of the subjects had a history of stroke, uncontrolled hypertension, alcoholism, psychiatric disorder, or major metabolic disorder. In the two groups with dementia there was no evidence for multi-infarct dementia based on the Modified Hachinski Ischemic Scale (41). Each subject was given a battery of neuropsychological tests, including the Mattis Dementia Rating Scale (DRS) (42), the 60-item Boston Naming Test (BNT) (43), and the Controlled Oral Word Association Test (FAS) (44).

The patients with Parkinson’s disease were sepa-
TABLE 1. Demographic and psychometric characteristics of study subjects

<table>
<thead>
<tr>
<th></th>
<th>Normal controls</th>
<th>Parkinson's disease without dementia</th>
<th>Parkinson's disease with dementia</th>
<th>Alzheimer's disease</th>
<th>Group differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>23</td>
<td>16</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Age, Y</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>67.5</td>
<td>64.1</td>
<td>72.3*</td>
<td>74.4*</td>
<td>3.6</td>
</tr>
<tr>
<td>SD</td>
<td>8.7</td>
<td>9.6</td>
<td>3.4</td>
<td>5.4</td>
<td>.02</td>
</tr>
<tr>
<td>Education, Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>14.6</td>
<td>15.3</td>
<td>10.5*</td>
<td>12.7</td>
<td>3.65</td>
</tr>
<tr>
<td>SD</td>
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<td>3.6</td>
<td>5.1</td>
<td>3.4</td>
<td>.02</td>
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<tr>
<td>Dementia rating scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>142.9</td>
<td>140.3</td>
<td>122.6*</td>
<td>124.4*</td>
<td>33.6</td>
</tr>
<tr>
<td>SD</td>
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<td>2.9</td>
<td>13.0</td>
<td>8.3</td>
<td>.0001</td>
</tr>
<tr>
<td>Boston naming</td>
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<td>Mean</td>
<td>53.1</td>
<td>56.5</td>
<td>46.3*</td>
<td>42.4*</td>
<td>5.5</td>
</tr>
<tr>
<td>SD</td>
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<td>10.5</td>
<td>13.2</td>
<td>.003</td>
</tr>
<tr>
<td>Verbal fluency test (FAS)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>52.3</td>
<td>40.8*</td>
<td>22.8*</td>
<td>32.6*</td>
<td>15.8</td>
</tr>
<tr>
<td>SD</td>
<td>12.8</td>
<td>10.8</td>
<td>10.2</td>
<td>6.3</td>
<td>.0001</td>
</tr>
<tr>
<td>Beck depression inventory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>5.7</td>
<td>6.8</td>
<td>6.6</td>
<td>3.3</td>
<td>0.7</td>
</tr>
<tr>
<td>SD</td>
<td>4.4</td>
<td>5.5</td>
<td>5.0</td>
<td>2.7</td>
<td>.5</td>
</tr>
<tr>
<td>Parkinson's disease severity rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>-</td>
<td>6.8</td>
<td>8.5*</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>-</td>
<td>1.9</td>
<td>2.3</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

* (P < .05) compared to controls.
\* (P < .05) compared to Parkinson's disease without dementia.

rated into demented and nondemented groups on the basis of their performance on the DRS. The DRS is relatively easy to administer, correlates well with the Wechsler Adult Intelligence Scale, and is useful for the identification of intellectual deficits. This scale measures cognitive function along the parameters of attention, perseveration, constructional ability, conceptualization, and memory. The maximum score is 144. The criterion for dementia was based upon normative data obtained in a series of normal control subjects tested previously (45). Patients with Parkinson's disease with scores falling outside the range obtained by these normal controls (133–144) were classified as having dementia. As indicated above, 9 subjects with Parkinson's disease had dementia (DPD), and 16 did not. The DPD patients also met DSM-III criteria for dementia (46). Severity of parkinsonism (Table 1) was assessed by rating rigidity, tremor, bradykinesia, gait, abnormal involuntary movements, and general impairment on a four-point scale (a rating of 4 represents maximal deficit) (47).

The patients with AD had a history of progressive decline in intellectual function without focal motor or sensory features. They all scored below 133 on the DRS. These patients had undergone a computed tomographic (CT) scan of the head, electroencephalogram, chest radiograph, and a battery of blood tests to screen for treatable causes of dementia. All the patients with AD met the criteria for “probable Alzheimer's disease” based on the NINCDS-ADRDA criteria (48).

Table 1 summarizes the age, education, and the Dementia Rating Scale score of the subjects. Performance scores on two other psychometric tests, the Boston Naming Test and Controlled Oral Word Association Test (FAS), as well as the Beck Depression Inventory are also summarized. There was a significant group difference in age (F_{3,31} = 3.60; P < .02) and in education (F_{3,31} = 3.65; P < .02).

PROCEDURE

Transformed Script Reading

Subjects were required to read aloud as quickly as possible and without mistakes, sentences in geometrically transformed script in which each letter was rotated 180 degrees about its vertical axis (39). This transformation preserves a left-to-right direction in reading and is much easier to read than mirror reversal (49). The sentences were taken from a brief essay on the history of modern popular music, but were presented in scrambled order. Each sentence appeared on a separate card and the entire card was visible when the subject was reading (39).

The sentences were divided into two sets of seven
sentences each. After reading one practice sentence, subjects read one of the two sets. At 20 to 30 minutes later the subjects were presented with 14 sentences consisting of the set of 7 sentences read earlier, randomly mixed with a new set of 7 sentences. Sentences designated as “old” and “new” were counterbalanced across subjects. Subjects were asked to read each sentence as quickly as possible without making mistakes and then to judge whether the sentence was “old” or “new.” This provided us with two measures of memory: an explicit measure based on recognition and an implicit one based on reading speed and accuracy. Comparison between the reading speed of repeated and nonrepeated items also reflects the two components of implicit tests of memory. Improvement in reading the nonrepeated sentences provides an index of general skill learning, whereas the additional improvement in reading the repeated sentences indicates retention of item-specific information.

A stopwatch was used to time the reading of the sentence from sentence presentation until the last word was read. Subjects could spend no more than 15 seconds deciphering any given word. Based on a previous study (39), this cutoff is a good compromise between interrupting subjects before they could use their decoding strategies effectively and letting them continue indefinitely in futile attempts to read the most difficult words. Once 15 seconds elapsed, the watch was stopped; subjects were told the word, and the timer then continued. When an error occurred, the subject was not allowed to proceed until the word was read correctly within the allotted 15 seconds.

Word-Stem Completion

Word-stem completion is an implicit test of memory in which subjects are not aware that their memory is being tested. Subjects were required to read and attend to 16 words, each written on an index card and presented for 3 seconds (e.g., finger, private). Later they were asked to say the first word that comes to mind in response to an initial three-letter word stem (e.g., fin, pri) (1, 50). To keep the subjects from being aware that their memory was being tested, we borrowed the following procedure from Graf and Schacter (1). After reading the target list of 16 words out loud, subjects were shown 15 irrelevant stems and were asked to complete them with the first person’s name that came to mind. The same procedure was repeated with names of places. Only then (about 5–7 minutes after reading the study items) were the subjects shown the 16 target stems distributed among 42 lures. They were asked to complete each stem with the first word that came to mind that was neither a person or place. There were always at least 10 possible words that could be used to complete each target stem, only one of which was presented at study. Four different sets were used. For each subject, one was the target set and a fixed list comprised the lures. To assess baseline guessing, 30 elderly control subjects were given the same word stems. Averaging across the four sets, baseline guessing was 3.13.

By embedding the implicit memory test in a more complex distracting procedure, we hoped that the subjects would not notice that some of the stems belonged to target words that they had encountered previously. Indeed, the method was so successful that not a single subject reported noticing the relation between target and stems upon later questioning.

Graphemic Cueing

Graphemic cueing was identical to word-stem completion except that the instructions made it an explicit test of memory. As in the word completion, 16 words were presented which subjects were instructed to read aloud and study. At 5 to 7 minutes later, subjects were told to use the three-letter word-stems as cues to recall explicitly the recently presented words. For half these subjects, one set of targets was used in graphemic cueing and another set for word completion, and vice versa for the other half of the other half of these subjects.

RESULTS

The data were analyzed using SAS, a computer system for data analysis (SAS, Statistical Analysis System Institute Inc., Cary, NC). Group comparisons were carried out by analysis of variance (ANOVA) with subsequent between-group testing using the least squares means procedure in SAS when appropriate. The results of transformed script reading and word-stem completion will be described in turn.

Transformed Script Reading

Table 2 describes the reading time in the four groups. In order to compare the reading performance between groups of subjects, reading times of transformed script in each condition (first reading, reading of nonrepeated sentences, and reading of repeated sentences) were considered as reading condition variables. A significant group difference was found for all three conditions ($F_{3,51} = 28.91; P < .0001$; ($F_{3,50} = 19.06; P < .0001$; ($F_{3,50} = 28.49; P < .0001$).

Although the subjects in all 4 groups were able to learn to read the transformed script, as indicated by
TABLE 2. Mean time (in seconds) to read seven transformed sentences

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>NRS</th>
<th>RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal controls</td>
<td>240</td>
<td>193</td>
<td>118</td>
</tr>
<tr>
<td>Mean</td>
<td>109</td>
<td>93</td>
<td>66</td>
</tr>
<tr>
<td>Parkinson’s disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>patients without dementia</td>
<td>271</td>
<td>211</td>
<td>146</td>
</tr>
<tr>
<td>Mean</td>
<td>100</td>
<td>100</td>
<td>78</td>
</tr>
<tr>
<td>Parkinson’s disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with dementia</td>
<td>838 (9)</td>
<td>529 (8)</td>
<td>427 (8)</td>
</tr>
<tr>
<td>Mean</td>
<td>312</td>
<td>173</td>
<td>57</td>
</tr>
<tr>
<td>Alzheimer’s disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>574</td>
<td>428</td>
<td>387</td>
</tr>
<tr>
<td>SD</td>
<td>239</td>
<td>101</td>
<td>178</td>
</tr>
</tbody>
</table>

F = first reading; NRS = non-repeated sentences; RS = repeated sentences.
* One demented patient with Parkinson’s disease did not agree to read the sentences in the second session.

the decreased reading time in the second session of the repeated and nonrepeated sentences, the degree of improvement in the different conditions varied across the different groups. Because baseline reading levels are not equivalent across groups, it is difficult to compare meaningfully the changes in the group performance with practice by comparing the absolute reading time among them. To deal with this problem, a measure of proportional improvement of reading time was chosen that is not unduly influenced by absolute levels of performance (39):

\[
\text{Initial reading time} - \text{New reading time} \\
\text{Initial reading time} + \text{New reading time}
\]

This ratio provides a measure that is relatively independent of initial differences in baselines among the groups. The improvement index was examined with respect to nonrepeated sentences (skill learning) or repeated sentences (RS) (item-specific acquisition). For nonrepeated sentences (NRS), the reading time of the set of new sentences was compared to the reading time of the initial set. For repeated sentences, reading time at test was compared to the initial reading time of the same set of sentences at study.

Table 3 shows the improvement index of repeated (RS) and nonrepeated sentences (NRS). An ANCOVA was carried out to determine whether there was a significant group difference in the nonrepeated sentences (NRS) improvement index. Because of the possible effects of age and education, these variables were included as covariates in the analyses. There was no significant relationship between NRS improvement index and any of the covariates. The group difference was also not significant ($F_{3,50} = 0.6; P < .62$).

Similarly, an ANCOVA with covariates of age and education was performed to determine whether there was a significant group difference in RS improvement index. There was no significant relationship between RS improvement index and any of the covariates. The group difference, however, was significant ($F_{3,50} = 5.26; P < .0003$). Subsequent between-group comparisons (using the least squares means procedure in SAS) showed that the patients with AD were significantly impaired relative to the NDPD patients ($P < .006$) and the normal controls ($P < .0008$). The DPD patients were impaired relative to normal controls ($P < .03$). There was no significant difference between NDPD patients and the normal controls ($P < .4$), or between the DPD patients and the patients with AD ($P < .3$).

Recognition

Recognition is an explicit test of memory. The mean percentage of incorrect forced choice responses to new and old sentences was 4% for controls, 12% for NDPD, 30% for DPD, and 37% for AD patients. Analysis of covariance showed no significant relationship between recognition and age or education. The group difference, however, was significant ($F_{3,51} = 14; P < .0001$).

Subsequent between-group comparisons showed that recognition in the patients with AD was impaired relative to NDPD patients and controls ($P < .0001$). DPD patients were impaired relative to NDPD patients ($P < .0008$) and normal controls ($P < .0001$). The NDPD patients were impaired relative to the normal controls ($P < .02$). There was no difference in recognition between AD and DPD patients.

Recognition on explicit memory was significantly correlated with the improvement index in reading time for repeated sentences, an implicit test ($P < .01$). No significant correlation was found between recognition and improvement index or nonrepeated sen-

TABLE 3. Percentage of improvement in reading time for repeated and non-repeated sentences

<table>
<thead>
<tr>
<th></th>
<th>Non-repeated sentences</th>
<th>Repeated sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal controls</td>
<td>10.9</td>
<td>34.9</td>
</tr>
<tr>
<td>Parkinson’s disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>without dementia</td>
<td>13.9</td>
<td>31.1</td>
</tr>
<tr>
<td>Parkinson’s disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with dementia</td>
<td>13.8</td>
<td>22.4</td>
</tr>
<tr>
<td>Alzheimer’s disease</td>
<td>6.2</td>
<td>14.9</td>
</tr>
</tbody>
</table>
TABLE 4. Word stem completion and graphemic cuing in the 4 groups

<table>
<thead>
<tr>
<th></th>
<th>Word stem completion</th>
<th>Graphemic cuing completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal controls</td>
<td>2.2</td>
<td>5.5</td>
</tr>
<tr>
<td>Parkinson’s disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>without dementia</td>
<td>3.1</td>
<td>5.6</td>
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<tr>
<td>with dementia</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Alzheimer’s disease</td>
<td>1.7</td>
<td>2.4</td>
</tr>
</tbody>
</table>

* The total number of study words = 16. The results represent the mean number of words above the baseline of 3.13.

ences (P < .9). This suggests that subjects may have used explicit memory strategies to help their performance in the repeated sentences condition (item-specific), an ostensibly implicit test, but not in the nonrepeated sentences condition (skill learning). Indeed, a number of subjects mentioned that they remembered having encountered the same words during the study phase.

Word-Stem Completion and Graphemic Cued Recall

Table 4 shows the group performance on word-stem completion and graphemic cuing. An ANCOVA with age and education as covariates was performed for word-stem completion and graphemic cuing. There was no significant relationship between either graphemic cuing on the word-stem completion test and any of the covariates. The group difference in word-stem completion was also not significant (F<sub>3,51</sub> = 1.38; P < .25). There was, however, a significant difference between groups on the graphemic cuing tests (F<sub>3,51</sub> = 4.81; P < .005). Subsequent between-group comparisons showed that the patients with AD were significantly impaired relative to NDPD patients and normal controls (P < .003). The DPD patients were impaired relative to the NDPD patients and normal controls (P < .04). No difference was found between the AD patients and the DPD patients (P < .3). When compared to word-stem completion, graphemic cuing improved performance only in nondemented subjects (P < .01).

DISCUSSION

The results did not wholly support the hypothesis that skill learning would be impaired in parkinsonian patients and that item-specific acquisition would be preserved in patients with Alzheimer’s disease. We will deal with each group of patients in turn, keeping in mind that sample size, though typical of this type of study, was small.

Skill and Item-Specific Learning in Parkinson’s Disease

The performance of nondemented parkinsonian patients was comparable to that of control subjects on all the implicit and explicit tests of memory except for recognition of transformed script, where a slight impairment was noted. It was expected that recognition and recall, as well as perceptual item-specific repetition priming, would be preserved in patients with Parkinson’s disease, since there is no evidence to suggest that damage restricted to the neostriatum affects the processes involved in those tests. Deficits on implicit item-specific tests are reported in Parkinson’s disease only if the tests require repetition for new associations between stimuli and responses (30). Thus, in our study, performance on word-stem completion, a perceptual implicit test, was preserved even in DPD patients, although performance on the corresponding explicit test, graphemic cuing was impaired.

Because performance on a number of procedural learning tasks, like pursuit rotor, serial reaction time task, and the Tower of Hanoi is impaired in patients with Parkinson’s disease (17, 18, 30), especially if they are demented, we thought that learning to read geometrically transformed script might also suffer. Both demented and nondemented parkinsonian patients, however, learned this skill normally. Recently, a similar finding was reported for nondemented parkinsonian patients by Bondi and Kazniak (34). The deficit that patients with Parkinson’s disease and dementia have in acquiring and attaining item-specific information on this task (i.e., for the repeated sentences) was related more to their poor explicit memory, than to their skill-learning abilities. The generalized slowing associated with Parkinson’s disease, and noted especially in our DPD patients, probably affected response initiation and execution but not the acquisition of a new perceptual skill. Deficits in learning to read transformed script, however, were noted in patients with Huntington’s disease (28), although their ability to learn sequential problem-solving tasks was preserved in the early stages of this disease (27).

Together, the results indicate a need to modify the proposed hypothesis that all procedural memory, as indexed by skill learning, is mediated by neostriatal structures. Because skills comprise different components, a more plausible alternative hypothesis is that deficits in procedural memory following neostriatal damage will be found only on certain types of skills. Examination of the pattern of preserved and impaired
Performance on different skill learning tasks suggests that nondemented parkinsonian patients are impaired on implicit tests that have a sequential problem-solving component, such as the Tower of Hanoi and serial reaction time test. These deficits may be associated as much with interference or interruption of the frontoneostriatal complex loop (51), as with neostriatal damage per se. Acquisition of more perceptual skills, such as reading transformed script, or of repetitive motor skills that require relatively little planning or organization, are preserved (30, 34).

The similarities and differences in skill learning between Huntington's disease and patients with Parkinson's disease suggest that the contribution of different regions in the neostriatum to skill learning is not uniform. Damage along the neostriatal-frontal pathway is likely to cause impaired learning of skills with a prominent "frontal" component. In addition, more extensive caudate nucleus damage, associated with Huntington's disease, will cause deficits in learning perceptual and perceptual motor skills. As both Huntington's and Parkinson's diseases progress, additional structures, particularly of the caudate, may become affected, and dementia becomes more prominent. Performance on other tests will become affected, thereby obscuring the difference between the two groups. Also, the dopamine reduction associated with basal ganglia disease may cause neocortical dysfunction, particularly in regions, like frontal cortex, that receive strong dopaminergic innervation. As a result, as Parkinson's disease progresses, some of the cognitive deficits may come to resemble those associated with AD (30). However, item-specific acquisition (as seen in word-stem completion) that does not involve any of the components mentioned may be preserved in all groups, even when dementia is present.

Skill and Item-Specific Learning in Alzheimer's Disease

As predicted, acquiring the general skill of learning to read geometrically transformed script was relatively preserved in AD patients. However, the results of implicit tests of acquisition of item-specific information, were contradictory. On the one hand, improvement in reading previously studied sentences was impaired in patients with AD, as well as patients with Parkinson's disease who had dementia. On the other hand, on word-stem completion, AD patients (and demented Parkinson's patients) benefited as much as nondemented subjects from prior exposure to the target items.

Analysis of performance on the corresponding explicit test of memory helps resolve these contradictory findings. Improvement on reading repeated sentences was highly correlated with recognition, whereas word-stem completion did not correlate with graphemic cued recall. Upon seeing a repeated sentence in transformed script, subjects may have used their explicit memory of it to identify words that they would otherwise have to decode anew.

Because we took pains to disguise the relation between the studied items and the word-completion test, no subjects noticed that the two were related. This prevented their adopting an explicit memory strategy in the service of an implicit memory test. In short, as designed in this study, word-stem completion was a more purely explicit test than reading transformed script.

Our interpretation may also explain the inconsistency of results among studies using word-stem completion as an implicit test of memory in patients with AD (17, 22, 33–39). None of the studies that reported deficits in AD attempted to control for the possibility that explicit memory of the target items was used in the word-stem completion task. In most studies, word-stem completion was tested immediately after the targets were studied. These testing conditions are likely to benefit subjects with adequate memory. Performance of patients with AD, however, is normal when the influence of explicit factors is removed either statistically (52) or by experimental manipulation as in our study which used a longer delay and smaller ratio of target to lures than is typically found in most studies.

In addition to deception, delay, and ratio of targets to lures, other factors such as the degree of dementia, the commonality of target words, and depth of processing (38) may also have biased the results. The point is that under optimal conditions, that is when dementia is mild, the words are common, and subjects are prevented from using explicit memory to augment performance on implicit tests, patients with AD perform relatively normally on perceptual item-specific implicit tests of memory, even though they remain very impaired on the corresponding explicit tests.

As with our analysis of skill learning, the hypothesis that repetition priming effects (implicit item-specific memory) are dependent on the integrity of posterior neocortex must be modified to take into account the component processes underlying performance on various repetition priming tests. Investigators have distinguished between conceptual and perceptual repetition priming tests (3, 13, 16, 21, 22, 36, 40). Perceptual repetition priming tests are driven directly by stimulus repetition that presumably reactivates infor-
mation stored in neural structures necessary for perceptual analysis of the input. These effects are sensitive to sensory but not semantic variables. Conceptual repetition tests, on the other hand, depend on reviving stored information associated with the semantic analysis of the target. A semantically related cue, rather than repetition of the target itself, is sufficient to reactivate that memory. Such tests are sensitive to changes in semantic, rather than sensory factors. Perceptual repetition effects are likely to be preserved in early stages of AD, and perhaps even later ones, because the degenerative process typically spares those structures such as the striate and prestriate cortex, mediating purely perceptual analysis (35, 36). Structures such as temporal and parietal cortex, that are involved in semantic analysis, are affected early in AD. As a result, AD leads to profound deficits on conceptual priming tests that may be as pronounced as those on explicit tests of memory (16, 17). Word-stem completion, although primarily perceptual, also has conceptual components (40, 53). The degree to which patients with AD are impaired on this test will therefore be determined by the integrity of the structures involved in semantic and perceptual analysis and by the extent to which the test itself makes conceptual demands (36).

CONCLUSION

Contrary to the suggestion that damage to the basal ganglia is associated with deficits on procedural learning tasks, we found normal acquisition of a reading skill in both demented and nondemented parkinsonian patients. Rather than reject the hypothesis, it was refined to state that deficits on procedural learning tasks are determined both by the functional components comprising the task and the neostriatal structures that comprise the neural substrate underlying those components. Patients with mild AD, whose relative pathology affects primarily association areas in neocortex rather than basal ganglia, also performed normally on general skill acquisition.

Although it was suggested that posterior neocortical structures mediate performance on some item-specific implicit memory tests, we found that patients with AD performed normally if such tests were purely implicit and largely perceptual. The component process approach can also be applied to the neocortex. Whether repetition priming effects are preserved or impaired in AD depends on the components comprising the task (perceptual vs semantic) and on the extent and location of neocortical degeneration.

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