Impairment of Semantic Knowledge in Parkinson Disease

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**Background:** Parkinson disease (PD) is commonly characterized by cognitive deterioration, but it is still unclear whether PD is associated with semantic impairments.

**Objective:** To evaluate semantic knowledge of concepts in patients with idiopathic PD, addressing concrete and abstract concepts, conceptual attributes, and conceptual relations.

**Methods:** Twelve patients with preserved cognitive status, 12 patients with mildly deteriorated cognitive status, and 12 control subjects were studied. The cognitive status of patients and controls was determined using detailed cognitive testing. Patients were participants in a university-based movement disorder program, and their PD diagnoses were clinically confirmed during long-term follow-up. The 2 patient groups were similar in age, level of education, disease duration, and parkinsonian disability. Patients were required to produce verbal descriptions of concrete and abstract concepts, to give ratings of the importance of concept attributes, and to assess and construct conceptual hierarchies. The description tasks included guiding questions, which were used if the spontaneous productions of the patients lacked any essentials expected in the answers.

**Results:** Patients with mild cognitive deterioration performed less well than the other groups in defining concrete and abstract concepts (P < .001 for both). External guidance did not help them markedly improve their performance. They also had difficulties in tasks calling for knowledge of the importance of given attributes to the concepts and in tasks demanding evaluation of hierarchical semantic relations between concepts (P < .001 for both).

**Conclusion:** Semantic disruption is implied in idiopathic PD in association with incipient cognitive impairment.

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**Semantic knowledge consists of conceptual meanings, such as knowledge of conceptual attributes and relations between concept domains.** In network models, concepts are represented in distributed activation patterns, which are primarily linked to structural and perceptual or functional properties of an object. Semantic knowledge has been studied using tasks of word finding (eg, naming and verbal fluency) and concept meaning (eg, vocabulary, attribute ranking, and category knowledge) or tasks of semantic context effects (eg, semantic priming). Impairments of conceptual representations have mostly been tested using verbal or pictorial tasks, but concrete rather than abstract concepts have been addressed.

Semantic knowledge is disrupted in Alzheimer disease (AD), a brain disease typically leading to cognitive deterioration and dementia, but, to our knowledge, there is no systematic study on semantic knowledge in Parkinson disease (PD). Primarily related to nigrostriatal dopamine deficiency, PD is often characterized by slowly progressing cognitive deterioration, which can be relatively mild or can reach the severity of dementia. There is some evidence suggesting that semantic deficits might also be associated with cognitive deterioration in PD. Parkinsonian patients have demonstrated impaired performance on a variety of tasks apparently calling for semantic processing: concept formation, verbal fluency, syntax or sentence comprehension, written sentences, naming, or Wechsler Adult Intelligence Scale similarities. These findings might reflect incipient semantic impairment in PD.

The purpose of the present study was to explore whether parkinsonian pa-
PARTICIPANTS AND METHODS

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We studied 24 patients with a long history of idiopathic PD and 12 controls. The patients were members of a regular medical follow-up study in the Department of Neurology, University of Turku, Turku, Finland. Inclusion criteria for patients were idiopathic PD, a positive response to levodopa therapy, age 50 to 79 years, normal visual acuity, and cognitive status suitable for either the “cognitively preserved” or the “cognitively mildly deteriorated” group (see the “Screening Tests” subsection). Patients with dementia,25 serious systemic or psychiatric disorders, or neurologic disorders other than idiopathic PD were excluded. On the Mini-Mental State Examination,26 which was not used as a criterion test, 3 deteriorated patients scored less than 24 points. At the time of the study, patients underwent a computed tomographic scan to rule out structural changes other than mild cortical or ventricular atrophy. Cerebral atrophy was not used as a criterion or predictor of performance, and only 6 patients (3 preserved and 1 deteriorated) had normal computed tomographic findings.

There were 6 men and 6 women in each patient group. The 2 patient groups were matched on parkinsonian disability,27 disease duration, and antiparkinsonian treatments. On the Hoehn and Yahr scale,28 the patients scored on grades II or III (mean, 2.3 for each group). Patients were treated with levodopa, dopamine agonist, and selegiline hydrochloride in various combinations; 4 patients in the preserved group and 2 in the deteriorated group were also taking anticholinergic agents. The doses and combinations of treatments were individually optimally adjusted. The control group (7 men and 5 women) did not have neurologic or psychiatric diseases other than idiopathic PD were excluded.

We compared 2 groups of parkinsonian patients—those with preserved cognitive performance and those with early, mild stages of cognitive deterioration—and control subjects.

SCREENING TESTS

Allocation of patients into 2 groups was based on a neuropsychologic screening battery29 comprising 8 criterion tests measuring verbal, visuomotor, and memory performances: the similarities (abstract reasoning), Digit Span (short-term memory and attention), Digit Symbol (visuomotor speed), and Block Design (visuococonstructive skill) subtests of the Finnish version of the Wechsler Adult Intelligence Scale91; the Benton Visual Retention Test91; immediate recall of 30 paired word associates92; and immediate recall and naming time of 20 objects.31 If the patient scored below −1.5 SDs on any screening test compared with our earlier reference values,34 he/she received 1 deterioration point; if below −2.0 SDs, 2 points; and if below −3.0 SDs, 3 points. Thus, the maximum deterioration score was 24 points.30 Patients were allocated to the cognitively preserved or the mildly deteriorated groups according to the cutoff value of 4 deterioration points, which was the highest score of the present controls. In addition, the delayed recall of 20 objects and 30 paired word associates was asked about after 1 hour.

These cognitively mildly deteriorated group performed more poorly than the cognitively preserved and control groups on all tests except naming time, immediate recall, and delayed recall of 20 objects and Digit Span (Table 2).

POST HOC COMPARISON WITH AD PATIENTS

The cognitive status of the mildly deteriorated parkinsonian group was compared with the results of 14 patients with AD9 (5 men and 9 women; mean [SD] age, 69.1 [5.3] years; P = .90; mean [SD] education, 8.6 [4.1] years; P = .12; mean [SD] Mini-Mental State Examination score, 21.9 [3.1]; P = .02; and mean [SD] deterioration score, 12.5 [3.9]; P = .005). Patients with PD and mild cognitive deterioration performed better than those with AD on episodic memory tests: immediate (P = .003) and delayed (P = .002) recall of 20 objects, immediate (P = .007) and delayed (P = .003) recall of 30 paired word associates, and the Benton Visual Retention Test (P = .009). On the 4 Wechsler Adult Intelligence Scale subtests, the performances of the 2 groups did not differ. Thus, the cognitive impairment profiles were different in the PD and AD groups.

PROCEDURE

All the tasks of semantic knowledge, their selection criteria, and their validity have been presented in detail earlier.9,35 Semantic knowledge was investigated using verbal tasks because it was considered important to study not only concepts referring to concretely observable objects but also more abstract concepts referring to events, relations, and abstract objects. Pilot studies8 were conducted to select concepts familiar to all. Performance in these tasks correlated with performance in more traditional semantic memory tasks such as confrontation naming, category fluency, and reasoning.35 The responses were first elicited through active, spontaneous production. If the subject failed, then guiding questions were used and, finally, forced choices were applied. Thus, the expression of semantic knowledge could

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The results on all semantic tasks are presented in Table 3. For the description of concrete concepts, the reliability between the scores of 2 independent raters was as high as 93.4%. The final scores were agreed on after discussion. Parkinsonian patients with mild cognitive deterioration performed less well than the other groups in producing superordinate categories and structural and functional attributes. They needed

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be achieved even through passive recognition. This was done to ensure that any semantic knowledge of concepts that subjects still possessed would be revealed in the test situation.

DESCRIPTION OF CONCRETE CONCEPTS

We defined concrete concepts as concepts that refer to tangible, observable, picturable, and imaginable objects. Each concrete concept belonged to a single, obvious superordinate category (eg, harp → musical instrument). In addition, each object had at least 2 obvious structural attributes (eg, harp → big, has a number of strings) and 1 obvious functional attribute (eg, harp → is played by plucking). We expected subjects to produce the superordinate category of each object to which the concept referred (a total of 15), altogether 44 structural features of the objects to which the concepts referred, and altogether 19 functional features of the objects to which the concepts referred. Thus, the complete semantic knowledge of the concrete concepts consisted of 15 + 44 + 19 = 78 separately scored items.

The subject was encouraged to express freely as much knowledge of the concept as possible in a spontaneous manner, without any further cues or guidance from the experimenter. For each correct feature mentioned the subject obtained 3 points. Thus, the maximum score was 3 x 78 = 234 points. If the subject did not produce some of the expected features of the concept, the experimenter cued the production of the correct answers by asking specific questions about the superordinate category, the structural features, or the functional features of the concept. Each correct answer produced after guiding scored 2 points. If the subject still did not produce some of the expected features, the experimenter presented the subject with 2 alternative answers from which he/she had to choose the one he/she considered to be correct. Each correct choice scored 1 point.

DEFINITION OF ABSTRACT CONCEPTS

Subjects were asked to produce verbal definitions of the given concepts. Abstract concepts were defined as concepts that refer to rather intangible, not readily observable or picturable entities, such as events, relations, and abstract (nonmaterial) objects (such as crime, news, and bachelor). If the spontaneous definition given by the subject lacked some of the essentials of the definition, at first general then more specific forced-choice questions were presented. Correct spontaneous definitions were scored as 3 points, right answers to general questions as 2 points, and correct answers to specific questions as 1 point. The maximum score in this task was 45 points.

ATTRIBUTE RANKING

In this task, understanding the importance of given attributes to the meaning of concepts was required. Subjects were given a list of 15 concepts with 4 attributes each. The attributes appeared in print in random order below the sentences. The task was presented to the subject as a sentence completion task: he/she was requested to complete the sentences with the given attributes in such a manner that the sentences made sense to the subject. One attribute was always an essential property of the concept in question (eg, an airplane always includes wings). Another attribute was a typical but not absolutely essential feature of the concept in question (an airplane often includes a motor). A third attribute was one that is atypical but nevertheless feasible for the concept to possess, at least sometimes (an airplane seldom includes a hijacker). The fourth attribute named a feature that cannot consistently be applied to the concept in question (an airplane never includes a runway). Each sentence correctly completed scored 1 point; thus, the maximum score was 60 points.

CONCEPTUAL HIERARCHIES

The purpose of these tasks was to evaluate the understanding of the hierarchical relations within conceptual domains. All 8 tasks consisted of a hierarchical, spatial configuration of 10 cards. A superordinate concept was at the top, followed by 3 subcategories, each with 2 instances at the bottom (Figure).

The first 4 tasks were error recognition tasks in which the cards were placed in hierarchical order but 5 or 6 cards were misplaced in such a manner that the hierarchy as a whole did not make sense. The subject had to identify and remove the misplaced cards. Correct recognitions were recorded (maximum, 22 points). The remaining 4 hierarchies were construction tasks. Subjects had to assemble a hierarchy from 10 written cards. A line configuration showing the empty conceptual scheme was provided on paper for each hierarchy. The maximum score for the recognition and construction tasks was 22 + 40 = 62 points.

STATISTICAL ANALYSES

Study groups were compared using analysis of variance and Duncan grouping (P<.05) with parametric variables and Kruskal-Wallis with nonparametric variables. In post hoc comparisons, the t test was used.

The attribute ranking task was easy for the controls and the preserved group: their total scores of the maximum correct score were 91% and 89%, respectively; however, the mildly deteriorated group achieved only 66% of the maximum score. Total raw scores were lower in mildly deteriorated patients compared with the others.

The tasks of conceptual hierarchies, the controls and the preserved group obtained 97% of the maximum score, whereas the mean of the mildly...
Results of the present study show that patients with PD and mild cognitive deterioration were clearly impaired in the tasks of defining concrete and abstract concepts and in understanding conceptual attributes and conceptual hierarchies. Even incipient cognitive deterioration was characterized by semantic memory disturbances, which could not be restored by guiding questions. The results provide new evidence of impaired semantic knowledge in PD.

In previous studies\textsuperscript{21,36-38} of semantic processes in PD, the study groups have been heterogeneous concerning the cognitive status of patients because often only the Mini-Mental State Examination was used for screening. We compared 2 carefully matched PD groups that had similar motor disability but exemplified 2 distinct levels of cognitive performance. One group exhibited pre-
served verbal, visuomotor, and memory functioning, whereas the other group showed early signs of cognitive deterioration but not dementia. The deterioration was obvious in some but not all criterion tasks, thus showing selectivity of cognitive impairment. In particular, abstract reasoning and aspects of episodic memory as well as visuomotor performances were impaired. Most subjects performed within the “normal” range on the Mini-Mental State Examination.

Another source of previous inconsistent or scanty findings of semantic impairment in PD might be due to the heterogeneity of the methods used. We used new methods and controlled the impact of other than semantic deficits as much as possible. Our tasks were applied without time limits to minimize the effect of cognitive slowing. Subjects did not need to produce specific, predetermined words or sentences to express their semantic knowledge. Circumlocutions and nonverbal expressions such as gestures were accepted where appropriate (eg, in showing the form or the size of an object) to avoid the confounding effect of linguistic problems as much as possible. Subjects were always first familiarized with the idea of the tasks by the administration of illustrative examples. In concrete and abstract tasks, mildly deteriorated patients produced significantly poorer definitions than the other groups. They had to resort to the guiding questions and forced-choice tasks, and they selected the incorrect alternative more often than the others. This finding conflicts with previous suggestions that patients with PD can improve their memory performance under cuing conditions, especially when cues have been explicitly presented. Furthermore, patients with mild cognitive deterioration had difficulty in the ranking tasks of conceptual attributes. Similarly, error recognition and more active construction of conceptual hierarchies caused problems for these patients. The findings hint at obvious conceptual-semantic impairments.

Impaired semantic knowledge has been found to characterize AD, and there is evidence that at least in some patients with PD diagnosed as having dementia, coexisting AD has been shown at autopsy. We minimized the possible comorbidity of AD by including only patients whose PD diagnoses were clinically confirmed during long-term dopaminergic treatments and who were not demented. Indeed, the cognitively deteriorated PD group showed a markedly different overall impairment profile compared with patients with AD studied earlier. They exhibited verbal, visuomotor, and semantic deficits similarly to the patients with PD. In contrast, patients with AD were clearly more impaired in episodic memory despite their slight advantage in education. The PD group performed better than the AD group in immediate and especially in delayed memory, which is consistent with earlier results in PD. Thus, it is not likely that concomitant AD explains the semantic disruption found in patients with PD and mild cognitive deterioration.

It is well known that besides lesions in the nigrostriatal dopamine neurons, other subcortical structures as well as anterior cortical regions might be affected and associated with cognitive dysfunction in PD. Our 2 patient groups had similar parkinsonian disability and other disease-related variables, and only their cognitive status was different. Hence, nigrostriatal damage primarily underlying motor symptoms in PD cannot on its own contribute to conceptual deficits in cognitively deteriorated patients, a result that agrees with previous findings. Our results do not conflict with the view that subtle cognitive deficits, implying disturbances in semantic processing in PD, might reflect frontal lobe dysfunction, which in turn is known to be associated with problem-solving deficits. However, if defective executive functions and, hence, an inability to use self-directed search strategies could explain our results of impaired semantic knowledge, then external guidance should have helped the patients. This did not happen, however. Therefore, frontal lobe abnormalities might not be a sufficient explanation for the impairment of semantic knowledge in PD.

Some ideas have been presented on the question of what the system that forms the neural basis of concepts is believed to be like. A model of semantic memory proposes a distributed network in which concepts are represented across a wide range of attributes in different patterns of activation. Consistent with this model, it has been argued that the basis for a concept consists of a collection of simultaneously activated sensory and motor represen-

| Table 3. Results on Semantic Tests of the Study Groups* |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                | Control Group   | Cognitively     | Cognitively     | P               |
|                                | (n = 12)        | Preserved Group | Deteriorated Group | (Kruskal-Wallis)* |
| Description of concrete concepts, maximum points | 202.8 (12.3) | 203.4 (11.2) | 169.4 (20.1) | <.001 |
| Structural attributes | 41.3 (2.8) | 42.0 (2.2) | 36.7 (5.1) | .005 |
| Functional attributes | 110.3 (8.6) | 110.7 (9.1) | 90.2 (13.4) | <.001 |
| No. of guiding questions | 31.1 (7.6) | 32.0 (6.5) | 51.9 (11.8) | <.001 |
| Wrong choices on the forced-choice tasks | 2.1 (2.3) | 2.4 (2.0) | 7.7 (5.1) | .003 |
| Definition of abstract concepts, maximum points | 38.3 (2.6) | 37.9 (2.9) | 25.4 (4.5) | <.001 |
| No. of guiding questions | 6.1 (2.5) | 6.8 (1.8) | 15.8 (4.2) | <.001 |
| Wrong choices on forced-choice tasks | 0.9 (1.4) | 0.9 (1.0) | 4.8 (3.0) | <.001 |
| Attribute ranking, maximum points | 54.3 (5.1) | 53.2 (4.3) | 39.7 (8.4) | <.001 |
| Conceptual hierarchies, maximum points | 60.2 (2.3) | 59.8 (3.0) | 37.6 (14.8) | <.001 |
| Correct recognitions | 21.8 (0.9) | 20.7 (2.3) | 13.7 (6.4) | <.001 |

* Data are given as mean (SD).
† Deteriorated patients differed from preserved patients and controls (Duncan grouping, P < .05).
tations that have a high probability of being triggered by the same (verbal or nonverbal) stimulus. It is proposed that the neural representations for such conceptual-semantic networks reside in the primary sensory areas of the cortex and in higher-order cortical areas. Therefore, impairment of semantic knowledge in our cognitively deteriorated group can be interpreted as showing that a verbal stimulus results in deficient activation of semantic representations. Because the performances remained impaired even after cueing or forced choice, it seems that the strength of the activation is probably not the only reason for the failure to access relevant semantic knowledge from the memory stores. To summarize, our results suggest that semantic networks are disrupted, i.e., patients have a storage deficit of semantic knowledge. Nevertheless, this disruption might be associated with even mild cognitive deterioration and progressive lesions not only in PD but also in other brain diseases. Functional imaging of the brain during semantic tasks is necessary to evaluate the pathology underlying the semantic processing deficit in PD.

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