Pragmatic communication skills in patients with Parkinson’s disease

Patrick McNamara* and Raymon Durso

Department of Neurology, Boston University School of Medicine, Boston, MA, USA
Boston VA Healthcare System, Boston, MA 02130, USA

Accepted 2 August 2002

Abstract

Background. Pragmatic communication abilities may depend on intact frontal lobe systems. Independent evidence suggests that some persons with Parkinson’s disease (PD) are impaired on measures of frontal lobe function.

Hypothesis. We therefore hypothesized in Study 1 that pragmatic communication skills would be impaired in some persons with PD and would be linked to frontal dysfunction in these patients. In Study 2 we hypothesized that PD patients would be unaware of their pragmatic communication deficits.

Methods. In Study 1 we administered tests of pragmatic abilities and frontal lobe functioning to twenty-two persons with Parkinson’s disease (PD) and 10 healthy controls. In Study 2 we obtained self-ratings of pragmatic abilities from 11 PD patients and then checked these self-ratings against ratings of these same abilities by the patient’s spouses.

Results. We found in Study 1 that patients with PD were: (a) significantly impaired on measures of pragmatic communication abilities, especially in the areas of conversational appropriateness, turn-taking, prosodics and proxemics, and that this impairment was significantly related to measures of frontal lobe function. In study 2 we found that PD patients overestimated their own abilities relative to spousal ratings of those abilities and thus were unaware of the extent of their problems with pragmatic social communication skills.

Conclusion. We conclude that pragmatic social communication skills are impaired in PD and that this impairment may be related to frontal lobe dysfunction.

Keywords: Pragmatics; Communication; Parkinson’s disease; Frontal lobes; Unawareness

1. Introduction

Pragmatic communication abilities refer to key conversational skills such as communicating appropriate amounts of information in the appropriate social context.
and at the appropriate time, knowing how to start, conduct and end conversations, making socially appropriate requests and commands and delivering thematically cohesive accounts or narratives of relevant events in one’s life (Gallagher & Prutting, 1983; Levinson, 1983; Prutting & Kirchner, 1983; Stemmer, 1999). Some forms of brain damage have been associated with loss of these key social communication skills with severe consequences for the individual concerned (Gallagher & Prutting, 1983; Penn, 1999; Ylvisaker & Szekeres, 1989). Loss of these pragmatic communication skills impairs the individual’s ability to effectively convey his desires and needs and to elicit help from others. They are essential skills to have if the brain-damaged individual is ever to integrate back into a job or personal social network. Even the simplest tasks of daily life are undermined if an individual cannot effectively convey needs, desires and information to another.

To date, most studies of pragmatic communication abilities in persons with brain damage have focused on populations with traumatic brain injury (Ylvisaker & Szekeres, 1994), aphasics (Joanette & Ansaldo, 1999) or persons with right hemisphere brain damage due to stroke (Myers, 1994). It is our clinical impression that persons with Parkinson’s disease may also experience severe difficulties with social communication. Even before the disorder affects motor systems involving gesture and speech intelligibility, some persons with PD appear to experience inordinate difficulty in social conversation, turn-taking, staying on topic and appropriately conveying emotion. In addition to our own clinical impression of pragmatic difficulties in PD, there is neuropsychologic evidence which suggests that the neurocognitive systems thought to support pragmatic communication skills (right hemisphere and frontal lobes—see McDonald, 1993; Ylvisaker & Szekeres, 1989; Zaidel et al., 2000; for reviews) are impaired in PD. Since many patients with Parkinson’s disease (PD) are known to perform poorly on tests traditionally linked to frontal lobe functions (Gotham, Brown, & Marsden, 1988; Taylor & Saint-Cyr, 1995), they may also perform poorly on tests of pragmatic competence. Pragmatic communication deficits might help to account for the well-known impairment in social and affective interactions in patients with PD as the disease progresses (Hoehn & Yahr, 1967; Hubble & Koller, 1995; Lang & Lozano, 1998; McNamara et al., 1995).

We could find only a single study of pragmatic communication skills in patients with PD but the patients described in that report were atypical. Kegl and Poizner (1998) described three patients with PD who could not hear or speak and thus used sign language to communicate. Given the severe motor deficits associated with PD, one would expect development of compensatory strategies to overcome the barriers to communication and that is what Kegl and Poizner found in the three signers they studied. The signers, for example, would physically reposition themselves relative to their interlocutors in order to enhance visual channels of communication. They used reiteration, repetition and other such devices to get their point across. They frequently shifted the burden of conversation onto their interlocutors. While Kegl and Poizner’s results concerning development of pragmatic compensatory strategies are interesting, they may not accurately describe the pragmatic skill base of most PD patients who do not rely on sign language for communication purposes. We could find no papers that systematically assess pragmatic communication skills in PD.

In what follows, in study 1 we assessed pragmatic communication abilities in patients with PD and then examined the relation between these and measures of frontal lobe function. We hypothesized that (a) PD patients would evidence significant impairment in some domains of pragmatic communicative performance and that this impairment would be related to frontal lobe dysfunction.
2. Study 1

2.1. Methods

2.1.1. Participants

Twenty patients with PD were recruited from the outpatient Movement Disorders Clinic at the Boston Veterans Administration (VA) Healthcare System, Boston, MA. Dr. Durso, Director of the PD clinic at the Boston VA, individually diagnosed patients. All were male and right-handed. Mean years of duration = 8.8 years. None of these patients were demented according to clinical examinations and DSM-III criteria. All were on some form of dopaminergic medication and were tested while on their medications. Patients with a history of substance abuse or head injury were excluded. Ten healthy control participants were recruited from the support staff of the same facility. They were also all males. There was no significant difference in education between the PD patients ($M = 12.8$ years) and the controls ($M = 13.3$ years) ($t < 1$). PD patients tended to be older ($M = 71.5$) than the controls ($M = 48.4$, $t(1,27) = -6.98$, $p < .0001$).

2.2. Materials/tests

2.2.1. Pragmatic communication skills

We used Prutting and Kirchner (1987)’s checklist of 30 general pragmatic abilities thought to be fundamental to social communication skills. This ‘Pragmatic Protocol’ has been widely used to identify the appropriateness of pragmatic skills in individuals with various kinds of communication disorder. The examiner fills it out during or after 10–15 min of conversation with the patient. We presented the patient with a series of pre-scripted open-ended questions in an attempt to elicit as much casual conversation as possible. The protocol covers verbal, paralinguistic and non-verbal aspects of the patient’s conversational and social skills. Verbal behaviors (e.g., speech acts, message specificity, cohesion, topic selection, topic initiation and topic maintenance, conversational turn-taking, and word use), paralinguistic behaviors (e.g., fluency, prosody, vocal quality, and speech intelligibility) and nonverbal behaviors (e.g., facial expressions, eye gaze, and gestures and physical proximity to the speaker) were scored as either appropriate or non-appropriate. Appropriate and inappropriate responses were tallied and then converted to percentage outcomes scores for each of the participants. We used percentage inappropriate as our main pragmatic outcome measure. Prutting and Kirchner (1987) show that the test protocol and scoring reaches adequate reliability and validity levels when used with brain damaged persons.

2.2.2. General cognitive measures

The FAS Verbal Fluency Test (Lezak, 1995) was used as a measure of verbal production. Participants are asked to generate as many words (proper names excluded) as they can beginning with the letter F in the space of 1 min. Then they are asked to do the same for A and S. Mean number of words produced across the three letter trials is the outcome measure. We used the Mini Mental State Exam (MMSE) (Folstein, Folstein, & McHugh, 1975) as a measure of general cognitive status. This is a short bedside exam that assesses basic orientation to time and place as well as short-term memory and simple calculating and spelling abilities. Higher scores indicate intact basic cognitive abilities. These control measures were used to confirm that dysfunction in pragmatic skills was not simply reducible to global deficits in cognition or poverty of speech.
2.2.3. Frontal tests

We used the interference condition of the Stroop color-word test to assess susceptibility to cognitive interference—a sign of frontal dysfunction. The Stroop procedure requires the subject to name the color of the ink in which a color-word is printed. Sometimes the word will name the color of the ink (the word blue in blue ink) and sometimes the word will be the name of a different color than the ink (e.g. the ‘incongruent’ word blue printed in green ink). The subject must ignore the word and name the color. Susceptibility to cognitive interference is calculated as the time taken to name the colors in the incongruent condition. PET studies show that orbitofrontal cortex is activated in normals during the interference condition (Bench et al., 1993).

We used the Tower of London (TOL) task to assess ability to mentally plan solutions to problems. In the TOL tasks three disks have to be moved from a starting configuration on three sticks of unequal length to a target arrangement in a minimum number of moves. Subjects are asked to rearrange the disks on the sticks so that their positions match the target array (presented as a colored drawing). The starting position of the pegs are varied so that in any particular trial the solution can only be reached following a minimum of 2, 3, 4, 5, or 6 moves. The subject’s task is to solve the problem with the minimum number of possible moves. Since we were interested in participant’s ability to mentally simulate/plan their moves we used ‘mean time elapsed before first move’ and ‘mean time per move’ as our outcome measures. A recent SPECT study has demonstrated left prefrontal cortex activation in subjects attempting to plan their moves (Morris, Ahmed, Syed, & Toone, 1993).

Recent neuropsychologic evidence links pragmatic communication skills (especially expression of emotion) to right hemisphere sites (Bloom, Borod, Obler, & Gertsman, 1993; McDonald, 1993). We therefore also asked participants to complete the Design Fluency task as it has been linked to right hemisphere functioning (Elfgren & Risberg, 1998; Lezak, 1995). In this task participants are asked to imaginatively generate and then draw as many 4-lined figures as possible within the space of 1 min. While controls were given 1 min to produce their designs, we allowed 2 min for patients with PD given their motor impairment. The motor problems of five of these patients were severe enough that they could not accomplish the task. Their data on this task was excluded from analysis.

2.3. Results

Results of pragmatic protocol assessment are presented in Table 1. Patients with PD were significantly impaired (scored as inappropriate) on 20.4% of the items (a mean of six items per patient) on the Pragmatic Protocol while controls were impaired on only 3.8% of items ($t(24) = -2.88, p = .008$). Among the PD patients, the most frequently cited items were (in ascending order of frequency): conversational initiation, pause time between phrases, quantity/conciseness, feedback to speaker, speech intelligibility, and gestures and facial expressions.

Table 1 also summarizes group comparisons on major neuropsychologic measures. The two groups of participants did not differ on the MMSE measure of cognitive status (M-controls = 27.4; M-PD patients = 24.8; $p = .14$) or on the FAS measure of verbal production (M-controls = 12.2; M-PD patients = 9.32; $p = .16$). These results suggest that the impairment in pragmatics in PD patients cannot be explained by a generalized cognitive deficit owing to the illness. Varying numbers of PD patients could not complete the frontal lobe tests at all, but a majority of the patients did complete the tests. On the Design Fluency task controls generated significantly greater mean numbers of designs (M-controls = 11.35) as compared to
On the Stroop interference test we found significant differences in mean interference completion times for controls ($M = 64.7s$) versus PD patients ($M = 80.2s$; $t(1,20) = -3.10, p = .037$). On the Tower of London task we found differences in mean times for first move for controls ($M = 194.6s$) versus PD patients ($M = 174.6s$; $p = .77$) and for mean times per move ($M = 2.7s$) versus PD patients ($M = 4.0s$; $t(1,17) = -1.38, p = .18$) but the differences were not reliable.

Some frontal lobe measures predicted pragmatic dysfunction. Within the PD group, pragmatic score correlated significantly with Stroop ($r = .63, p = .01$), TOL time to first move ($r = -.46, p = .05$) and TOL time per move ($r = -.50, p = .05$; all $p$ values Bonferroni corrected).

2.4. Discussion

In this initial study we found that patients with PD were significantly impaired on measures of pragmatic communication abilities, particularly in the realms of conversational appropriateness, prosodies, and gestures and facial expression. While the gestural, facial and prosodic impairment are undoubtedly influenced by motor impairment, these deficits should be seen as pragmatic in nature as they severely curtail the patient’s ability to convey emotion and interest during social encounters. The impairment in aspects of conversational appropriateness (pauses, feedback, conciseness, etc.) point to a deficit in fundamental pragmatic competence and may be due to the brain dysfunction associated with PD. Correlations of pragmatic performance with measures of frontal lobe performance support this possibility. Because the PD patients did not differ from controls on general measures of cognitive skills, we cannot attribute the pragmatic deficit to general cognitive impairment.

PD patients were significantly older than the controls and therefore age was an uncontrolled factor in this initial study that may account for the pragmatic performance differences in the two groups. On the other hand, even the youngest of the PD patients (who were in their late 40s) evidenced significant pragmatic deficits relative to the controls. In addition, pragmatic communication deficits may not be reliably associated with normal aging (Baltes, 1993; Nocentini, Goulet, Drolet, & Joanette, 1999).

The pragmatic deficit undoubtedly is associated with greater difficulty in coping with the chronic disorder. Quality of life for these patients may be significantly improved if pragmatic skills could be improved. The first step in such a program of remediation would be to assess awareness of deficit in these patients. Self-awareness or self-monitoring- may be fundamental for appropriate social communication. Conversational turn-taking and topic maintenance may, for example, require the

<table>
<thead>
<tr>
<th>Measure</th>
<th>PD</th>
<th>Control</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pragmatics</td>
<td>.20 (.18)</td>
<td>.03 (.11)</td>
<td>.008</td>
</tr>
<tr>
<td>MMSE</td>
<td>24.4 (3.63)</td>
<td>27.4 (2.76)</td>
<td>.14</td>
</tr>
<tr>
<td>FAS</td>
<td>9.32 (15.7)</td>
<td>12.22 (11.5)</td>
<td>.16</td>
</tr>
<tr>
<td>Design Flu</td>
<td>5.48 (4.0)</td>
<td>11.3 (3.5)</td>
<td>.002</td>
</tr>
<tr>
<td>Stroop</td>
<td>80.2 (9.1)</td>
<td>64.7 (13.1)</td>
<td>.37</td>
</tr>
<tr>
<td>TOL 1st</td>
<td>174.6 (154.8)</td>
<td>194.6 (125.9)</td>
<td>.77</td>
</tr>
<tr>
<td>TOL T/move</td>
<td>4.01 (2.6)</td>
<td>2.76 (1.3)</td>
<td>.18</td>
</tr>
</tbody>
</table>

Note: Value is the mean, value in parenthesis is the standard deviation.
ability to monitor the target topic and to keep the target topic in working memory, to resist interference from other salient topics capturing attention and to self-monitor for the tendency to not yield the floor. Self-awareness of communication abilities is also critical for maintaining sensitivity to social context and more generally for maintaining independence in routine activities of daily living (Sohlberg, 2000). Patient’s abilities to use compensatory strategies to overcome cognitive and communication problems also depends crucially on their awareness that these problems exist (Alderman, Fry, & Youngson, 1995; Giacino & Cicerone, 1998; Sohlberg, 2000). Interestingly, self-awareness may depend on activation of right frontal circuits involved in attentional and intentional responding (Stuss, Shallice, Alexander, & Picton, 1995). As mentioned previously, independent neuropsychologic evidence points to frontal dysfunction in PD (Taylor & Saint-Cyr, 1995) suggesting that they might be at risk for unawareness syndromes as well. We have previously documented significant unawareness of speech errors in a group of mildly to moderately impaired PD patients (McNamara, Obler, Au, Durso, & Albert, 1992) relative to age-matched controls. We know of no published assessments of awareness of social pragmatic communication deficits in patients with PD despite the clinical importance of self-awareness of social skills. We therefore studied unawareness of pragmatic deficit in another group of PD patients. Our aims were to: (a) extend findings of Study 1 concerning the existence of a pragmatic deficit in PD and (b) to test the hypothesis that patients with a pragmatic deficit are unaware of this deficit. Our overall strategy was to ask both patients and spouses of patients to rate the patients’ pragmatic skills. When the ratings diverged we would have evidence for unawareness.

3. Study 2

3.1. Methods

3.1.1. Participants

There were 11 patients with idiopathic PD whose spouses were willing to be interviewed. No PD patients who participated in Study 1 participated in Study 2. Mean age = 62.7 years; range 45–77 years. All were male and right-handed. Mean Hoehn–Yahr (Hoehn & Yahr, 1967) scale rating was = 3.0 indicating moderate severity. Mean years of schooling = 14.0. Mean digit span backwards was 5.4 (2.3). Mean for the 60 second ‘FAS’ word generation task with letters was 11.3 (3.3) while the category fluency was 15.1 (2.5). None of these patients were depressed or demented according to clinical examinations and DSM-III criteria. All were on some form of dopaminergic medication and were tested while on medications.

3.1.2. Materials

To measure self-awareness we asked patients to rate themselves on specific pragmatic communication skills—the same skills assessed on the Prutting and Kirchner pragmatic protocol. We then asked spouses or significant others to rate patients on these same pragmatic communication skills. We used the categories assessed on the Prutting and Kirchner “Pragmatic protocol” to create a series of statements concerning the patients’ skill in each area (i.e., speech acts, maintaining topic, turn-taking, lexical selection, style, prosodics, and proxemics) of pragmatic communication competence. Patients were tested individually. A statement was read aloud to the patient and then the patient was asked to rate his level of agreement with the statement. There were a total of 47 statements. Spouses or significant others who knew the patient well used the same scale to rate their level of agreement with each statement.
concerning a given patient's abilities. One indicated no agreement with the statement and seven indicated complete agreement. High scores indicate high or appropriate pragmatic skills. There were 11 statements concerning speech acts (e.g., “I can tell when someone is requesting something of me without them actually asking me.” “I am able to make a promise when necessary.”); five concerning topic maintenance (“I am able to stay on topic throughout a conversation without any trouble.”), nine on turn-taking (“I am able to turn the floor over to my partner at the appropriate time in a conversation.” “I give feedback to the speaker to keep the conversation moving forward.”), seven on lexical selection (“I can find words to express exactly what I wish to express.”), two on style (“I adjust my style of speaking to the person I am talking with.”), nine on prosodics (“My voice itself is clear.” “I am able to express negative emotions in my voice.”) and four on proxemics (“I like to keep an appropriate distance between me and my conversation partner during a conversation.” “I am comfortable making eye contact with my partner during a conversation.”). Mean percentage scores (number of points endorsed per category over total possible for each category) for each of the six pragmatic domains and for both patients' self-ratings and for spouses' rating on the patients were computed.

3.1.3. Awareness of own pragmatic communication deficit

Spouse or significant other ratings on the patient were compared to the patient's own self-ratings on the pragmatic communication statements. If there were large differences between spouse and patient perceptions of the patient’s skills then this disagreement was considered as preliminary evidence that the patient’s awareness of his pragmatic communication skills were clinically impaired. We used t tests for independent groups to compare self vs. spousal ratings on the major pragmatic domains and Pearson's product moment correlation coefficient to study relationships between these pragmatic domains and age, stage of disease, verbal fluency, and digit span backwards.

3.2. Results

Mean percentage appropriate scores (from spousal ratings) ranged from 50% on the prosodics domain to an 80% appropriateness score on lexical selection. Several domain scores revealed substantial evidence of impairment: speech acts: 72%; turn-taking: 68%; conversational style: 57%; prosodics 50% and proxemics: 67% (see Table 2). These results partially confirm and extend findings from Study 1 indicating a clinically significant pragmatic communication deficit in PD. With respect to the unawareness issue, patients consistently overestimated their communication abilities relative to spouse's ratings of these same abilities (the overall mean difference score was \( M = 10 \)). Spousal-self ratings differences were significant for speech acts, lexical selection, stylistics, and conversational appropriateness (each at the .05 level two sided; see Table 2). Correlational analyses revealed a significant relation (\( r = .81, p = .027 \)) between digit span backwards and topic maintenance (with spouse's ratings of the patient's ability). Age was significantly and inversely correlated (\( r = -0.70, p = .015 \)) with self-rated abilities in the proxemics domain. No other significant correlations were obtained.

3.3. Discussion

In two separate studies of pragmatic abilities of patients with PD, we found that patients with PD were significantly impaired on measures of pragmatic communication abilities (conversational appropriateness, speech acts, stylistics, gestures, and
prosodics) and significantly unaware of the extent of their problems in these domains. The impairment, furthermore, was correlated with measures of frontal lobe performance.

Parkinsonism in the middle and later stages is associated with severe dysarthria (Lang & Lozano, 1998) and thus deficits in the prosodic domain were expected. Problems with conversational appropriateness, turn-taking, quantity conciseness and stylistics while noticeable clinically have never to our knowledge been documented before. Spouses indicated that their husbands were impaired in all these areas and in addition in using/responding to speech acts (queries, comments, commands, etc.). These pragmatic communication difficulties may translate into problems with communicating needs and desires and thus impairment in activities of daily living. Spousal ratings of the patient’s pragmatic abilities suggested a more severe pragmatic deficit than that revealed by examiner ratings of patients with PD. The spousal ratings may be more reliable as they are able to interact with and observe the patient daily. Examiner ratings, on the other hand, are derived from a single 10–15 min conversation in a setting of formal neuropsychologic testing. Thus, the spousal ratings suggest that the examiner ratings from Study 1 may underestimate the degree of pragmatic deficit in PD patients. This is an extremely important clinical finding as unawareness may hinder attempts to overcome social communication problems.

Evidence for unawareness of cognitive deficit has been previously reported in PD (McNamara et al., 1992). Establishing awareness of deficit is a crucial prerequisite for successful treatment of several types of cognitive deficit (Alderman et al., 1995; Giacino & Cicerone, 1998; Sohlberg, 2000). The insight-impaired patient will not consistently attempt compensatory cognitive strategies for higher-order social and cognitive skills when he does not realize he is deficient in these skills. Alderman et al. (1995) have shown that in the case of patients with brain injuries, merely increasing the patients’ awareness of inappropriate and impulsive behaviors can significantly decrease those behaviors. The patient learns to recognize inappropriate behaviors and then to reduce them. Similar results should be obtainable for patients with PD. One source of this unawareness deficit in PD may be the well-known frontal lobe dysfunction associated with PD (Taylor & Saint-Cyr, 1995).

The fact that PD patients were significantly impaired in several domains of pragmatic communication skills raises the issue of whether PD patients can be said to exhibit a syndrome of pragmatic impairment. Other authors have pointed to pragmatic syndromes in aphasic and developmentally disabled patients. Hawkins (1989) referred to a “disorder aphasia.” Rapin and Allen (1983) identified a “semantic-pragmatic deficit syndrome” in developmentally delayed children who evidenced impairment in comprehension of connected discourse. Prutting and Kirchner (1983) divided pragmatic problems in language-disordered children into three groups that looked like syndromes: insensitivity to social context; lexical deficits, and coherence deficits. Patients with PD would appear to evidence special difficulty in the

| Table 2 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | self-ratings    | spouses         | self-ratings    | spouses         | self-ratings    | spouses         | self-ratings    | spouses         |
| sa, speech acts| 83              | 72*             | 85              | 77              | 74              | 68              | 91              | 80*             |
| top, topic maintenance | 74 | 68 | 71 | 80* | 71 | 57 | 91 | 57* |
| turn, turn-taking | 91 | 80* | 71 | 57 | 57 | 50 | 74 | 67 |
| lex, lexical selection | 71 | 57 | 75 | 67 | 75 | 67 | 76 | 61* |
| sty, style | 71 | 57 | 75 | 67 | 75 | 67 | 76 | 61* |
| pros, prosodics | 57 | 50 | 75 | 67 | 75 | 67 | 76 | 61* |
| prox, proxemics | 57 | 50 | 75 | 67 | 75 | 67 | 76 | 61* |
| con, conversational appropriateness | 76 | 61* | 76 | 61* | 76 | 61* | 76 | 61* |

sa, speech acts; top, topic maintenance; turn, turn-taking; lex, lexical selection; sty, style; pros, prosodics; prox, proxemics; con, conversational appropriateness; *, patient–spouse differences significant at .05 level.
first area: insensitivity to social context. But to constitute a syndrome the cluster of deficits must be selectively related to a single anatomical locus. Although we have shown that pragmatic deficit in these patients is significantly related to measures of frontal lobe performance, we did not rule out a role for other neurocognitive systems not measured in these studies.

In conclusion, we found that patients with PD were significantly impaired on measures of pragmatic communication abilities and that this impairment was related to measures of frontal lobe performance. In addition, we found that PD patients were significantly unaware of the extent of their problems in these domains. Pragmatic impairment undoubtedly contributes to the key clinical features of the Parkinsonian cognitive and personality profile. Future studies should explore the scope and degree of this pragmatic deficit, as well as its impact on daily functioning, and then move rapidly toward development of an intervention program that can target pragmatic social communication skills and improve the quality of life for persons with Parkinson’s disease.

References


