Procedural learning eliminates specific slowing down of response selection in patients with idiopathic Parkinson syndrome

Thomas Lachmann \textsuperscript{ab}, Bettina Schumacher \textsuperscript{ac}, Michael Joebges \textsuperscript{c}; Horst Hummelsheim \textsuperscript{c}; Cees van Leeuwen \textsuperscript{b}

\textsuperscript{a} University of Kaiserslautern, Kaiserslautern, Germany
\textsuperscript{b} Laboratory for Perceptual Dynamics, Brain Science Institute, RIKEN, Wako-shi, Japan
\textsuperscript{c} University of Leipzig, Leipzig, Germany

First Published on: 21 July 2007


To link to this article: DOI: 10.1080/1380390701399278
URL: http://dx.doi.org/10.1080/1380390701399278

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.
Procedural learning eliminates specific slowing down of response selection in patients with idiopathic Parkinson syndrome

Thomas Lachmann,1,2 Bettina Schumacher,1,3 Michael Joebges,3 Horst Hummelsheim,3 and Cees van Leeuwen2

1University of Kaiserslautern, Kaiserslautern, Germany
2Laboratory for Perceptual Dynamics, Brain Science Institute, RIKEN, Wako-shi, Japan
3University of Leipzig, Leipzig, Germany

Patients with idiopathic Parkinson syndrome and normally aged controls participated in a psychological refractory period experiment. Two tasks were presented on each trial: auditory discrimination of high versus low tones, followed by visual classification of letters versus their mirror images. Speeded responses to both tasks were required. Stimulus onset asynchrony between the tasks was varied (short vs. long). Both groups showed equal response times overall, but patients were slower on the second task in the short stimulus onset asynchrony condition. This effect was eliminated with practice. The results were interpreted in terms of reduced capacity for cognitive processes involving decision making as a secondary symptom of the Parkinson syndrome.

The idiopathic Parkinson syndrome (IPS) has an incidence rate of 1% of all over-65-year-olds in typical western countries. Proteinaceous inclusion bodies accumulate within neurons, leading to cell death in specific vulnerable areas. The process advances in a predictable sequence to other areas. During early stages, synuclein accumulations can be detected as precursors of the inclusion bodies in the medulla oblongata and olfactory bulb and later in the substantia nigra. In addition, other nuclear substances of the midbrain and basal forebrain are the focus of initially subtle and subsequently more severe changes. At this point the disease reaches its symptomatic phase. Patients show rigor, hypokinesia, or tremor. During the end-stages, the pathological progression encroaches upon the telencephalic cortex, and additional symptoms like postural instability occur (Braak et al., 2002).

Parkinson (1817) originally considered IPS as an exclusively motor system disease. Since then, however, a number of studies have suggested considering cognitive deficits as well (see Brown & Marsden, 1987, for an overview). General cognitive slowing down (bradyphrenia) has been proposed (Naville, 1922; Smith et al., 1998) but such symptoms could also be attributed to normal aging (Phillips et al., 1999), dementia, or late-life depression (Butters et al., 2004). Others have argued for more specific deficits (Sullivan & Sagar, 1989; Brown & Marsden, 1987), involving mainly two specific functions: visuo-spatial processing (Amick, Cronin-Golomb, & Gilmore, 2003; Lee, Harris, & Calvert, 1998; Natsopoulos, Bostantzopoulou, Katsarou, & Grouios, 1993; Pirozzolo, Hansch, Mortimer, Webster, & Kuskowsky, 1982; Proctor, Riklan, Cooper, & Teuber, 1964; Taylor, Saint-Cyr, & Lang, 1986) and memory search (Ivory, Knight, Longmore, & Caradoc-Davies, 1999; Pirozzolo et al., 1982).

Regarding visuo-spatial processing: McDowell and Harris (1997), using questionnaires, found that...
patients reported problems with depth and motion perception but not with color, brightness, and shape perception. Lee et al. (1998) showed that IPS patients have impairments in mental rotation tasks, in which visuo-spatial representations have to be manipulated internally. Other experimental studies, however, failed to find visuo-spatial orientation problems in IPS patients (Hsieh, Hwang, Tsai, & Tsai, 1996).

Regarding memory search, Appollonio et al. (1994) and Breen (1993) found free-recall impairment in IPS, whereas recognition memory was normal. Brown and Marsden (1987) and Flowers, Pearce, and Pearce (1984) similarly found specific deficits in memory retrieval. It was concluded that although patients were able to adopt adequate processing strategies, they were less efficient in using these (Breen, 1993). Press, Mechanic, Tarsy, and Manoach (2002) investigated memory search in IPS patients using a classical Sternberg task (Sternberg, 1966). Multiple items are kept in memory, and participants must search for a given item within this memory set. Linear increase in memory search time as a function of the number of items in memory set is understood as memory search rate. Press et al. (2002) found a slower memory search rate in IPS patients than in normal controls. Wilson, Kasniak, Klawans, and Garron (1980) had previously found reduced retrieval rates in IPS patients. Posner, Walker, Friedrich, and Rafel (1984) failed to find such a difference, but reported a general increase in reaction time (RT).

Visuo-spatial perception and memory retrieval studies both involve manipulating information internally in the service of guiding behavior. Such central processes are typically a function of the frontal network (Taylor et al., 1986), which is limited in its processing capacity. To alleviate its workload, proceduralization (Anderson, 1982) results in the formation of automatized behavioral routines for efficient task execution. Deficits in proceduralization may therefore be held responsible for capacity limitations in IPS patients (Haaland, Harrington, O’Brien, & Hermanowicz, 1997; Pascual-Leone et al., 1993; Sommer, Grafman, Clark, & Hallett, 1999). Press et al. (2002) found that the reduction in memory search rate in IPS patients disappeared after the first experimental session. The authors suggested that there was a delay in proceduralization of memory search.

Our aim is to establish whether there is a delay in proceduralization in IPS patients in visuospatial processing. We investigate to what extent the involvement of the frontal system disappears with practice. To do so we need to show the involvement of the frontal system in our visuo-spatial processing task and study the effect of practice. To this aim we use the psychological refractory period (PRP) paradigm (Szameitat, Lepsien, von Cramon, Sterr, & Schubert, 2006; Szameitat, Schubert, Mülker, & von Cramon, 2002).

The PRP paradigm belongs to the family of dual-task paradigms. Cognitive processing capacity is limited, so when two tasks that require central processes are performed simultaneously, performance is usually worse than when these tasks are performed independently (Telford, 1931; Welford, 1952). When they are performed in rapid succession, performance is degraded most when the difference between the onset of the first and second task (stimulus onset asynchrony, SOA) is minimal. These results are an effect of the central information-processing bottleneck (Pashler, 1984; Pashler & Johnston, 1998; Welford, 1952), which may be identified with the frontal system. Szameitat et al. (2002) located PRP-related activity in various frontal areas (inferior frontal sulcus, middle frontal gyrus) and the intraparietal sulcus. These brain areas were activated in a dual-task situation but not when the tasks were performed separately.

In the PRP bottleneck paradigm (Pashler, 1984, 1994), the SOA is systematically varied with different levels of a task complexity variable (e.g., Lachmann & van Leeuwen, 2007; Schwarz & Ischebeck, 2001). Priority is given to the first task. To involve the central bottleneck, this task must require a decision (as in a choice response task), but should otherwise be kept simple. Binary classification of tones is typically used (Pashler, 1994). Central processing of the second task will have to wait until the bottleneck is cleared from the first task. As a result RT increases with decreasing SOA. The waiting time for clearance, however, will be equal for all these processes, independently of their level of complexity. In a factorial design, this means that effects of SOA and central processing complexity will have additive effects.

In contrast, processes prior to the central bottleneck stage of the second task may overlap with the bottleneck stage of the first task, without diminishing the rate of processing for either task. With decreasing SOA, an increasing proportion of pre-bottleneck second-task processes will overlap. Thus, the complexity of these processes will increasingly be buried in the overlap if the SOA is diminished. As a result, we would observe a subadditive interaction of second task complexity with decreasing SOA.

Thus, using the PRP paradigm allows us to distinguish between perceptive, central-cognitive and motor processes for a given task. If there are RT
differences between IPS patients and controls, the PRP effects tell us why, where, and how. By looking at practice effects, we may observe effects of proceduralization.

Previous dual-task studies with IPS patients have yielded mixed results. Malapani, Pillon, Dubois, and Agid (1994) found that IPS patients performed equal to controls on visual and auditory go/no-go tasks, but when the two tasks were presented simultaneously the speed of performance in the former showed a greater drop than that in the latter. This indicates that IPS patients find complex decision making particularly hard. Other studies supported this hypothesis (Brown & Marsden, 1991; Dalrymple-Alford, Kalders, Jones, & Watson, 1994; Fournet et al., 1996; Horstink, Berger, van Spaendonck, van den Bercken, & Cools, 1990; Robertson, Hazlewood, & Rawson, 1996).

In contrast, Hein, Schubert, and von Cramon (2005) found no greater drop in performance in IPS patients than in normal controls when two tasks were presented close in time. Similarly, Hsieh (2000) presented two tasks with an SOA of 50, 150, or 650 ms. The first task was a tone discrimination task, the second a digit identification task (replication of Pashler, 1989). She found increased RT and error rates for the first task. For the second task she found increased RT for IPS, but no interaction with SOA. Hsieh concluded that extra motor execution time might have produced the group main effect. The main problem with all these experiments, however, is that they lack a task complexity variable, with which SOA could interact, as in the PRP bottleneck paradigm. In addition, they fail to provide us with data on the effect of practice.

**EXPERIMENT**

**Method**

**Participants**

We recruited a total of 28 participants through advertisement in the monthly magazine of a local Parkinson self-help group. A total of 16 of them were in the patients group (experimental group), 10 of whom were females. Average age in this group was 66 years, ranging from 52–75. Patients’ IPS diagnosis was validated by experienced neurologists specialized on the area of IPS, according to brain bank criteria. The Hoehn and Yahr state of all patients was diagnosed as between 2.0 and 2.5. Duration of illness, medication, and laterality of the patients are reported in Table 1. According to Press et al. (2002), medication, and its corresponding dopaminergic state, has no influence on the performance in a typical RT task, such as memory search.

Participants of the control group were 12 family members of the patients, 8 of whom were females. Average age was 67 years, ranging from 52–81. Participants in the control group were selected for reporting no history of neurological disorders and not receiving any psychopharmacological drugs.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Duration of illness</th>
<th>Laterality</th>
<th>Cum. diurnal dose of L-dopa</th>
<th>Cum. diurnal dose of L-dopa agonists</th>
<th>Hoehn &amp; Yahr state</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>69</td>
<td>5</td>
<td>left</td>
<td>300</td>
<td>—</td>
<td>2.0</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>68</td>
<td>13</td>
<td>left</td>
<td>700</td>
<td>Cabergolin: 6</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>62</td>
<td>4</td>
<td>right</td>
<td>150</td>
<td>Cabergolin: 8</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>58</td>
<td>4</td>
<td>left</td>
<td>350</td>
<td>—</td>
<td>2.0</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>71</td>
<td>8</td>
<td>right</td>
<td>100</td>
<td>Pergolide: 1</td>
<td>2.5</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>72</td>
<td>4</td>
<td>left</td>
<td>300</td>
<td>Ropinirole: 9</td>
<td>2.5</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>75</td>
<td>4</td>
<td>left</td>
<td>150</td>
<td>Cabergolin: 3</td>
<td>2.5</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>64</td>
<td>8</td>
<td>right</td>
<td>400</td>
<td>Pramipexole: 3.5</td>
<td>2.5</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>65</td>
<td>3</td>
<td>right</td>
<td>250</td>
<td>Cabergolin: 4</td>
<td>2.5</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>74</td>
<td>4</td>
<td>left</td>
<td>100</td>
<td>Cabergolin: 6</td>
<td>2.5</td>
</tr>
<tr>
<td>11</td>
<td>F</td>
<td>52</td>
<td>19</td>
<td>left</td>
<td>100</td>
<td>Cabergolin: 4</td>
<td>2.5</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>68</td>
<td>10</td>
<td>right</td>
<td>400</td>
<td>Cabergolin: 4</td>
<td>2.5</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>52</td>
<td>7</td>
<td>left</td>
<td>350</td>
<td>Pergol: 8.5; Cabergolin: 8</td>
<td>2.5</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>72</td>
<td>5</td>
<td>left</td>
<td>300</td>
<td>Pramipexole: 3</td>
<td>2.0</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>68</td>
<td>9</td>
<td>left</td>
<td>200</td>
<td>Cabergolin: 4</td>
<td>2.0</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>57</td>
<td>1</td>
<td>right</td>
<td>—</td>
<td>Pramipexole: 1.75</td>
<td>2.0</td>
</tr>
</tbody>
</table>

*Note.* IPS = idiopathic Parkinson syndrome. F = female, M = male.

*In years. In mg.*
Patients and controls received 10 euros for their participation. All participants had normal or corrected-to-normal seeing and hearing abilities. An interview was held prior to the experiment with all participants to assure normal intelligence and to exclude ailments such as acute untreated depression or other psychiatric or psychological illnesses that might influence the level of cognitive processing.

**Stimuli**

Tones were presented for 33 ms at either 900 (high) or 300 Hz (low) using standard sound card and speakers. The letters F, R, g, and their mirror images were presented visually. Letters were composed of straight-line segments drawn on a 5-cm (horizontal) by 7-cm (vertical) grid and were displayed on a 14-inch standard PC monitor. The visual angle was about 5° horizontally and about 6.5° vertically. There was no fixation of the participant's head.

**Procedure**

Participants were seated at 60-cm distance from the monitor in a sound-attenuated and darkened room. They were instructed to rest their hands on a wooden panel, 50 cm long, which contained four response keys, two on the left-hand side and two on the right-hand side, one next to each other. As keys, 7.5 × 7.5-cm standard light push-buttons were used. The keys on the left side contained the labels “high” and “low.” The keys on the right side contained the labels “normal” and “mirrored.”

Participants started with a 25-trials training session of the auditory discrimination task, for which they were instructed to respond as fast and accurately as possible depending on whether the tone presented was “high” or “low,” using the response keys on the left-hand side. Subsequently they were trained for 30 trials on the letter discrimination task. There, in each trial a fixation cross appeared for 300 ms prior to the presentation of a letter in the center of the screen. Participants were instructed to respond as fast as possible whether the letter presented was “normal” or “mirrored” by using the response keys on their right-hand side.

Speed and accuracy feedback were given during the training sessions. Following a correct trial, the response time in ms was briefly presented in green; following an incorrect response, the time was given in red. Feedback on the auditory task was given in the lower left corner of the screen, on the visual task in the lower right corner of the screen.

After training participants were instructed to perform both tasks together. They were told to respond to the tone first and that, although both tasks were important, they should focus on responding to the tones. At the beginning of a trial, a fixation cross was shown for 300 ms in the center of the screen, followed by a tone. High or low tones were used with equal frequency in the experiment. The visual stimulus was presented with either a short (50-ms) or long (400-ms) SOA. Visual stimuli were shown until the response occurred. All stimuli occurred with equal frequency within the experiment. Whenever participants failed to respond to the tone within 1,600 ms, the text: “Please respond faster to the tone!” appeared on the screen in addition to the feedback. If the response time in the first 16 trials was above 1,600 ms on average, the program was interrupted briefly, and a full-screen text appeared: “Please try to be a bit faster! Average response time to the tone: [e.g., 1,892] ms.” When a response to a tone was given faster than 200 ms, the sentence: “Please do not guess the tone!” appeared. No feedback was given for correct responses. The next trial started 2 s later.

A total of six blocks of 24 trials was presented, in which equal numbers of long and short SOA trials were randomly intermixed. Halfway through and at the end of each block participants were offered an optional short break. After each block they received feedback on their within-block average response times and percentages correct on both tasks.

**Results**

Individual mean response times and error rates were positively correlated in the first task (\(R = .586, p < .01\)); in the second task no correlation was obtained.

**Task 1: Auditory classification**

The overall mean RT was 946 ms (\(SD = 504\)), and the mean error rate was 8.6%. Analysis of variance (ANOVA) on RT, with factors group (IPS vs. control) as between-subjects factor and SOA (long vs. short) and reflection (normal vs. mirrored items in the second task) as within-subjects factors, resulted in a main effect of SOA, \(F(1, 26) = 51.88, p < .001\). Performance was weaker with short (1,018 ms, \(SD = 550\)) than with long SOA (877 ms, \(SD = 444\)), and for reflection, \(F(1, 26) = 8.725, p < .01\), faster for normal (925 ms, \(SD = 483\)) than for mirrored letters (967 ms, \(SD = 523\)). The interaction of SOA and reflection reached significance, \(F(1, 26) = 5.10, p < .05\); for short SOA, normal letters yielded 977 ms (\(SD = 507\)), mirrored 1,060 ms.
(SD = 588), and for long SOA, normal letters yielded 874 ms (SD = 453) and mirrored 879 ms (SD = 436). Thus, the interaction is based on the restriction of the effect of reflection to short SOA. For group, (F = 0) no other effect approached significance. The same analysis on error rates yielded no significant effect.

**Task 2: Visual classification**

The mean RT for the second task was 1,564 ms (SD = 770 ms), and the mean error rate was 7.6%. ANOVA on RT, with factors group (patients vs. controls) as between-subjects factor and SOA and reflection as within-subjects factors, resulted in main effects for SOA, F(1, 26) = 268.37, p < .001, with faster responses for long (1,336 ms, SD = 649) than for short SOA (1,801 ms, SD = 813), and for reflection, F(1, 26) = 11.10, p < .005, with faster responses for normal (1,522 ms, SD = 718) than for mirrored letters (1,607 ms, SD = 817). No main effect of group was obtained (F < 1; controls = 1,527 ms, SD = 685; patients = 1,595 ms, SD = 833).

Two interactions reached significance. Figure 1 shows the interaction Group × SOA, F(1, 26) = 5.36, p < .05. Patients (1,861 ms, SD = 905) were slower than controls (1,727 ms, SD = 677) for short SOA but not for long SOA. The direction of the interaction is opposite to what would have resulted if the difference between the two groups had been based on an automatic, bottleneck-independent process. The other interaction is that of Reflection × SOA, F(1, 26) = 9.29, p < .001. Figure 2 shows that for short SOA, normal letters are faster (1,719 ms, SD = 722) than mirrored (1,885 ms, SD = 889) but not for long SOA. The direction of this interaction, too, is opposite to what would have been expected from an automatic, bottleneck-independent process.

The same analysis on error rates resulted in a main effect of group, F(1, 26) = 5.268, p < .05—more errors were made in the patients group (9.9%) than in the control group (4.5%)—and of SOA, F(1, 26) = 7.808, p < .05—more errors were made for short (8.8%) than for long SOA (6.4%). No interactions reached significance.

The present study involves many trial repetitions. It is therefore possible to investigate the question of whether practice can remedy the specific deficit in IPS patients. To study this question, the complete session was divided into four practice stages (I–IV). An ANOVA with factors group, SOA, and practice resulted in main effects of SOA, F(1, 26) = 296.3, p < .001, and practice, F(3, 78) = 53.30, p < .001. The first result duplicates that of the first analysis; the second shows that practice leads to improvement in both groups. As before, there was no group main effect. Significant interactions were obtained of Group × SOA, F(1, 26) = 4.69, p < .001, of SOA × Practice, F(3, 78) = 5.00, p < .005, and a triple interaction of Group × SOA × Practice, F(3, 78) = 2.99, p < .05.

Figure 1. Interaction of group and stimulus onset asynchrony (SOA); reaction times (RTs) and 95% confidence interval of IPS patients versus controls on the secondary mirror image task for short (50-ms) and long (400-ms) SOA between the first and second tasks.

Figure 2. Interaction of reflection and stimulus onset asynchrony (SOA); reaction times (RTs) and 95% confidence interval for normal versus mirrored letters on the secondary task for short (50-ms) and long (400-ms) SOA between the first and second tasks.
Post hoc analyses showed that the effect of SOA remained in all practice stages separately, $F(1, 26) = 68–226, p < .001$. An interaction of Group $\times$ SOA, however, was found in Practice Stage 1, $F(1, 26) = 5.76, p < .05$, but not in any of the subsequent stages (see Table 2 for detailed data information).

The same ANOVA was run on error rates. Main effects were found for SOA, $F(1, 26) = 8.95, p < .01$, and group, $F(1, 26) = 5.47, p < .05$, duplicating former results, and for practice, $F(1, 26) = 4.07, p < .05$, with decreasing error rates with practice in both groups (see Table 2 for detailed data information). No interactions were found.

**Discussion**

Patients with IPS and age-matched controls performed a dual-task experiment using a PRP paradigm. The first task involved auditory classification, the second task visual classification of normal versus mirrored letters. For the first task, no group differences were obtained. Equally in the two groups, both the first and second task showed main effects of SOA. This means that a bottleneck has occurred in this experiment. At present, the debate is still on about whether limited capacity resources of the bottleneck are allocated in an all-or-none fashion (Pashler, 1984, 1989; Welford, 1952), or whether capacity sharing between tasks is allowed (Navon & Miller, 2002; Tombu & Jolicoeur, 2002). When there are effects of SOA on both tasks this implies, according to the logic of the PRP paradigm, that resource sharing has taken place between the first and second task. In other words, the limited capacity has not been devoted exclusively to the two tasks in sequence, but has been divided over the tasks, resulting in a slowing of both. In accordance with this explanation, there is an effect of reversal (longer response times with mirrored than with normal letters), a complexity variation of the second task, on the response times of the first task when SOA between the two tasks is short. With long SOA between these tasks, such cross-talk does not occur.

In the second task, IPS patients made more errors than did controls, but showed no differences overall in response times. For RT an interaction between SOA and reflection was obtained; higher RT for mirrored letters than for normal letters was only found in the short SOA condition, whereas there were no effects in the long SOA condition. Had this pattern of interaction been opposite (bigger effect for long SOA), this would mean evidence for automatic processing of reversed letters. The present result, however, suggests that letter reversal involves the central bottleneck, equally in both groups of participants. This result indicates that, in accordance with Ruthruff, Miller, and Lachmann (1995), the central bottleneck is involved in visuo-spatial manipulations (such as reversal decisions).

IPS patients and normal controls showed no difference in overall performance on the second task, contrary to the notion of general cognitive slowing down in IPS patients.

The IPS patients, however, were showing specific cognitive slowing down when the SOA between the first and second task was short. If this were caused by primary motor symptoms of the disease, this would have occurred in both SOA conditions. IPS patients, therefore, may find it particularly difficult to combine overlapping decision processes.

With practice, the effect of SOA was reduced in both groups. Proceduralization means that both tasks can be executed more efficiently together. In accordance with Press et al. (2002), we may ascribe the initially weaker performance in IPS patients to lack of proceduralization. Performance of IPS

**TABLE 2**

Reaction times and error rates for different SOA levels in controls and Parkinson patients for different levels of practice

<table>
<thead>
<tr>
<th>Practice level</th>
<th>Controls (SOA = 50)</th>
<th>Controls (SOA = 400)</th>
<th>IPS patients (SOA = 50)</th>
<th>IPS patients (SOA = 400)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT</td>
<td>SD</td>
<td>Error rate</td>
<td>RT</td>
</tr>
<tr>
<td>1</td>
<td>2,092</td>
<td>872</td>
<td>8.6</td>
<td>1,688</td>
</tr>
<tr>
<td>2</td>
<td>1,749</td>
<td>645</td>
<td>7.2</td>
<td>1,240</td>
</tr>
<tr>
<td>3</td>
<td>1,579</td>
<td>535</td>
<td>2.1</td>
<td>1,224</td>
</tr>
<tr>
<td>4</td>
<td>1,572</td>
<td>545</td>
<td>4.3</td>
<td>1,168</td>
</tr>
</tbody>
</table>

Note. IPS = idiopathic Parkinson syndrome. SOA = stimulus onset asynchrony. Reaction times in ms. Error rates in percentages.
patients approached that of the controls already after about the first 25% of the trials within a single, one-hour, session.

Not only is it difficult to assess cognitive deficits in Parkinson patients, it is also possible that they reflect secondary symptoms, resulting from a vicious circle of lack of practice, lack of confidence, and avoidance behavior in performing certain tasks, and depression. The currently observed deficit may be in fact such a secondary symptom. Let this be so; the value of the present study is that this deficit can easily be remedied by practice.

Original manuscript received 20 November 2006
Revised manuscript accepted 11 April 2007
First published online 21 July 2007

REFERENCES


