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Strategy instruction in Parkinson's disease: Influence on cognitive performance

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ABSTRACT

Objectives: Though strategic deficits are extensively investigated in Parkinson's disease (PD), little is known about the effects of instruction for PD patients. Thus, we compared the ability to internally generate a cognitive strategy with the ability to use a strategy after elaborate strategy instruction.
Methods: Patients with PD ($n = 14$) and matched healthy controls ($n = 22$) were administered a Numerosity Judgement task in which they had to determine different numerosities of blocks presented in a square grid. In more complex task configurations, healthy participants tend to use a subtraction strategy. Participants in our study were confronted with a counting condition (A), a strategy initiation condition without instruction (B), and a strategy elaboration and strategy training condition (C).
Results: Patients and controls were comparable with respect to basic cognitive measures. PD patients and controls performed equivalently within the counting condition (A), but patients needed significantly more trials to initiate the subtraction strategy. With the exception of 1 PD patient, all patients were able to internally initiate the strategy (condition B). In condition C, both groups increased reaction times, but patients were significantly slower than controls. Moreover, only patients significantly increased error rates after strategy instruction.
Conclusion: As long as sufficient time is provided for solving the task, results do not show a general deficit in the ability to internally generate a cognitive strategy in PD. Failures in strategy utilization strongly depend on cognitive load (working memory, executive functions). This bears important implications for the neuropsychological rehabilitation of PD patients.

1. Introduction

Deficits in executive cognitive functions affecting the ability to plan, monitor, and control goal-directed behaviour are one of the major characteristics of neuropsychological alterations in Parkinson's disease (PD) (e.g., Brown & Marsden, 1988; Dubois & Pillon, 1997; Mega & Cummings, 2001; Saint-Cyr, 2003; Zgaljardic, Borod, Foldi, & Mattis, 2003). These are usually attributed to the altered functional interactions between frontal cortex and basal ganglia due to the depletion of dopamine-producing neurons of the basal ganglia (e.g., Alexander, DeLong, & Strick, 1986; Cools, 2006, 2008; Lewis, Dove, Robbins, Barker, & Owen, 2003; Owen, 2004; Price, Filoteo, & Maddox, 2009).

The inability to internally implement adequate cognitive strategies, especially in the absence of external guidelines, has been held responsible for a multitude of cognitive deficits in PD patients. Deficits in self-initiated strategy use leading to impaired performance in neuropsychological tests were, for example, seen in a spatial locomotor task (Leplow et al., 2002), in the Tower of London problem (e.g., Cools, 2006; McKinlay et al., 2008; Owen, 2004), or in the utilization of semantic cues (Tweedy, Langer, & McDowell, 1982) and clustering strategies, respectively (e.g., Buytenhuis et al., 1994; Knoke, Taylor, & Saint-Cyr, 1998; Taylor, Saint-Cyr, & Lang, 1990; van Spaendonck, Berger, Horstink, Borm, & Cools, 1996). Also, deficits in spatial memory have been attributed to impaired strategic processing (Pillon et al., 1998). In addition, PD patients show deficits in other tests comprising a strategic component such as various aspects of intentional learning (e.g., Vingerhoets, Vermeule, & Santens, 2005), self-ordered pointing tasks (e.g., Gabrieli, Singh, Stebbins, & Goetz, 1996), conditional associative learning (e.g., Canavan et al., 1989; Gotham, Brown, & Marsden, 1988; Pillon et al., 1998), problem solving (e.g., Kamei et al., 2008; Morris et al., 1988), conscious decision-making (e.g., Brand et al., 2004), attentional set shifting (e.g., Williams-Gray, Hampshire, Barker, & Owen, 2008), or temporal ordering (e.g., Vriezen & Moscovitch, 1990). Thus, PD patients are typically impaired in the internal generation and initiation of effective cognitive strategies.

However, strategic deficits have not only been demonstrated within the laboratory. Inferior utilization of metacognitive memory strategies seems to induce problems of PD patients in real-life situations (Johnson, Pollard, Vernon, Tomes, & Jog, 2005). Even the

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increased risk of falls has been associated with a deficit in strategic behaviour (Bloem, Grimbergen, van Dijk, & Munneke, 2006).

Thus, one of the most fundamental deficits in PD is the inability to elaborate internally guided behaviour (e.g., Berger et al., 2004; Brown & Marsden, 1988, 1990; Cools, van den Bercken, Horstink, van Spaendonck, & Berger, 1984; Dubois & Pillon, 1997; Flowers & Robertson, 1985; Gabrieli et al., 1996; Jahanshahi et al., 1995; Norman & Shallice, 1986; Pollux, 2004; Taylor, Saint-Cyr, & Lang, 1986; Werheid, Koch, Reichert, & Brass, 2007). Thus, the aspect of self-initiated, as opposed to externally triggered, cognitive behaviour seems to play an important role for cognitive performance in PD. Concordantly, PD patients regularly show difficulties in solving cognitive tasks which lack external guidelines and, consequently, necessitate the subjects to initiate and implement their own cognitive strategy.

On the other hand, strategy use following verbal instructions was less impaired. For example, Knoke et al. (1998) used the CVLT under three conditions of graded cueing. They demonstrated that PD patients show deficits in internally guided strategic behaviour leading to deficient verbal memory. However, patients benefited significantly from increasingly explicit cueing. In contrast, normal controls did not benefit from external cues. This was attributed to the fact that they were able to spontaneously and internally generate these cues themselves, i.e., showed optimal strategic behaviour without external cueing.

To date, this distinction between the internal initiation as well as the application of externally provided cognitive strategies in PD is not well understood. For example, it is unclear to what extent PD patients benefit from external strategy instruction. Moreover, strategic behaviour of PD patients has mainly been assessed via complex verbal memory paradigms, which might be problematic due to the limited working memory capacity of PD patients (e.g., Gabrieli et al., 1996).

Therefore, we compared the ability of PD patients to internally initiate a strategy with their ability to utilize an externally provided strategy in a simple Numerosity Judgement task. This paradigm requires subjects to determine different numerosities of blocks that are presented in a square grid. In tasks with a high number of presented blocks, healthy subjects often use the subtraction strategy, whereby the number of empty squares is subtracted from the total number of squares in the grid instead of counting the blocks (e.g., Luwel, Verschaffel, Onghena, & De Corte, 2003). We compared participants' ability to internally initiate the subtraction strategy with the ability to implement the strategy after its external provision and elaborate strategy instruction. Our main predictions were (i) that PD patients would be especially impaired in the self-initiated strategy use and (ii) that strategy instruction would lead to enhanced performance, especially in PD patients.

2. Methods

2.1. Participants

Fourteen right-handed patients (seven males) with mild to severe PD and 22 healthy controls (HC), closely matched for sex, age, level of education, and intelligence participated in the study. Experience in using a PC was assessed by means of a structured interview. No differences were found between patients and controls. The mean age of the patient group was 66.2 (8.3) with a range from 49 to 78 years (Table 1). PD patients were recruited from two local self-help groups. Two of the patients (14.3%) displayed a Hoehn and Yahr score of 1, 4 (28.6%) had a score of 2, 6 (42.9%) had a score of 3, and the remaining 2 displayed a score of 4. All patients received L-dopa, none were on anticholinergics, 8 were being treated with amantadines, and 4 received MAO-inhibitors. None of the patients had undergone deep brain stimulation. Mean time of diagnosis was 8.9 years (range 2–15 years). Patients with depression ($n = 1$, assessed by the BDI) or dementia ($n = 3$, measured by the MMSE) were excluded. Patients and controls with concomitant neurological diseases, severe medical complications, additional psychiatric disorders, or with a history of DSM IV-/ICD 10-disorders ($n = 6$) were also excluded. Four additional patients had to be excluded due to a pronounced resting tremor that made it impossible to differentiate between voluntary and involuntary responses in the tests presented on the computer. Thus, altogether 28 patients were recruited, 18 completed the procedure, and 14 constituted the final sample.

2.2. Accompanying measures

Premorbid level of intelligence was estimated using the Mehrfachwahl-Wortschatztest MWT-B (Lehrl, 1999), a test of word recognition which is functionally equivalent to the widely used NART test (Nelson & O'Connell, 1978). In addition, an estimation using educational and socio-demographic data (Leplow & Friege, 1998) similar to the formula of Barona (Barona, Reynolds, & Chastain, 1984) was used (Table 1). Handedness was assessed by means of a German translation of an abbreviated version of the Annet handedness questionnaire (Annett, 2002). Assessment of anterograde memory was done by the Buschke Selective Remaining Test BSRT (Buschke & Fuld, 1974) consisting of 12 items using a delayed recall interval of 20 min. Digit Span (Forward and Backwards; Wechsler, 1987) served as an indicator of verbal short-term and working memory. Block Tapping (Forward and Backwards) (Wechsler, 1987) was used for assessment of visuo-spatial short-term and working memory. A German version of the Controlled Oral Word Administration test COWA (Benton & Hamsher, 1989), a lexical fluency task using the letters "L"–"B"–"S", as well as the Five-point Test (Regard, Strauss, & Knapp, 1982) were applied as estimators of executive functions (Table 2).

Reaction time was assessed via two simple reaction time tasks directly before and after the experimental paradigm, respectively. A cross was presented in aperiodic intervals at the centre of the screen, demanding the participant to press the left mouse button as quickly as possible. The cross had a size of 1.2 cm. The task was adapted from the TAP, a widely used German computerised attention test battery (Zimmermann & Fimm, 1994). Moreover, a more complex choice reaction task was administered where participants had to choose one of the two mouse buttons. In this task, the cross-disappeared non-centrally either 3.5 cm left or right of the centre of the screen. The subject had to press the corresponding (i.e., left or right) mouse button. All experimental procedures were written with presentation 0.55 and presented via a customary laptop (14.1" monitor with a resolution set to 800 x 600 pixels, Pentium III processor).

2.3. Materials

Strategic abilities were tested using a Numerosity Judgement task in which participants were required to judge different numerosities of blocks presented in a 4×4-grid structure (see Luwel et al., 2003). Each square had a size of $1.2\,\text{cm} \times 1.2\,\text{cm}$. The 16 square units could either be "on" (i.e., be filled with a grey-coloured block) or "off" (i.e., remain empty and thus have the same black colour as the background of the screen). In each item, subjects had to indicate the number of presented ("on") blocks within the grid. For this, two alternative answers were presented on the screen beneath the grid; one indicating the correct answer, the other the wrong answer, respectively (Fig. 1). The two answers were always consecutive numbers. The smaller digit was displaced 3.5 cm to the left of the centre, the greater digit was correspondingly displaced to the right. Trials in which the respective right or left mouse button indicated the correct answer were presented in a pseudo-randomized order. Thus, the correct number was not associated with one mouse button more than three times in a row. In each test condition, there were five different correct answers, each occurring four times in a pseudo-randomized order. However, no two correct stimuli were alike. During each trial, participants were requested to verbalize their solution strategies ("loud thinking").

In the first part of the task (Part A, "*unstrategic condition*"), the number of presented blocks ranged from 2 to 6 (Fig. 1, left). In a pre-study that was conducted prior to the experiment, 20 participants aged 24–56 (M = 31.5; S.D. = 8.7) that were free from neurological disorders demonstrated that the most rapid and most accurate responses are made by counting the numbers of presented blocks. In the second test condition, the number of presented blocks ranged from 10 to 14 (Part B, "strategy initiation", Fig. 1, right). Here, counting the blocks led to slower reaction times and more mistakes compared to using the subtraction strategy. Utilization of the sub-

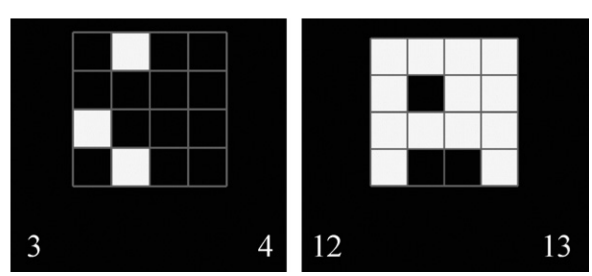

Fig. 1. Example of a simple (left) and a complex (right) trial. Participants had to indicate via the respective right or left mouse button, whether the number of white blocks within the grid matched the respective left or right presented digit. In the left trial, for example, the grid contains three white squares; therefore, the left answer is correct and the subject has to press the left mouse button.