BRAIN AND COGNITION **29**, 115–126 (1995)

Shifting Behavior: An Analysis of Response Patterns of Parkinson Patients in Discrimination Learning

J. P. A. JOOSTEN,* C. J. H. COENDERS,† AND P. A. T. M. ELING†

**Department of Neuropsychology, University of Nijmegen, The Netherlands; and †Department of Physiological Psychology, University of Nijmegen, The Netherlands*

Parkinson patients often show decreased performance on what is generally referred to as "shift tasks." This does not necessarily imply that Parkinson patients have problems with shifting, since task performance reflects not only shifting but also other factors. Using a discrimination learning task, we analyzed response patterns to determine the decision rules used. As well, we varied the manner of problem alternation (implicit versus explicit) and the type of problem alternation (extradimensional versus intradimensional shifts). In accordance with the literature, we found that Parkinson patients needed more trials to solve the problems. However, the response patterns of the Parkinson patients and controls were practically the same. An important finding was that Parkinson patients did not hold on longer to a rule, which was correct in a former problem, than controls did. Therefore, we concluded that Parkinson patients are able to shift from one decision rule to another. © 1995 Academic Press, Inc.

INTRODUCTION

During the past 20 years, the interest in cognitive disorders related to Parkinson's disease has grown. Many studies focused on the ability to shift, using tasks such as the Wisconsin Card Sorting Test (WCST). In this task, figures varying on three dimensions are presented and the subject has to sort the figures according to a rule, for example, color or form. When the subject has solved the problem—i.e. the subject has discovered the correct decision rule—another problem is presented. Then, the subject has to change the decision rule and try to find the new correct rule. Generally, by "shifting" is understood to be the ability to alternate rules during concept learning. Studies concerning shifting behavior in general and Parkinson's disease in particular are difficult to compare for several reasons. First, studies vary widely in the use of concepts, hypotheses, and interpretations. Some studies find that a

Address reprint requests to J. P. A. Joosten at present address: Department of Research and Development, St. Maartenskliniek, P.O. Box 9011, 6500 GM Nijmegen, The Netherlands.

0278-2626/95 $12.00

reduced performance on shift tasks may be due to a specific deficit in forming (Bowen et al., 1975), holding (Flowers & Robertson, 1985), or alternating (Cools et al., 1984) cognitive sets. Other studies explain problems with shift tasks by reference to more general disorders of attention (Brown and Marsden, 1988, 1991; Downes et al., 1989) or speed of mental processing (Sharpe, 1990).

Second, many different tasks have been used, for example, Stroop tasks, the Trailmaking task, and the WCST. Sometimes different cognitive functions are measured with the same shifting task. For example, Heitanen and Teräväinen (1986) studied disorders in shifting behavior with the Stroop Color–Word task. Cools et al. (1984) used the same task as an indication for attention. On the other hand, the same cognitive function is studied through different tasks. For example, both the WCST and the Word Fluency task are used as shift tasks (Cools et al., 1984), while the Word Fluency task is generally taken as a task for investigating the speed of generating semantic information.

Third, it is difficult to compare studies because the instructions to subjects and the manner problems are alternated—explicitly or implicitly—vary by task and by author. In an explicit alternation condition, the experimenter indicates when the problem has been solved and a new problem will be presented. In an implicit alternation, the start of a new problem will not be indicated. Explicit alternation leads to better performance on a shift task (Eimas, 1966; Ludvigson & Caul, 1964; Grant & Cost, 1954; Stevenson & Moushegian, 1956). If a subject is not told that a decision rule changes (implicit condition), a bad performance does not necessarily imply that he is not able to change the rule. In the original version the WCST has an instruction for implicit alternation (Milner, 1963) and in the adapted version it has an explicit alternation (Nelson, 1976). Some studies use the original version (Bowen et al., 1975; Taylor et al., 1986, 1987); others use the adapted version (Lees & Smith, 1983; Brown & Marsden, 1988; Gotham et al., 1988).

Fourth, the type of shift varies over studies. Human and non-human experiments show that the type of shift is important for the rate of solving problems. In an intradimensional (ID) shift, the solution alternates within one dimension, e.g., the alternation between "white" and "black" on the dimension "color." In an extradimensional (ED) shift, a stimulus aspect in another dimension becomes relevant. For example, after the previous rule white, a solution in the dimension color, the rule circle, which is a solution in the dimension form, is correct. People as well as animals learn ID-shifts faster than ED-shifts (Shepp & Eimas, 1964; Roberts et al., 1988). Downes et al. (1989) studied the ability of Parkinson patients and controls to perform ID-shifts and ED-shifts. Both groups used more trials to solve ED-shifts than ID-shifts. In ID-shift no difference was found between Parkinson patients

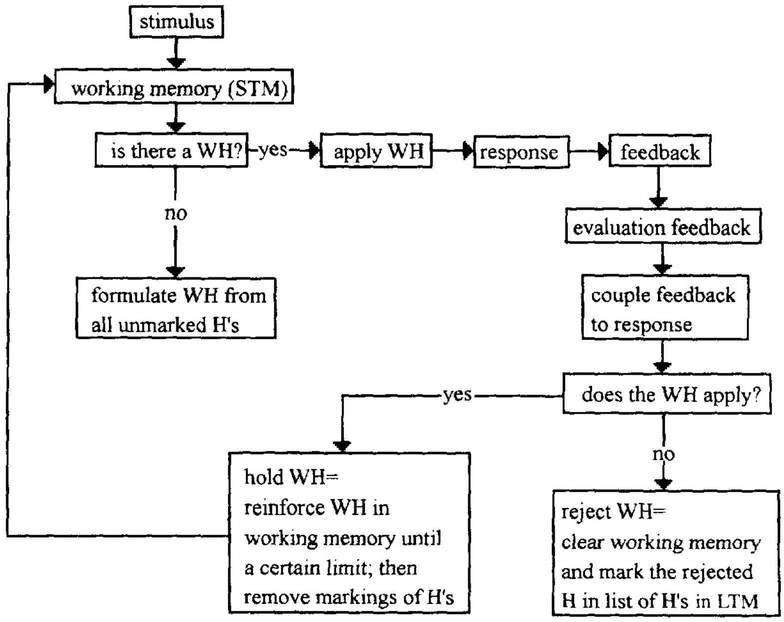

FIG. 1. Description of decision processes involved in discrimination learning (Bakker, 1989). H, hypothesis; WH, working hypothesis; STM, short-term memory; LTM, long-term memory.

and controls. However, Parkinson patients needed more trials than controls to solve ED-shifts.

These four points of comparison must be taken into account in experiments concerning shifting behavior. One needs to analyze and describe the learning process and the performance on a shift task in more detail to obtain a better understanding of the shift problems of Parkinson patients. Researchers mostly report only the final result: the rate of learning, the number of errors, or the number of categories achieved. However, it is also important to consider how a subject arrives at a solution. A given performance can be achieved in different ways. Bakker (1989) has described the decision process in discrimination learning (Fig. 1). Her model is based on classical concept learning and the theory of discrimination learning of Levine (1975); it assumes that the subject knows all possible hypotheses in advance. A subject temporarily selects a decision rule, the working hypothesis (WH). After feedback, he decides whether the WH has to be rejected or not. If the WH is rejected, the subject clears working memory and places the hypothesis in long-term memory (LTM) and marks it. If the WH is not rejected, the subject reinforces the WH in working memory by increasing its activation level. If activation of the WH has reached a certain limit, the subject regards the problem as solved. The presentation of a new stimulus triggers the process all over again. In order to solve a new problem, the subject first has to remove all the markings of hypotheses in LTM.

In each phase of this decision process a problem can occur, which may result in a deviant performance. For instance, problems with formulating a WH result in the absence of possible decision rules. If the evaluation of feedback is disturbed, a correct rule will not be reinforced sufficiently and the correct rule can be rejected unjustly. In this way it takes longer to solve the problem. Another example is that if incorrect decision rules are not rejected and marked, they may be used again as a WH. A final example is a shift problem that occurs if the markings in LTM are not removed after reaching the criterion. A subject will not be able to reject the WH that was previously correct and which is incorrect for the next problem. In that case, a subject holds on to the previously relevant hypothesis after a shift.

Bakker's model describes processes involved in discrimination learning; it can be used for a more detailed analysis of shift problems. To analyze the formulation and alternation of conceptual sets, we developed a discrimination task based on the discrimination learning studies of Levine (1975). A special stimulus sequence was used that enabled us to detect decision rules. A comparable procedure is used in animal research in our laboratory (Coenders et al., 1992).

In this experiment, we investigate the formulation and shifting of decision rules for Parkinson patients, by analyzing response patterns, varying problem alternation (implicit versus explicit) and intra- and extradimensional shifts.

METHOD

Subjects

Twenty-eight patients were recruited with help from the Association for Parkinson patients ($N = 17$) and the Department of Neurology of a general hospital ($N = 11$). Twelve patients were not able to finish all the 10 problems in the test session, because it was too demanding for them. These subjects were excluded from the experimental group. Thus the data of 16 Parkinson patients (6 women and 10 men) were analzyed. The average age was 59.8 years ($SD = 9.5$). The diagnosis "Parkinson's disease" had been assessed between 0 and 25 years ago. Years of medication use also varied between 0 and 25 years. A restriction for participation in the experiment was that the level of medication should be stable. Patients were examined at home to reduce the effects of stress. The control group consisted of 25 persons (14 women and 11 men) without neurological symptoms. The average age was 57.6 years ($SD = 7.4$). Level of education was known for all subjects; it ranged from primary school to university and there were no significant differences between the groups. Informed consent was obtained from all subjects.

Procedure

Each subject received a practice problem, in which the solution was told in advance, and 10 successive discrimination problems. The intention of the task was explained in a standard instruction. The subject had to discover the correct rule of each discrimination problem in as few trials as possible. To exclude problems with formulating solutions, the four possible solutions (white, black, circle, and triangle) were mentioned in the instruction.

In each trial, a pair of figures appeared on a computer screen, controlled by an Apple Macintosh computer (512K). The stimuli consisted of figures differing in two dimensions: form (circle, triangle) and color (black, white). The subject could choose the left or right figure by pressing the left or right key, which were marked on the keyboard. Immediately after responding, the subject received auditory and visual feedback, consisting of a high (good) or low (wrong) tone and the words "good" or "wrong," presented for 400 msec at the bottom of the screen. Then, a message appeared on the screen indicating that the subject had to push the marked space bar to start the next trial. Five Parkinson patients were not able to push the keys because of motor problems. They were assisted. A problem was considered solved when the subject made eight correct responses in succession.

Half the Parkinson patients and controls were given an explicit manner of problem alternation: in this case a text appeared on the screen saying that the problem had been solved and a new problem was to begin. For the other half of the subjects problem alternation was implicit: the problem alternation was not announced. Two problem sequences were used to control for order effects. In both groups, half the subjects received one sequence, the other subjects, the other (Sequences 1 and 2).

Analysis of Response Patterns

In order to enable unique matching of stimulus and response patterns (Table 1), the sequential order of stimuli was subjected to certain restrictions (Coenders et al., 1992). The form and color stimuli were never given more than three times in succession at the same key (left or right) or more than four times in regular left–right alternation. Care was taken to not let coincide the presentation of white and circle (and therefore also black and square) at the same choice key more than three times in a row. In four trials a subject could produce 16 possible response sequences of left–right choices, e.g., RRLR which in the example in Table 1 would match choosing the black figure. A subject is assumed to use a certain decision rule if he chooses the same stimulus aspect on four successive trials. There are four relevant decision rules from these response patterns: black, white, triangle, and circle. Furthermore, there are three irrelevant decision rules related to place: left, right and alternation between left and right. Other response patterns can not be related to simple decision rules. This procedure offers the advantage that one may determine which rules subjects use during discrimination learning.

Variables and Statistical Analysis

First, it was investigated whether Parkinson patients were able to shift solutions, i.e., whether they were able to abandon a previous correct rule and try a new one. The most adequate measure for studying this is the number of trials that a subject holds on to the previous solution after the start of a new problem: the number of Trials to Shift (TTS).

Second, it was investigated whether Parkinson patients had problems discovering the correct decision rule. For that purpose the number of trials needed to solve a problem was calculated (Trials to Criterion or TTC, excluding the eight correct criterion trials).

Third, frequency of the usage of the different decision rules was analyzed to examine whether Parkinson patients show response patterns different from those of controls. The frequency of correct, incorrect, the previously relevant and irrelevant rules were analyzed. Incorrect rules are all responses within the dimension form and color except the correct one. Irrelevant rules are responses with regard to place (left, right) and alternation of place.

Furthermore we studied whether variation in the manner problems alternate affects the per-

TABLE 1
All Possible Response Sequences on Four Consecutive Trials, Given the Order of Presentation of Stimuli

Trials:	N	$N+1$	$N+2$	$N+3$	
Stimuli:	△●	○▲	▲○	△●	
White:	L	L	R	L	
Triangle:	L	R	L	L	
	Response Sequence				Response Rule
1	R	R	R	R	Place
2	L	L	L	L	Place
3	L	R	L	R	Alt. place
4	R	L	R	L	Alt. place
5	L	L	R	L	White
6	R	R	L	R	Black
7	L	R	L	L	Triangle
8	R	L	R	R	Circle
9	L	L	L	R	Undefined
10	R	L	L	L	Undefined
11	L	R	R	R	Undefined
12	R	R	R	L	Undefined
13	R	R	L	L	Undefined
14	L	L	R	R	Undefined
15	L	R	R	L	Undefined
16	R	L	L	R	Undefined

formance on a discrimination task. TTSs and TTCs were calculated for both the implicit and explict conditions.

Finally, it was examined whether problem solving is affected by the type of alternation: extradimensional (ED) or intradimensional (ID). The 10 problems were categorized as ID- and ED-shifts and the average TTC was calculated for each condition. The dependent variables were analyzed in a 2 × 2 × 2 ANOVA with repeated measures (Group × Sequence × Impl/Expl), using the ANOVA-repeated-measures procedure of SuperANOVA (Abacus Concepts Inc., 1989–1990).

RESULTS

Parkinson versus Controls

Trial to shift (TTS). No difference was found in TTS's for Parkinson patients and controls ($F(1, 33) = 2.8, p > 0.05$). Thus, Parkinson patients had no problems with shifting away from a previous correct rule. This holds for both implicit and explicit conditions and for both ED- and ID-shifts.

Trial to criterion (TTC). The Parkinson group showed higher TTC's for the ten problems than the control group ($F(1, 33) = 7.05, p < 0.01$, see Fig. 2). The TTC's of the 10 problems fluctuated ($F(9, 33) = 6.33, p <$

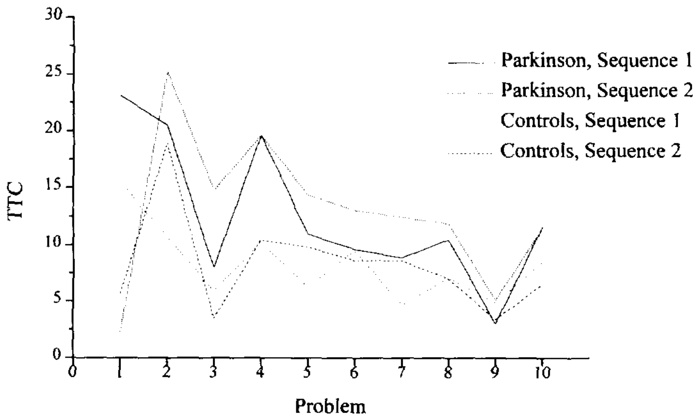

FIG. 2. Mean TTC values; data of Problem*Group*Sequence.

0.01), but the pattern of TTCs were not different in both groups: there was no significant interaction between the factors "Group" and "Problem." The two sequences of problem presentation did not affect TTC ($F < 1$). No interaction between sequence and group was found ($F < 1$).

Taking the practice problem as a starting point, one sequence started with an ED-shift and the other with an ID-shift. Because ED-shifts are more difficult than ID-shifts (see further on) in both groups the first problem in one sequence was more difficult than in the other (mean TTC was 18.55 (SD = 13.61) and 4.38 (SD = 4.69), respectively, Fig. 2). An ANOVA without the first problem did not reveal a difference due to sequence between problems ($F(9, 33) = 3.77, p < 0.01$).

Response Patterns

We have taken into account that Parkinson patients needed more trials for each problem in order to reach criterion. Therefore, the frequencies of decision rules were divided by the total number of TTC's, the relative frequencies.

No differences were found in the relative frequency of correct and incorrect response patterns of Parkinson patients and controls ($F(1, 33) < 1$). Furthermore, no differences were found in the use of the irrelevant rule "alternation place" ($F(1, 33) < 1$) and undefined rules ($F(1, 33) < 1$). No difference was found on responding to the previous relevant stimulus ($F(1, 33) < 1$). The only difference found was that Parkinson patients used the irrelevant rule "place" more frequently than controls did: Parkinson 4.4% and controls 2.2% of the total number of trials ($F(1, 33) = 13.49, p < 0.01$).

To summarize, Parkinson patients performed worse than controls in an absolute sense. They needed more trials for all problems to reach the criterion. However, the response pattern over all problems did not differ between

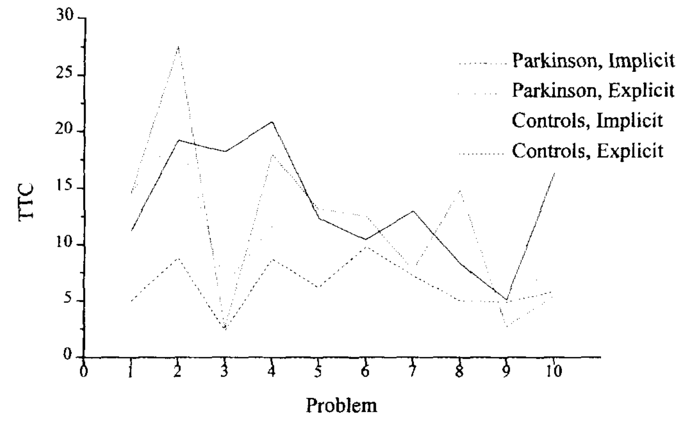

FIG. 3. Mean TTC values; data of Problem*Group*Imp/Exp.

groups. Both groups needed more trials in the first problem, especially in the ED-shift. Parkinson patients performed qualitatively not differently from controls; they only used the rule place more often.

Implicit versus Explicit Condition

The implicit condition appeared to be more difficult than the explicit condition (Fig. 3). The difference within the group of Parkinson patients was not significant (average TTC for the implicit condition was 13.51 (SD = 14.97) and for the explicit condition 11.91 (SD = 13.76); $F(1, 14) = 0.21$, $p > 0.05$). For the controls, the implicit condition was more difficult than the explicit condition. The average TTC was 9.78 (SD = 9.59) and 6.39 (SD = 6.53), respectively ($F(1, 23) = 6.07$, $p < 0.05$).

ED versus ID-shift. ID-shifts were easier than ED-shifts, for the Parkinson group as well as for the control group ($F(1, 33) = 49.00$, $p < 0.01$; Fig. 4).

The first shift seemed to contribute most to the difference between ID- and ED-shifts. Therefore, the analysis was repeated without the first problem. Differences in type of alternation remained significant ($F(1, 33) = 26.37$, $p < 0.01$).

ID-shifts were easier in the explicit condition than in the implicit condition for both groups (Fig. 5). In ED-shifts, the controls benefited from the explicit condition, Parkinson patients did not. This positive effect of the explicit condition in ED-shifts was significant for both groups, however, when the analysis was repeated without the first problem ($F(1, 33) = 4.1$, $p < .05$).

DISCUSSION

The objective of this study was to investigate whether Parkinson patients have problems with shifting on what is generally referred to as "shift" tasks.

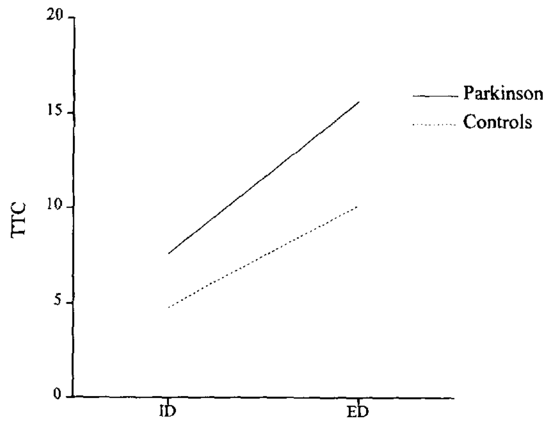

FIG. 4. Mean TTC values; data of ID/ED*Group.

The discrimination task and the analysis of response patterns provide the opportunity to study the number of trials needed to alternate a decision rule (TTS), after reinforcement contingencies have been changed. The results show that Parkinson patients have no problems with shifting. Parkinson patients are able to abandon the previously correct rule and select a new rule.

In accordance with the literature, Parkinson patients needed more trials to solve problems (TTC). However, a higher TTC does not necessarily imply a shifting problem. In the model of Bakker (1989), a number of subprocesses are assumed for performing a discrimination or concept learning task. Shifting is only one aspect of this process. The notion of a "shifting task" is

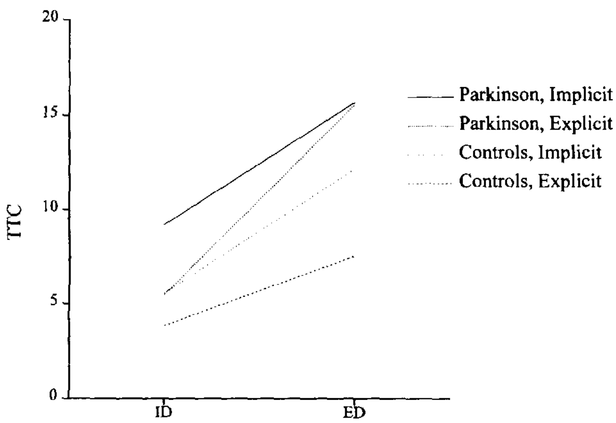

FIG. 5. Mean TTC values; data of ID/ED*Group*Imp/Exp.

deceptive, because it suggests that such a task measures only or especially shifting. No independent evidence has been put forward for this assumption. Reviewing our results, it seems that other aspects than the ability to alternate are important for the impairment of performance of Parkinson patients on this type of tasks.

By analyzing response patterns, we have shown that Parkinson patients use the same decision rules as controls do with the same relative frequency. Patients only use the irrelevant solution "place" a little more often (4.4% of the trials, control 2.2% of the trials). In other words, the response behavior of Parkinson patients is not systematically different from that of controls. A possible explanation is that in Parkinson patients, the activation level of the working hypothesis is not increased by positive feedback to the same degree as in controls. Therefore, Parkinson patients need more trials to reach the limit. In that case no systematic deviations in response pattern are expected, only a more frequent occurrence of correct, incorrect, and irrelevant rules. An explicit condition is generally found to be easier than an implicit condition (Eimas, 1966; Ludvigson & Caul, 1964; Grant & Cost, 1954; Stevenson & Moushegian, 1956). However, our results do not clearly show this difference between the explicit and implicit condition. Still, the manner of problem alternation needs further investigation, because our results indicate a differential effect for groups: the controls learned faster under the explicit condition, while Parkinson patients performed similarly under both conditions (Fig. 3).

Downes et al. (1989) conclude that Parkinson patients have a selective disorder in the ability to make an ED-shift. We found that the Parkinson and control groups exhibit an equal increase of TTC in extradimensional (ED) shifts compared with intradimensional (ID) shifts (Fig. 4). This means that Parkinson patients perform worse on *both* types of shifts. At first sight our results seem to contradict the conclusion of Downes et al. (1989). However, this is not completely true. We find that for controls ED-shifts are easier in an explicit than in an implicit alternation (see also Lachman & Sanders, 1963; Stevenson & Moushegian, 1956). For Parkinson patients however, this facilitatory effect under the explicit condition on ED-shift does not seem to occur (Fig. 5). So our results also indicate a decreased ability for Parkinson patients to solve a problem after an ED-shift. However, this holds only for the explicit condition.

There is a difference between the study of Downes et al. (1989) and our study in the way shifts were operationalized. Two types of ID-shifts are often distinguished: a *reversal* shift and a *pure* intradimensional shift (Slamecka, 1968). In a reversal, the same stimulus aspects (e.g., white and black) of a dimension (e.g., color) are used. The solution (e.g., white) of the consecutive problem is the opposite of the previous solution (e.g., black). In a pure intradimensional shift, stimuli are substituted by new stimuli of the same dimension (e.g., red and blue instead of white and black). According to this terminology, we compared ED-shifts with reversal shifts. Downes et al. (1989)

compared *pure* ID-shifts with ED-shifts in their experiment. In the literature the types of shifts used vary widely. The Wisconsin Card Sorting Test for example only consists of ED-shifts. Whether or not the different types of shifts effect the number of trials that a subject needs to solve a problem (TTC), it seems questionable whether the difference between ED- and ID-shifts is still relevant for the statement that Parkinson patients have problems with shifting (TTS). For, we find that Parkinson patients have no problems with abandoning the previous relevant rule in both ED- and ID-shifts.

Finally we will discuss the subjects that were not able to perform the discrimination task and were excluded from the experimental group. Twelve subjects dropped out: 1 control and 11 Parkinson patients. The drop-outs did not differ from the Parkinson patients that completed the task, with respect to education and the number of months during which the patients used medication for Parkinson's disease. The average age of the subjects that dropped out was higher than the experimental Parkinson patients: respectively 70.2 and 59.8 years. All subjects were given three neuropsychological tests: Trailmaking-A test, 5-words memory test and a Word Fluency test. The drop-outs performed worse on the Trailmaking-A test than the Parkinson group. Besides, memory was worse as measured with a word list, with regard to learning and especially recognition. No difference in the number of words in the categories animals and occupations of the Word Fluency test was found. The number of problems presented to the subjects that dropped out ranged from one to seven problems. The mean TTC for the drop-outs was much higher (mean TTC = 38.0) than for the experimental Parkinson group (mean TTC = 12.8).

These results indicate that the drop-outs generally performed worse than the experimental group. By excluding this group we may have underestimated the problems of Parkinson patients.

Taken together, this study suggests, in agreement with the literature, that Parkinson patients need more trials to solve a problem. The most important finding is that Parkinson patients do not hold on longer to the previous relevant rule than controls do. Low scores on so called shift tasks are not due to a selective shift problem.

REFERENCES

Bakker, C. 1989. *The cognitive problems with parkinson's disease.* Unpublished master's thesis, in Dutch, Catholic University of Nijmegen, The Netherlands.

Bowen, F. P., Kamienny, R. S., Burns, M. M., & Yarhr, M. D. 1975. Parkinsonism: effects of levodopa treatment on concept formation. *Neurology,* **25,** 701–704.

Brown, R. G., & Marsden, C. D. 1988. Internal versus external cues and the control of attention in Parkinson's disease. *Brain,* **111,** 323–345.

Brown, R. G., & Marsden, C. D. 1991. Dual task performance and processing resources in normal subjects and patients with Parkinson's disease. *Brain,* **114,** 215–231.

Coenders, C. J. H., Kerbusch, J. M. L., Vossen, J. M. H., & Cools, A. R. 1992. Problem solving behaviour in apmorphine-susceptible and unsusceptible rats. *Physiology and Behavior*, **52**, 321–326.

Cools, A., Bercken, J. van den, Horstink, M., Spaendonck, K. van, & Berger, H. 1984. Cognitive and motor shifting aptitude disorder in Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry*, **47**, 443–453.

Downes, J. J., Roberts, A. C., Sahakian, B. J., Evenden, J. L., Morris, R. G., & Robbins, T. W. 1989. Impaired extra-dimensional shift performance in medicated and unmedicated Parkinson's disease: Evidence for a specific attentional dysfunction. *Neuropsychologia*, **27**, 1329–1343.

Eimas, P. D. 1966. Effects of overtraining and age on intradimensional and extradimensional shifts in children. *Journal of Experimental Child Psychology*, **3**, 348–355.

Flowers, K. A., & Robertson, C. 1985. The effect of Parkinson's disease on the ability to maintain a mental set. *Journal of Neurology, Neurosurgery and Psychiatry*, **48**, 517–529.

Grant, D. A., & Cost, J. R. 1954. Continuities and discontinuities in conceptual behavior in a card sorting problem. *Journal of General Psychology*, **50**, 237–244.

Gotham, A. M., Brown, R. G., & Marsden, C. D. 1988. "Frontal" cognitive function in patients with Parkinson's disease "on" and "off" levodopa. *Brain*, **111**, 299–321.

Heitanen, M., & Teräväinen, H. 1986. Cognitive performance in early Parkinson's disease. *Acta Neurologica Scandinavica*, **72**(2), 151–159.

Lachman, R., & Sanders, J. A. 1963. Concept shifts and verbal behavior. *Journal of Experimental Psychology*, **65**, 22–29.

Lees, A. J., & Smith, E. 1983. Cognitive deficits in the early stages of Parkinson's disease. *Brain*, **106**, 257–270.

Levine, M. 1975. Human discrimination learning: the subset sampling assumption (reading no. 17). In M. Levine (Ed.), *A cognitive theory of learning: Research on hypotheses testing*. Hillsdale, NJ: Erlbaum. Pp. 213–220.

Levine, M., Gholson, B., & Phillips, S. 1975. Hypotheses, strategies, and stereotypes in discrimination learning (reading no. 18). In M. Levine (Ed.), *A cognitive theory of learning: Research on hypotheses testing*. Hillsdale, NJ: Erlbaum. Pp. 225–243.

Ludvigson, H. W., & Caul, W. F. 1964. Relative effect of overlearning on reversal and nonreversal shifts with two and four sorting categories. *Journal of Experimental Psychology*, **68**, 301–306.

Milner, B. 1963. Effects of different brain lesions on card-sorting: the role of the frontal lobes. *Archives of Neurology*, **9**, 90–100.

Nelson, H. E. 1976. A modified card sorting test sensitive to frontal lobe defects. *Cortex*, **12**, 313–324.

Roberts, A. C., Robbins, T. W., & Everitt, B. J. 1988. The effects of intradimensional and extradimensional shifts on visual discrimination learning in humans and non-human primates. *Quarterly Journal of Experimental Psychology*, **40B**(4), 321–341.

Sharpe, M. H. 1990. Patients with early Parkinson's disease are not impaired on spatial orientating of attention. *Cortex*, **26**, 515–524.

Shepp, B. E., & Eimas, P. D. 1964. Intradimensional and extradimensional shifts in the rat. *Journal of Comparative and Physiological Psychology*, **57**, 357–361.

Slamecka, N. J. 1968. A methodological analyses of shift paradigms in human discrimination learning. *Psychological Bulletin*, **69**, 423–438.

Stevenson, H. W., & Moushegian, G. 1956. The effect of instructions and degree of training on shifts of discriminative responses. *American Journal of Psychology*, 281–284.

Taylor, A. E., Saint-cyr, J. A., & Lang, A. E. 1986. Frontal lobe dysfunction in Parkinson's disease: the cortical focus of neostriatal outflow. *Brain*, **109**, 845–883.

Taylor, A. E., Saint-cyr, J. A., & Lang, A. E. 1987. Parkinson's disease: cognitive changes in relation to treatment response. *Brain*, **110**, 35–51.