The Drawing of Angular Figures in Parkinson’s Disease Patients: Preliminary Report

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Abstract. Results from a pilot study on drawing behavior in PD patients are reported below. Subjects were asked to copy angular patterns made of 2 or 3 segments of different lengths, showing either acute or obtuse angles. Their drawing behavior was recorded using a digitizer, and compared to performance obtained from age-matched control subjects. In comparison to controls, PD patients performed their drawings much slower, with longer pauses at the angles, and produced more copying errors. These errors mainly indicated a tendency to avoid some movement directions in favor of others corresponding to more fluent movements according to the literature. Facilitating effects in the drawing of acute patterns as compared to obtuse patterns were shown in both groups, but they were most evident for the 2-segment-patterns in PD patients. Interesting information was also provided by an analysis of axial pressure in PD subjects. It is suggested that the present preliminary data provide support to the hypothesis that PD subjects encounter particular difficulties in mobilizing or activating different effectors, either in parallel or in sequence, and particular impairments in force adjustments.

1. Introduction

Parkinson’s disease (PD) is a neurodegenerative disease involving impairments of basal ganglia functions, primarily caused by pharmacological deficiencies, among which a dysfunctions of the dopaminergic system appears to be most critical for the disease. PD is clinically characterized by the presence of symptoms, such as a global motor slowness (« akinesia »), as well as, more specifically, a slowness of voluntary movement, « bradykinesia ». The presence of a resting tremor and of a rigidity of the musculature can also be noted. These symptoms have been shown to affect the motor functions linked to drawing and handwriting behavior. In relation to handwriting, a noticeable effect of PD on performance results in « micrographia », a more or less important reduction in size of handwriting patterns, but this symptom is not frequently associated with the disease (around 12% of cases according to McLennan, Nakoma, Tyler & Schwab, 1972). Several authors also stated that PD leads to some specific cognitive deficits, in particular with regard to recall memory and to executive functions of higher order (Pilon, Dubois, Ploska
& Agid, 1991; Rogers, Lees, Smith, Trimble & Stern, 1987; Canavan, Passingham, Marsden, Quinn, Wyke & Polkey, 1989). However, opinion in this domain asserts that these cognitive deficits may be due to a dysfunctioning of the frontal lobes, in consequence of the degenerations of some subcortical subcortical-cortical connections (Taylor, Saint-Cyr & Lang, 1986).

A scientific investigation of motor organization in PD patients appears useful from different points of view, which extend largely beyond the scope of a better understanding of the disease in its own right. For researchers in neuroscience, the study of motor functions in PD patients provides valuable information about the contribution of basal ganglia structures in the planning and execution of movement in humans (Stelmach, 1991). For clinicians, quantitative and reproducible measurements of motor parameters in these patients may be helpful from a rehabilitative point of view, and also for an assessment of the effects of drug therapy on their behavior.

What are the motor parameters affected by PD, particularly in relation to drawing and handwriting? A general slowness of writing or drawing velocities in Parkinsonians as compared to age-matched controls is frequently reported in the literature (for a review, see Stelmach, 1991; Phillips & Stelmach, 1991). These patients generally show longer movement preparation times than controls do, in a handwriting task (Phillips, Müller & Stelmach, 1989a) as well as on simple RT tasks (Goodrich, Henderson & Kennard, 1989). With respect to handwriting, Margolin and Wing (1983) have shown that these patients tended to progressively decrease their letter height and writing velocity as a function of the length of the sequence to be written, i.e. as they progressed through the sequence. Nevertheless, upon request and within certain limits, Parkinsonians have been shown to be able to increase writing sizes (Teulings & Stelmach, 1991a), but it appears more difficult to train these subjects to speed up their movement than to achieve larger writing strokes (Phillips, Stelmach & Teasdale, 1989b). As highlighted by Teulings and Stelmach (1992), it is therefore unlikely that PD patients write slowly because they aim at producing an acceptable writing size, as suggested by Margolin and Wing (1983). Even though both force timing and force amplitude are perturbed in Parkinsonians, Teulings and Stelmach (1992) concluded that the impairment in the control of force amplitude is stronger than the deficits in force timing. This seems to be the case especially when the production of short force bursts is required, as it is the case in handwriting movements, where patients demonstrate particular difficulty in scaling the magnitude of force as a function of stroke length (Stelmach & Castiello, 1992).

A task variable which provides insights in respect to the deficits of fine motor abilities in PD patients is related to the production of sequences of movements, as appear in most tasks that request the production of movements in parallel. Impairments in performance emerge as soon as these patients are required to link together several movements units, either in sequence or in parallel. In prehension studies for example, it has been shown that the hand opening phase was slightly temporally uncoupled with the limb transport phase, a greater delay between both phases being recorded in PD subjects than in controls (Zackon, 1989, see Castiello, Bennett & Scarpa, 1994, for a more recent view on this question). Drawing behavior also reveals a difficulty in the execution of consecutive movement segments: longer pauses at the vertices of geometric figures have been produced by Parkinsonians (Berardelli, Accornero, Argenta, Meco & Manfredi, 1986), and a similar result has been reported for schizophrenic patients (Auff & Schnabel, 1991). Deficits in coupling of movements to produce a series of movements (such as licking the tip of a pen with the index finger and vice versa) (Phillips & Silverman, 1989).

As pointed out in a previous study (Lacquaniti, Ferriglio, 1992) have suggested that the production of movements may be regulated by a mechanism that involves a sequential arrangement of muscle contractions. The above hypothesis has been tested by Thomassen (1991) and further extended by van Doorn, Post, Hamers, and De Graaf (1994). The results of this study indicate that PD patients are able to produce movement sequences consisting of two or more movements, but they fail to produce complex sequences involving three or more movements. This finding is consistent with the hypothesis that PD patients have difficulty in the planning and execution of a large number of sequential movements. The results also suggest that PD patients may have difficulty in learning new movement sequences, as their performance on the task is significantly worse than that of controls. In conclusion, the present study provides evidence for a deficit in the planning and execution of sequential movements in PD patients.
result has been reported for the execution of other sequential skills (Goldenberg, Wimmer, Auff & Schnabeth, 1986). Handwriting studies equally lead to the conclusion that a special deficit in coupling different motor programs within the same limb exists in PD. When asked to produce a series of letter strings such as ‘elele’ in cursive script, Parkinsonians show difficulties in coping with the changes in force amplitude required by the switch from ‘e’ to ‘1’ and vice-versa because of the differences in the length of the strokes forming the letters (Phillips & Stelmac, 1991).

As pointed out by Teulings and Stelmac (1992), a crucial deficit in PD motor functioning may be seen in the production of movements that involve a coactivation of several components in parallel. Flash, Henis, Inzelberg and Korczyn (1992) reported that in motor tasks requiring multi-joint movements, Parkinsonians tended to finish one movement before executing the following one, as if they attempted to avoid superimposing different movement units. As soon as movement amplitude increases in handwriting, the participation of several muscles and joints are needed in order to perform the movements (Laqueanit, Ferrigo, Pedotti, Soechting & Terzuolo, 1987). Teulings and Stelmac (1992) have suggested that micrographia may result from a tendency to employ a reduced number of muscle and joint systems in parallel. Incidentally, it is the case that, if only fingers and wrist joints are recruited, writing size becomes smaller.

The above hypothesis is particularly useful to an investigation of drawing behavior in PD. In an attempt to account for stroke direction preferences in handwriting, Meulenbroek and Thomassen (1991) provided a simplified anatomical description of the production of movement directions, showing that some directions require a combination of several joints, while others do not. More precisely, it appeared that oblique directions were the simplest directions to perform from a motor point of view, as they involved only one effector, either the fingers or the wrist. Vertical and horizontal directions required the participation of both effectors, moving either congruently (verticals) or incongruently (horizontals). Clearly this anatomical description is dependent upon movement amplitude, and is valid for small amplitudes like those present in normal handwriting. The interesting point that emerged from this analysis is that PD patients may encounter special difficulties in the production of some movement directions, those which involve a co-activation of several joint systems. Teulings and collaborators (this volume) effectively showed that, in the production of back and forth movements, stroke directions mobilizing more than one effector were performed with highly dysfluent movements in Parkinsonians when compared to controls.

In the same vein, the study of the production of angular figures in PD patients seems very interesting for several reasons. Firstly, an angular figure is composed of 2 or more concatenated segments which may be a combination of obliques, verticals and horizontal. Secondly, the drawing of angular figures has already been investigated in normal subjects and has revealed interesting effects with regard to the difference between the drawing of acute and obtuse angles (Meulenbroek & Thomassen, 1993; Desbiez, Vinter & Meulenborek, 1996). Under speed constraints, subjects draw acute angles without producing pauses at the angle, whereas pauses are systematically observed for obtuse angles. Furthermore, normal subjects tend to lengthen the size of the segment leading up to an acute angle, while no similar size deformation is observed for the segment leading to an obtuse angle. Meulenbroek and Thomassen (1993) suggested that the graphic production of acute angles reveals a capacity of subjects to exploit biomechanical properties such as
muscular elasticity in movement execution. Desbiez, Vinter and Meulenbroek (this volume) showed that the ability to take advantage of such a biomechanical property depends on several contextual factors, among which it is interesting to highlight the role played by movement amplitude.

The present pilot study aimed at comparing PD patients to elderly control subjects in a drawing task of angular figures. Because of their motor slowness, PD patients were expected to produce longer pauses at the angles than controls, but a facilitating effect of the drawing of acute angles could nevertheless be observed in these patients. Differences between the drawing of acute or obtuse patterns may also have been dependent on the type of segments which constituted the patterns. Particular difficulties could have been expected from PD patients when they were required to draw segments involving a co-activation of several joints, with longer pause durations at angles followed by such type of segments.

2. Method

2.1 Subjects

Two groups of subjects participated in the study. The first group consisted of 4 right-handed adults (2 males and 2 females) with idiopathic Parkinson’s disease (age range: 69 to 83 years; onset of PD diagnosis: 3 to 18 years). Data from 3 other patients could not be analyzed (they produced too many errors in figure copying), and data from a young patient (49 years) was not included in the present study, because the patient was too divergent from those of the other patients. The patients were tested at the Hospital of Dijon. They were under medication, and measurements were made when no resting tremor in their upper limb was detectable. The second group was made of 6 right-handed elderly subjects (2 males and 4 females) who did not present any signs of neurological or psychological disturbances (age range: 64 to 76 years). These subjects were tested at home.

2.2 Apparatus

Subjects drew on a white sheet of paper (format A4) fixed on a digitizer (Calcomp Drawingboard), with a special pen measuring axial pressure (Teulings & Maarse, 1984). Movements were sampled at a frequency of 100 Hz, with a spatial accuracy of 0.2 mm. The subject’s forearm rested on the digitizer when drawing. Pen-tip displacements were low-pass filtered (transition band between 12 and 24 Hz), and were analyzed off-line by means of an interactive program (Teulings & Maarse, 1984). Individual drawing segments corresponding to those of the models were segmented by selecting time points at successive velocity minima corresponding to sharp changes of direction from up to down. Different kinematic variables were computed for each segment. Pauses at angles were defined as any time interval between two consecutive segments of which duration exceeded 10 msec, and during which velocity was lower than 1 cm/sec.

2.3 Models and procedure

Subjects had to copy models drawn in black ink in squares of 3x3 cm in identical squares located immediately below the models (see Fig. 1, first row in each example). Twelve models per sheet, subjects (the bottom-right were told to p it were the us always aligned subjects to such a way movements p their posture. Subjects v well as draw the patterns v and size. Fa requirement segments, fo obtuse (see correspondi patterns; 0.2 cm, 1 cm, 1 were within models we obt angles; sma by subject v When pe the followi segment at.

3. Results

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controls, F(1,8) = 9.55, p < .01; 2nd angle: 665 ms for PD subjects, 210 ms for controls, F(1,8) = 11.95, p < .008). Concerning pause duration at the first angle, a complex Group x Angle x Pattern interaction was significant (F(1,8) = 5.726, p < .04). In control subjects, pauses lasted longer at obtuse angles than at acute angles, regardless of the number of segments of the pattern. In PD subjects, the 2-segment-acute pattern elicited shorter pauses than the other patterns did, but, unexpectedly, pauses were the highest for the 3-segment-acute pattern, and not for the obtuse patterns. It is worth pointing out that the 2-segment-acute pattern is the only one which can be executed in an almost back-and-forth oblique movement, i.e. without any modification in the system of muscle or joint elicited. However, the 3-segment-pattern, either acute or obtuse, involves a sequence of oblique-vertical-oblique, but, considering the selected sequencing of the movement, in one case (the acute pattern), the drawing of the oblique and the drawing of the vertical both require a flexion of the effectors, while in the other case (the acute pattern), the drawing of the oblique involves an extension, followed by a flexion for the vertical. This incongruent coordination of movements may be difficult enough for PD subjects to cancel the potential facilitating effect of drawing an acute angle compared to an obtuse one.

Thus, as expected, pause durations provide some interesting information about the differences between PD patients and controls in a drawing task of angular figures. It has been confirmed that Parkinsonians produce longer pauses at angles than age-matched subjects, and a facilitating effect may be suspected for the drawing of the simplest acute pattern in these patients.

3.3 Pattern length and velocity

A global examination of pattern lengths revealed that PD patients drew patterns with a slightly smaller size than controls (1.05 cm against 1.20 cm for the 2-segment-patterns, .72 cm against .84 cm for the 3-segment-patterns). The difference was not however statistically significant, though the probability level was near an acceptable level for the 3-segment-pattern (p = .111). No other effect differentiated the Parkinsonian group from the control group with respect to length production. In particular, no length decrement as a function of the progression through the drawing in PD patients, was observed.

In both groups, interesting effects of angle and size may be worth mentioning. Acute patterns were drawn with larger lengths than obtuse patterns, but a significant interaction occurred with pattern size, for the 2-segment-pattern as well as for the 3-segment-one. Figure 3 illustrates these interactions.

To make easier the reading of the figure, it is worth recalling the model lengths corresponded to the different patterns copied by the subjects: 2-segment-pattern (small = 0.30 cm, medium = 1 cm, large = 1.5 cm), 3-segment-pattern (small = 0.33 cm, medium = 0.66 cm, large = 1.16 cm). Compared to the models, sizes of small patterns were largely underestimated, those of large patterns were underestimated, and those of medium patterns were the most precise, though still underestimated. This phenomenon of « regression to the mean » is quite classical in psychophysics, and testifies for perceptual effects on drawing activity. Figure 3 also shows that medium and large acute patterns were drawn with longer lengths than obtuse patterns of similar sizes, a result similar to those reported in the literature (Meulebroek & Thomassen, 1993; Desbies, et al., this volume), but not small
acute patterns, which were drawn as long as obtuse ones. Yet, obtuse patterns are perceived longer than acute patterns, because of a somewhat illusory effect similar to the Muller-Lyer illusion. Velocity is probably the key parameter for an understanding of these results: if velocity is too low, no benefit of drawing acute patterns can occur, and consequently, in terms of length, no difference with obtuse patterns emerges. It would be the case for small patterns, because of a natural trade-off between length and velocity. As soon as velocity increases, the lengths of segments leading up to acute angles would be overestimated, despite perceptual effects acting in favor of obtuse patterns. A brief report of results regarding velocity seems consequently necessary.

![Figure 3. Mean segment length (in cm) as a function of pattern, angle and size.](image)

PD patients performed significantly more slowly than age-matched controls, for the drawing of 2-segment-patterns ($F(1,8) = 20.57, p < .002$) as well as for the drawing of 3-segment-patterns ($F(1,8) = 21.78, p < .002$). For the entire set of observations, mean tangential velocities ranged between 0.66 to 3.47 cm/sec in PD patients, and between 2.28 to 7.58 cm/sec for control subjects. However despite the fact that PD patients constantly drew slower than controls, no other clear differences emerged between both types of subjects with regard to velocity as a function of the figure’s characteristics. Both drew acute patterns faster than obtuse patterns (in average, across the groups, 2.34 cm/sec for acute patterns against 1.93 cm/sec for obtuse ones), and the highest peak of tangential velocity was observed for the simplest acute pattern (2-seg). However, only medium and large acute patterns were produced with higher peaks of velocities than obtuse figures of similar sizes. Small patterns were drawn at a similar rate, regardless of whether they were acute or obtuse (the interaction between Size and pattern was significant, for the 2-segment-pattern, ($p < .04$), as well as for the 3-segment-pattern, ($p < .03$)). This result confirms that length differences between acute and obtuse patterns are induced by differences in velocities.

3.4 Axial pressure

Insofar as axial pressure exerted on the moving pen may be considered an indicator of forces applied during movement, it appears interesting to compare PD subjects to age-
matched controls on this variable. Reduced axial pressure can be expected from PD subjects because of their impairment in force regulation.

As a matter of fact, whether they drew 2-segment-patterns (F(1,9) = 12.91, p < .005) or 3-segment-patterns (F(1,9) = 18.41, p < .002), PD subjects exerted a much lower axial pressure than age-matched controls (2-seg: 84.52 g on average against 354 g for controls; 3-seg: 84.33 against 387, 56 g). But more interesting, the ANOVAs revealed a significant Group x Segment interaction, as illustrated by Figure 4 for both the 2-segment-patterns (F(1,9) = 12.39, p < .006) and the 3-segment-pattern (F(2,18) = 15.29, p < .0001).

![Figure 4](image)

Figure 4. Mean axial pressure (in gr.) as a function of group, pattern and segment.

Figure 4 shows that, whereas in control subjects, pressure increased as a function of the segment, that is as a function of task progression, Parkinsonian patients did not modulate pressure through the task. They rather tended to use low and homogeneous forces all along the drawing task.

4. Discussion

A simple drawing task such as the one studied in the present experiment, the drawing of acute and obtuse patterns made of 2 or 3 segments, proves itself to be interesting for an understanding of drawing behavior in PD patients. In comparison to age-matched control subjects, PD patients performed their drawings much more slowly, with longer pauses at the angles. Similar results have been reported in the literature (Berardelli, et al., 1986). Thus impairments in drawing performance are observed in these subjects when the task requires linking sequentially two or three segments. To get an understanding of what may reveal pause duration at angles in Parkinsonians, it would be appropriate to compare a tracing task (tracing over the model) and an «evocation» task (copying the model in its absence) to the copying task used in the present experiment. Planning would be reduced in the tracing task, but increased in the evocation task in comparison to the copying task, and thus may be helpful to understand to what extent pause duration at angles reflects difficulties in planning and/or in executive processes. However, while age-matched control subjects spent more time at angles of obtuse patterns than of acute ones, which is in agreement with results reported in the literature (Meulenbroek & Thomassen, 1991; Desbiez, et al., 1996), similar behavior was observed only for the drawing of the 2-
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segment-pattern in PD subjects. We suggested that the structure of the 3-segment-acute pattern, requiring an incongruent sequence of movements, prevented from a potential facilitating effect for movement, induced by acute angles.

PD patients also showed a tendency to produce drawings of slightly smaller sizes, but no behavior close to micrographia in handwriting, such as a decrease in movement amplitude during the course of drawing, was observed. However, because micrographia does not seem to be such a frequent symptom in PD (McLennan et al., 1972), it would be necessary to differentiate patients showing this deficit from patients without this impairment before forming conclusions on the relationship between handwriting and drawing with regard to length production. In our drawing task, more copying errors were produced by PD patients, and these errors mainly indicated a tendency to avoid some movement directions, in favor of others which corresponded to more fluent movements according to results reported by (Teulings, Contreras & Stelmach, 1995). Facilitating effects in the drawing of acute patterns as compared to obtuse patterns were shown in both groups, but they were most evident for the 2-segment-patterns in PD patients.

Finally, PD subjects largely differed from age-matched controls with regard to axial pressure. Not only was pressure much lower in PD subjects, which may attest for their impairment in force adjustment, but more interesting, pressure was insensitive to task progression, while in normal subjects, pressure is known to increase as a function of task progression (Kao, 1983; Kao, Hong & Wah, 1986). Several experiments have shown that in handwriting for instance, pressure tends to increase at the end of the letter (Freeman, 1914), at the end of the word (Denier Van der Gon & Thüring, 1965; Van der Plaat & Van Galen, 1990), at the end of the sentence (Maarse, Schomaker & Teulings, 1986). Kao et al. (1986) suggested that higher pen pressures at the end of the task might reflect an increasing use of feedback in the monitoring of movement. According to Van der Plaat and Van Galen (1990), it may also revealed that subjects used the force exerted on the pen as a «brake» for movement. Our results showed that PD subjects were unable to modulate pressure, i.e. to modulate forces in the course of movement. Because velocity was also very low in Parkinsonians, using axial pressure as a «brake» at the end of movement was probably not necessary for these subjects.

Thus, either in terms of errors, pause duration or velocity, performances recorded for the drawing of acute patterns were better than for the drawing of obtuse patterns in PD patients, if only the 2-segment-pattern was considered. Because of the very low speed adopted by these subjects in the task, it is hard to suggest that facilitating effects of acute angles may in some way reveal phenomena similar to those observed in young normal subjects, such as a capacity to exploit bielasticity (Meulenbroek & Thomassen, 1993; Desbiez et al., 1996). But it can be sustained that as acute angles elicit movements approaching back-and-forth movements, they can be drawn at higher velocities than obtuse angles, and consequently with shorter pauses at angles. However, we saw that this pattern of results did not hold any more for the 3-segment-acute pattern in PD subjects. The present preliminary empirical data may provide support to the hypothesis that PD subjects encounter particular difficulties in mobilizing or activating different effectors, either in parallel or in sequence. As a matter of fact, the 2-segment-acute pattern required a drawing movement close to a back-and-forth movement along an oblique axis oriented in a preferred direction (2-8 o'clock). This movement may be performed activating only the
wrist joint system. By contrast, the 3-segment-acute pattern includes a vertical segment, i.e., a segment of which execution requires both the fingers and wrist joints' systems according to Meulenbroek and Thomassen (1991), and also this pattern involves an incongruent sequence of movements. In this perspective, a systematic investigation of drawing different types of segments (oblique, horizontal, vertical) of various sizes, in different movement directions, and concatenating different orientations, seems promising, and actually provides most interesting results (see Teulings et al., this volume). PD patients seem to experience strong difficulties when coordination requirements are high in the drawing task, which may cause them to avoid the superimposition of different movement units.

References


