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Comparisons of Fine Motor Functions in Subjects with Parkinson's Disease and Essential Tremor

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***Abstract*—**This study explores the clinical features of neurodegenerative disease patients with tremor. We study the motor impairments in patients with Parkinson's disease (PD) and essential tremor (ET). Since uncertainty exists on whether Parkinson's disease (PD) and essential tremor (ET) patients have similar degree of impairment during motor tasks, this study based on the self-developed computerized handwriting movement analysis to characterize motor functions of these two impairments. The recruited subjects were diagnosed and confirmed one of neurodegenerative diseases. They were undergone general clinical evaluations by physicians in the first year. We recruited 8 participants with PD and 10 with ET. Additional 12 participants without any neuromuscular dysfunction were recruited as control group. This study used fine motor control of penmanship on digital tablet for sensorimotor function tests. The movement speed in PD/ET group is found significant slower than subjects in normal control group. In movement intensity and speed, the result found subject with ET has similar clinical feature with PD subjects. The ET group shows smaller and slower movements than control group but not to the same extent as PD group. The results of this study contribute to the early screening and detection of diseases and the evaluation of disease progression.

***Keywords*—**Parkinson's disease, essential tremor, motor function, fine motor movement, computerized handwriting evaluation.

I. Introduction

BRADYKINESIA, rigidity, resting tremor and poor posture control are general clinical features in Parkinson's disease (PD). In addition, flexed posture and freezing (motor blocks) have been included among classic features of parkinsonism, with PD as the most common form. Because of the diverse profiles and lifestyles of those affected by PD, motor and non-motor impairments should be evaluated in the context of each patient's needs and goals.

Essential tremor (ET), a similarly progressive neurologic disease, is among the most prevalent movement disorders [1]. Slower progression and less impairment in function can be noted on patients with ET. However, uncertainty exists on whether Parkinson's disease (PD) and essential tremor (ET) patients have similar degree of impairment during motor tasks.

The clinical differential diagnosis between PD and ET is relatively simple in most patients. However, up to 10% of PD patients are misdiagnosed with ET and vice versa [2]. There is a continuing debate as to whether ET is potentially reversible disorder of tremorogenic neuronal oscillation [3] or a more complex and phenotypically heterogeneous degenerative disorder, possibly related to other neurologic diseases, including Alzheimer disease, Parkinson's disease (PD), and dystonia [4].

Few neurophysiological studies have assessed the problem from the perspective of movement analysis in ET and PD. Some studies found no difference in the movement time for repetitive wrist or upper-limb movements between ET patients and healthy subjects [5], [6] whereas others, using different movement paradigms of the fingers, wrist, or upper-limb, reported motor performance levels in ET patients comparable to those of PD [7], [8] and different from healthy controls, suggesting the presence of some degree of bradykinesia in ET [9]-[11].

Several epidemiological studies reported a higher likelihood of PD patients to have ET in comparison to healthy controls and to patients with other diseases presenting with a parkinsonian syndrome [12]-[14]. In ET, rigidity, bradykinesia, and also postural instability may accompany postural tremor [15]. Besides tremor, these features contribute to the impairment of movement performance in ET patients. Also, action tremor may occur in PD not only in advanced stages but can also impair the performance of slow alternating movements at early PD stages [16]. Both PD and ET patients may exhibit slowness of motor initiation and execution, as well as disrupted time-constraint behaviors, such as in the performance of repetitive rhythmic movements [17], [18].

In addition to tremor, PD and ET have different characteristics in fine movement control. To enhance our understanding on the mechanisms leading to impairment of movement performance in PD and ET patients, we have performed a series of dynamic analysis of fine motor movements. Our overarching goal is to characterize the motor deficits in PD and ET.

II. Methods

A. Subjects Recruitment and Confirmed Diagnosis

In this study, subjects were undergone an evaluation by a neurologist and complete a standardized neurological work-up. A detailed history and interview with the patient and informant, neurological and physical examinations were performed as part of the initial visit. For the recruitment of subjects with PD, all the recruited subjects met the following inclusion criteria: adult-onset (>40 years) of asymmetric arm tremor with a rest component; a previous clinical diagnosis of PD made by their physician or neurologist. Patients who had possible other

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causes for their asymmetric rest tremor (psychogenic tremor, neuropathic tremor, use of medication associated with drug-induced tremor/parkinsonism) were excluded. Eight participants with PD and ten with ET were identified and recruited into this study. Twelve normal elderly were also recruited as control group. All diagnoses and clinical evaluations were assigned by neurologists.

B. Instruments and Apparatus

In the computerized drawing and handwriting tests, a digital tablet was used to collect the trace and temporal data of handwriting movement for kinematic and kinetic analyses. The drawing and handwriting tasks were performed on an A4 size paper affixed to the surface of a 2-D digitizing tablet (623 x 429 x 36mm, Wacom, Intuos 3, Japan) using a wireless electronic inked pen with force sensitive tip (1024 levels). The digital tablet samples the X (horizontal) and Y (vertical) positions of the pen tip as well as the axial pen force, with a sampling frequency of 200 Hz, a spatial accuracy of .01cm, and a temporal accuracy of 1ms. The top panel of the tablet is an electronic surface that records the position only when the pen comes in contact with its surface or within 10mm of its surface. The pen used in this study is of a size and weight similar to that of pens typically used in writing (length = 150mm, circumference = 35mm, weight = 11gm).

C. Geometric Graph Tasks

In this study, the geographic drawing tasks have two figure patterns for fine motor test. It includes (a) a circle and (b) 4 different-sized circles with an identical center. The diameter of the circle in (a) is 5cm. The diameter of the largest circle in (b) is 5cm. With a 5mm decrement, there are four circles with an identical origin. For curvature stroke tests, '*llll*' tasks and a row of circles were chosen for test the 2/3 power law in elderly handwriting movement control (Fig. 1).

After surveying the results of related researches and the results and experiences of our previous studies, the parameters were obtained directly from the temporal and spatial data of the pen-tip movement. The parameters include (1) stroke trajectory length and (b) mean stroke velocity.

D. Fitt's Paradigm

In the second part, Fitt's paradigm will be designed on a digital tablet for examining the fine motor skills of the participants. Three levels of complexity will be designed by using three sets of circles with 2.2, 4.4, and 8.8mm in diameter. The distance of the paired circles was fixed in a length of 25mm (Fig. 2). In addition to the task complexity, there are two testing paradigms with a crossover procedure. One is discrete type with 20 separated movements in every task complexity. The other is continuous type with a series of consecutive movements in every task complexity. The first one is used to examine the performance of closed-loop control. The later one is used to examine the performance of open-loop control.

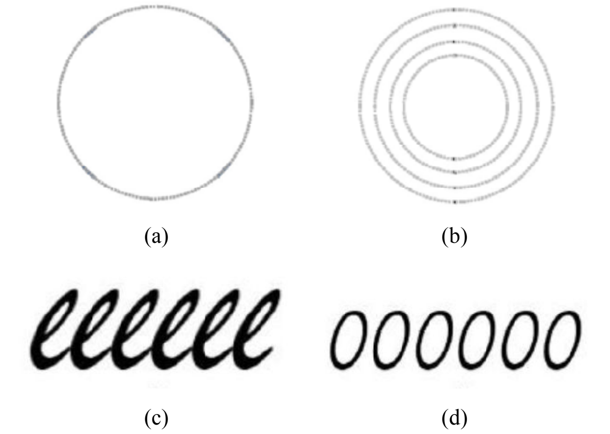

Fig. 1 (a) A circle and (b) four different-sized circles with an identical center (c) continuous strokes with various curvatures (d) slanted circles for discrete curvature figures

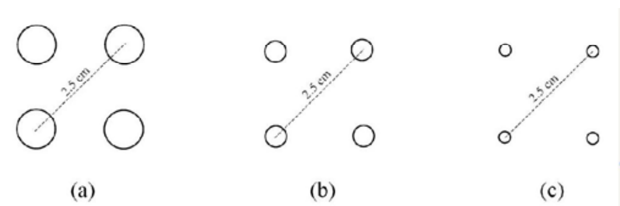

Fig. 2 In every test sheet, 4 circles with different diameters are depicted in a fixed diagonal distance of 25mm. The diameter of the three circles is (a) 8.8, (b) 4.4, and (c) 2.2mm

E. Statistical Analyses

If MANOVA analyses were used to test for the group differences across tasks in parameters of motor control. To examine the source of the significant differences between groups, the data from each task were subjected to univariate ANOVAs. Post hoc tests were utilized to compare the difference among the control, ET and PD subjects. The analysis was made using SPSS statistical software (version 12, 2002). The variables endpoint error and movement time were modeled using a normal distribution to represent the random error component, whereas trajectory length ratio will assumed to be Gamma distributed.

III. Results and Discussions

A. Single Geometric Graph Tasks

1. Circle

In circle task, as shown on Fig. 1 and Table I, there is no significance among three groups in task size (p>0.05). However, there is significant difference between CN and PD in mean speed (p<0.05).

2. Concentric Circles with Different Radius

In concentric circle task, as shown on Fig. 3 and Table I, significant difference was found among three groups in task size and mean speed (p<0.01). There is significant difference between CN and PD group in trace length and mean speed (p<0.01).

TABLE I
RESULTS OF SINGLE GEOMETRIC GRAPHS

	Mean trajectory length (cm)		Mean speed (mm/s)	
	Single circle	Concentric circles	Single circle	Concentric circles
PD	10.8 (1.6)	28.2 (8.7)	22.2(4.5)	12.3(3.4)
ET	11.5 (1.8)	38.4 (10.2)	17(3.5)	15.3(4.2)
CN	13.2 (1.9)	39.9 (11.1)	27(4.3)	26(7.4)
Sig	$p>0.05$	$p<.05$	$p<.01$	$p<.01$

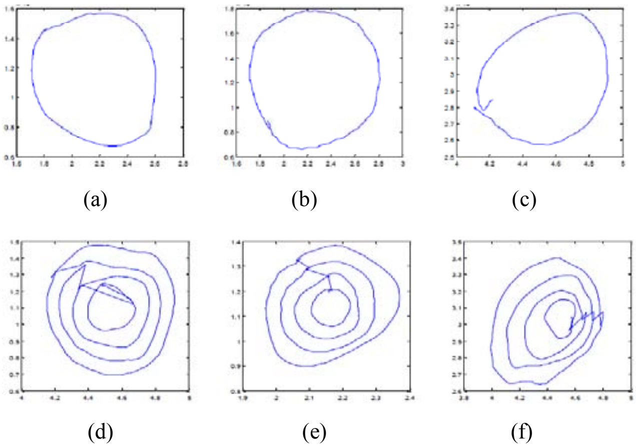

Fig. 3 Single circle (upper) and concentric circles (lower). (a), (d) cn, (b), (e) et, (c), (f) pd

B. Horizontal Geometric Graph Tasks

1. ‘*lllll*’ Tasks

‘*lllll*’ tasks are commonly used in computerized handwriting movement analysis. From Fig. 4, ET and PD groups have the same trend in the shift of the trace in a right upper way. This finding is important since only this task showed significant difference between CN and PD/ET groups.

In continuous ‘*lllll*’ tasks, subjects in ET/PD group tend to shift the trace to right upper. According to 2/3 power law, early studies by Viviani and Terzuolo (1980, 1982) on handwriting and drawing movements observed that there is a systematic relationship between the velocity of the end-effector trajectory and the geometric path that it describes [19]. This observation was quantified by Lacquaniti et al. (1983) as the "2/3 power law" [20].

From the results, subjects in PD group are difficult to maintain a speed large enough to form a curve with a radius large enough to the bottom of the trace. The curve with shorter radius turns the trace to form another circle composed of the whole trace.

2. A Row of Circles

As shown on Fig. 4, circles also shift to right upper. The 2/3 power law seems not able to interpret this phenomenon. It is probably that lack of forearm movement leads the wrist and finger movement toward right upper. The whole handwriting movement pivots on the wrist joint. This is also an indicative task for classifying control and pathological conditions.

C. Fitt's Tasks

In Fitt's task, as shown on Fig. 5 and Table II, the PD group show least accuracy to point directly into the target. More than 90 % of accuracy in control group was reached in control group. Less than 70 % of accuracy was found in PD group to point correctly in the largest task. In pen movement analysis, Table II shows significant differences among the three groups. The PD and ET groups showed slower movements in all the tests than the CN group.

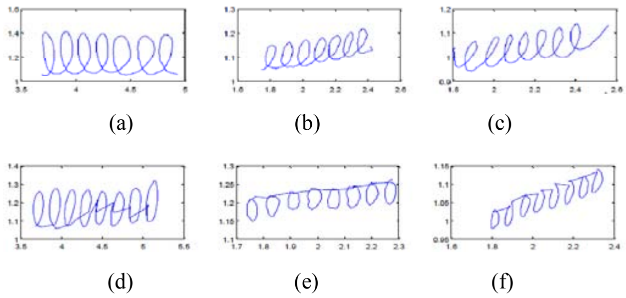

Fig. 4 ‘*lllll*’ (upper) and a row of circles (lower). (a)(d): cn, (b)(e): et, (c)(f): pd

TABLE II
RESULTS OF FITT'S TASKS

	Mean proportion of accuracy			Mean speed (mm/s)		
	8.8 mm	4.4 mm	2.2 mm	8.8 mm	4.4 mm	2.2 mm
PD	88.3 %	73.3 %	88.2 %	9.2	11.4	7.24
ET	92.2 %	92.1 %	53.2 %	14.3	14.6	15.3
CN	95.5 %	78.2 %	88.3 %	23.9	24.5	24.3
Sig	$p>0.05$	$p<.05$	$p<.05$	$p<.01$	$p<.01$	$p<.01$

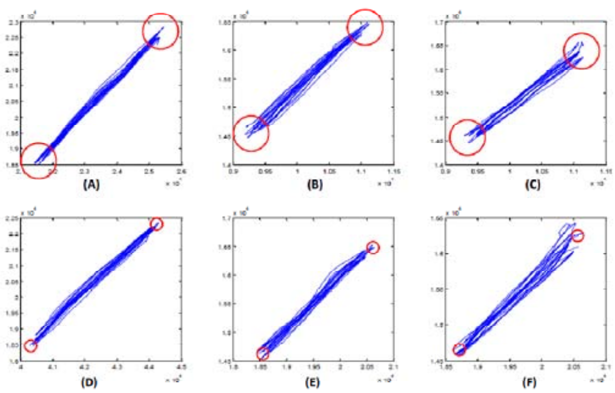

Fig. 5 Fitt's tasks. Red circles are the movement targets of 8.8 and 2.2 mm in radius (A), (D): CN, (B), (E): ET, (C), (F): PD

From the results of this study, impairment movement performance is more predictable in PD and ET than in controls. However, slowness and irregularity of movement in PD and ET cannot be fully explained by tremor. Some common pathogenic mechanisms leading to bradykinesia may contribute to these impairments. Different to conventionally clinical evaluation, computerized evaluation provides the handwriting evaluation much more quantitative approaches. The task of handwriting has been employed for studying fine motor control or executive functioning shows the possibility of early detection of fine motor impairment in both PD and ET subjects. However, further researches are needed to know how large the proportion of essential tremor subject turns to PD group.

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