

Analysis of Responses of a Healthy Subject and Subjects with Cerebellar Hemorrhage and Parkinson's Disease in Eye–Hand Coordination Pointing with Pencil Test

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Abstract: Purpose: The objectives of this study were to quantitatively analyze the reaction patterns of ataxia and Parkinson's disease cases that are cognitively harmless and to examine the characteristics of pathological reactions, such as ataxia, rigidity, and motor control, compared to the patterns of a healthy subject.

Methods: An eye–hand coordination pointing with pencil test (EHCPPT) app was developed that requires patients to tap a bullseye target with a pencil for screening testing. This app is intended to be used during regular check-ups of the elderly to help them maintain their home lifestyle through self-management of health. The EHCPPT consists of two tasks, both of which require the patient to tap a bullseye target as a test of eye–hand coordination in response to a stimulus sound. In one task, the sound is repeated rhythmically; in the other, it is generated irregularly and infrequently. The EHCPPT app is based on the “oddball paradigm” experimental design and can be administered in just a few minutes to measure the time lag between the sounds and taps as well as the distance between the target and tapped locations automatically.

Results: The data generated when the app was used by a healthy subject, an ataxia patient, and a patient with Parkinson's disease were analyzed. In each case, the data exhibited a distinctive pattern.

Conclusion: The EHCPPT app is simple and fast and shows potential as a screening test.

Keywords: eye–hand coordination, pointing test, tapping test

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1. Introduction

A finger-tapping test [1], a type of tapping task, is used in neurophysiological research and for the simple clinical evaluation of Parkinson's disease [2, 3] and cerebrovascular disorders [4, 5]. In recent years, researchers have begun exploring how finger-tapping relates to age and cognitive function as well as to the motor control functions of the hand and arm; studies

have also reported relationships with attention capacity and short-term memory [6, 7]. A center-of-target tapping task is, by its nature, highly sensitive to coordinated movement; therefore, we believe that it can be used to evaluate poor physical yield and cognitive function. However, during examinations of elderly people, this test may produce poor or widely varying results caused by patient unfamiliarity or nervousness.

According to Kropotov, the oddball paradigm is generally considered an “active paradigm.” In other words, it is a behavioral task that requires an action from the subject, such as pressing a button in response to deviants or silently counting the number of deviants [8]. Unlike the traditional speed test, which is administered under strict conditions, we opted for a bullseye-target tapping task. Therefore, we created an eye–hand coord-

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Table 1 Subject characteristics (case 2: ataxia; case 3: Parkinson's)

	Right Grip	Left Grip	TUG	GDS	SF8	MMSE	CDT	TMT-A	TMT-B	BI	Lawton
Case 2	11.5 kg	10.5 kg	14 s	3	9	28	9	250 s	321 s	80	2
Case 3	11.4 kg	8.7 kg	10 s	3	10	27	9	269 s	350 s	75	3

TUG: Timed up to go test; GDS: Geriatric depression scale 15; SF8: MOS 8-Item Short-Form Health Survey; MMSE: Mini-Mental State Examination 0 (severe) to 30 (normal), cutoff 23 points; CDT: Clock drawing test, 0 (severe) to 5 (normal), dementia at 3 points or less; TMT-A, TMT-B: Trail Making Test age 64 years and under, A 84.5 s, B 117.0 s; BI: Barthel Index; Lawton: Lawton's IADL (instrumental activities of daily living).

dination pointing with pencil test (EHCPT) app. This app is available in both iOS and Android versions. The study investigated the usefulness of the test based on the contrast in performances between a healthy individual and patients with ataxia and Parkinson's disease.

2. Methods

2.1 Subjects

Case 1: Healthy subject: 23-year-old man; 16 years of education; working in the medical field.

Case 2: Ataxia patient: 69-year-old man; 16 years of education; 3 years since onset of cerebellar hemorrhage; scale for the assessment and rating of ataxia (SARA) score [9] of 11/40 points.

Case 3: Parkinson's disease patient: 70-year-old woman; 15 years of education; 5 years since Parkinson's onset; Hoehn and Yahr IV, Life Disability Classification II.

Cases 2 and 3 received regular home care from visiting nurses. No dementia was observed. A small level of assistance was required in their activities of daily living (ADLs) and instrumental activities of daily living (IADLs).

2.2 Measurement methods

2.2.1 Patient position during examination and measurement

The examination was conducted with the subject seated in a chair or wheelchair. The subject sat with their nondominant hand in a fist on the desk, forming a fist-sized barrier between their body and the top of the desk, and then performed the test with the dominant arm resting on top of the nondominant hand. The subject practiced tapping the tip of the stylus pen from a distance of at least 10 cm from the screen for each tap. During the examination, the bullseye-target tapping task was presented to the subject via the EHCPT app running on an Apple iPad tablet (MP2F2 J/A). The subject held a stylus, which was used as the input device, in their dominant hand and tapped the bullseye target at the center of the concentric circles on the screen in synchrony with the stimulus sounds. Before the measurement, the researcher ran the application several times and made

practice measurements.

2.2.2 EHCPT app

The EHCPT is an eye-hand coordination test that requires the subject to tap a bullseye at the center of six concentric circles in synchrony with stimulus sounds played at regular intervals. The details of the task are as follows. In Task A, the subject must tap in time with a low-pitched (1 kHz) tone played 60 times in 1 s intervals. In Task B, 65 low-pitched (1 kHz) tones and 35 high-pitched (2 kHz) tones are played at random, and the subject must tap only after hearing the high-pitched tone. Prior to this measurement, five healthy people in their 20s were measured, and the test-retest reliability was 0.95 on average (0.91–0.97).

2.2.3 Measurement data and processing

The app obtains the (x , y) coordinates (in pixels) of the iPad screen location at which the subject taps the stylus and converts them into (X , Y) coordinates (in mm) relative to the origin at the center of the bullseye. The coordinates are then stored along with the time at which the stylus makes contact. The measurement data are saved as a CSV file. For each tap of the stylus, the app measures the "deviation from target" (in mm), that is, the distance of the tap from the center of the bullseye, and the "simple reaction time" (in seconds), that is, the time lag between the tap and stimulus sound.

The experimenter counts an "omission error" (OE) if the subject fails to tap when the stimulus sound is played and a "commission error" (CE) if the subject taps by mistake.

2.3 Ethical considerations

This study was conducted with the consent of the subjects and the approval of the ethics review boards of Kyoto University Medical Center (approval number R1379) and Fuchinobe General Hospital (approval number 19-006).

3. Results

Table 1 shows the background data for cases 2 and 3. Figures 1-1, 2-1, and 3-1 summarize the data obtained

(1)

Task	Parameter	Case 1: Healthy	Case 2: Ataxia	Case 3: Parkinson's
Task A	Deviation from target (mm)	0.11 ± 0.06	0.14 ± 0.12	0.21 ± 0.10
	Simple reaction time (s)	0.14 ± 0.06	0.52 ± 0.28	0.57 ± 0.15
	Omission error (count)	0	0	0
	Commission error (count)	0	15	5
Task B	Deviation from target (mm)	0.01 ± 0.05	0.28 ± 0.28	0.16 ± 0.07
	Simple reaction time (s)	0.55 ± 0.05	0.65 ± 0.12	0.78 ± 0.34
	Omission error (count)	0	24	24
	Commission error (count)	0	2	3

(2)

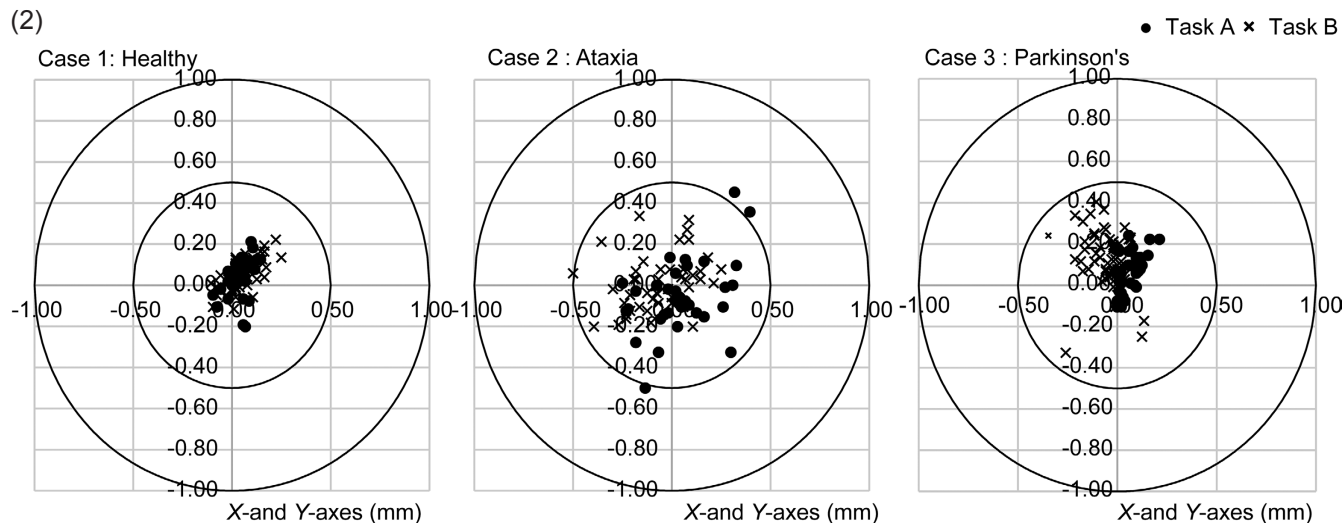


Fig. 1. (1) Results summary, task A, task B. (2) Results of deviation from target (mm).

using the EHCPT app and the number of omission and commission errors for each task. Figures 1, 2, and 3 show the results over time for cases 1, 2, and 3, respectively.

As the results show that OE was 0 in all cases in task A, but CE was 15 and 5 in cases 2 and 3, respectively. In contrast, in task B, OE was 24 in both cases 2 and 3, and CE was 2 and 3 in cases 2 and 3, respectively (Fig. 1-1). Regarding the deviation from target, in case 2, the patient results in tasks A and B were observed to spread by two to three times more than those of the healthy subject, and in case 3, the task B results were spread by about two times more (Fig. 1-2). Regarding the degree of deviation from the target of cases 1 and 2, the initial deviation in patient results was small in task A compared to in those of the healthy subject, but increased in the latter half, resulting in more CE. The results were large at the beginning of task B and had many OEs (Figs. 1-1, 2-1). Regarding simple reaction time, in task A, this was a characteristic measurement result that repeated a cycle in which the deviation increased with each iteration. In task B, the measurement results were quite difficult

(Figs. 1-1, 2-2).

Regarding the degree of deviation from the target of cases 1 and 3, there was a deviation in the patient results in task A compared to those of the healthy subject, and the deviation was large, especially in the latter half. There was little deviation from task B (Figs. 1-1, 3-1). Regarding simple reaction time, in task A, there was a large fluctuation in the first half, but subsequently there was a constant deviation. In task B, there was a large deviation and there were many OEs (Figs. 1-1, 3-2).

4. Discussion

SARA is a semiquantitative evaluation method that is easy to use in daily medical practice; however, its upper-limb ataxia outcome measures have been reported to vary widely across evaluators [9]. For Parkinson's disease, the severity classification of Hoehn and Yahr is widely used; further, the Unified Parkinson's Disease Rating Scale (UPDRS) is a standard evaluation index the reliability and validity of which have been verified, although this evaluation is time-consuming [10].

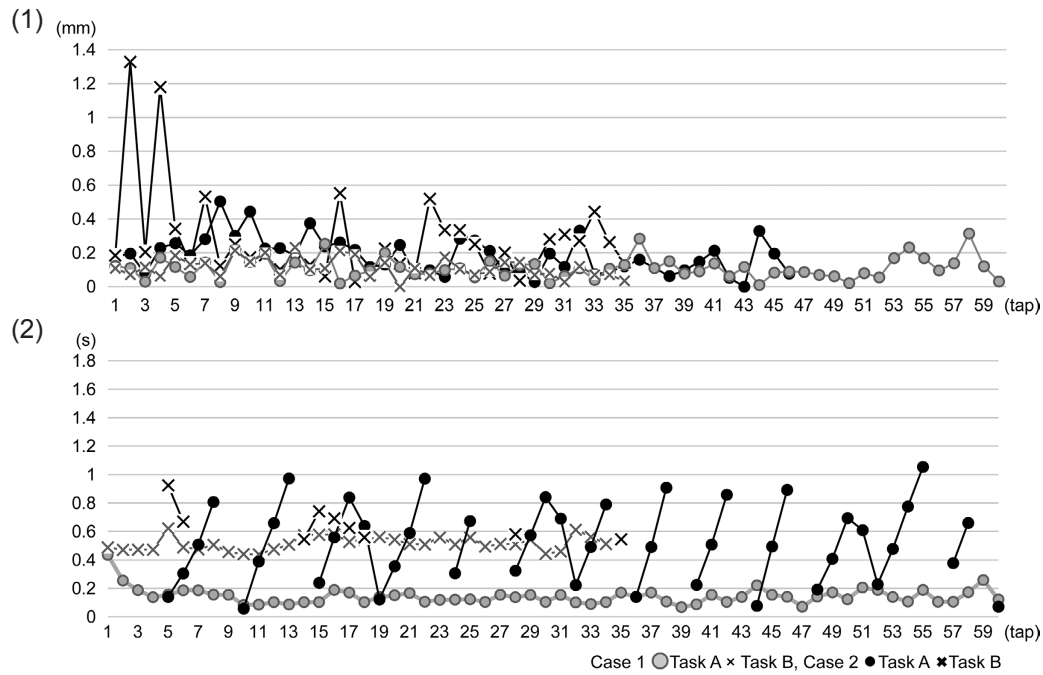


Fig. 2. (1) Degree of deviation from target (mm). (2) Simple reaction time (s) (case 1: healthy and case 2: ataxia).

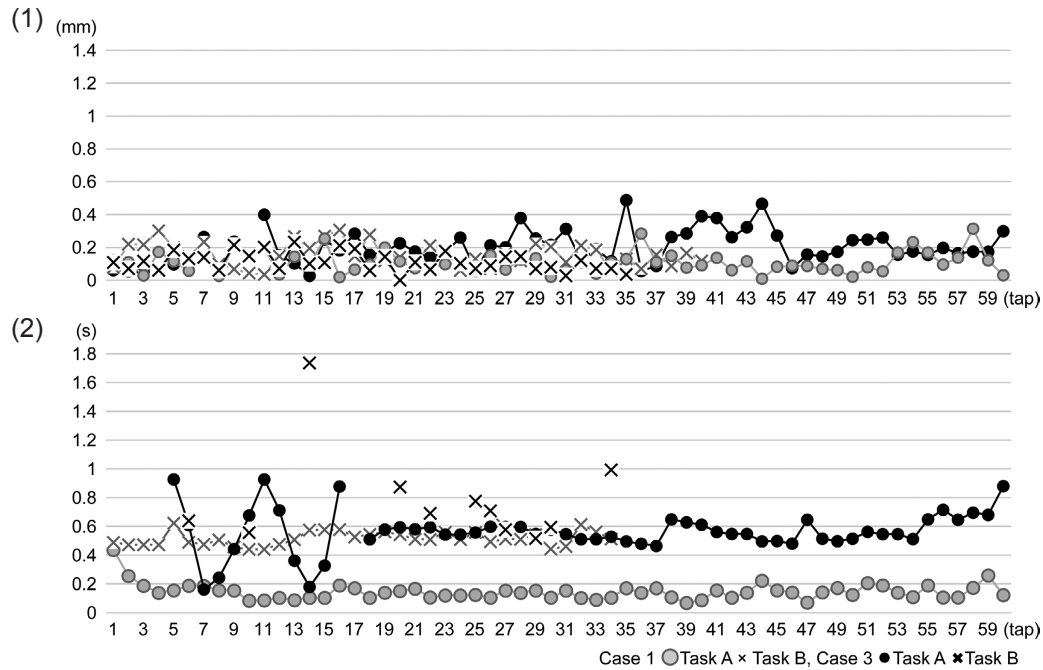


Fig. 3. (1) Degree of deviation from target (mm). (2) Simple reaction time (s) (case 1: healthy and case 3: Parkinson's).

In contrast, the EHCPT measurements performed in this study were simple and rapid. Furthermore, our results suggest that the test may reveal disease-specific characteristics. In the ataxia case (Table 1, Fig. 2), the deviation from the target in task 2 was around twice that in task A, and the time lag was around 1.5 times greater. Task A requires movement control to match a constant

rhythm. Because the patient suffered from a rhythm disorder, we expected them to show more erroneous reactions, difficulty with time control, and longer simple reaction time. Furthermore, we noticed that they tried to control their deviation from the target using strategies such as pressing their elbow to their body for stability, which resulted in a certain amount of deviation and

early tapping. Task B required reaction to one sound at a time and therefore was less susceptible to the effects of rhythm disorders. However, the subject seemed to have faced difficulties in controlling the initiation of each motion and was unable to react in time before the next stimulus sound.

In the Parkinson's case (Table 1, Fig. 3), the deviation from the target in task B was less than that in task A, whereas the time lag (including standard deviation) was around 1.5 times greater. In task A, no omission errors were recorded, and the tapped area was smaller than that in the ataxia case. This patient may have faced difficulties in initiating motions independently but not in reacting to the stimulus sound. In task B, their muscle rigidity may have led to decreased deviation from the target but increased lag time from detection to reaction.

The study results suggest that disease-specific characteristics exist; however, the small sample size and the likelihood of individual differences in the use of spatio-temporal and spatial strategies to tap the target make this suggestion difficult to prove. In future work, in addition to increasing the number of cases, we will examine different parameters, for example, by calculating the average double product or comparing the tapped areas. We would also like to perform further investigations regarding whether the developed app can be used as a drug efficacy index, for example, for describing disease severity or on–off syndrome.

5. Conclusion

We developed an EHCPPT app as a screening test that requires patients to tap a bullseye target and performed measurements for three cases: a healthy subject, an ataxia patient, and a patient with Parkinson's disease. This app enables the assessment of disease-specific characteristics, suggesting that it may be useful as a screening test.

Conflict of interest disclosure

There are no conflicts of interest that need to be disclosed in connection with this research.

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