

The Symbol-Digit Modalities Test in Mild Cognitive Impairment: Evidence from Parkinson's Disease Patients

Maddie Pascoe^a Yassar Alamri^{a, b} John Dalrymple-Alford^{a–c}
Tim Anderson^{a, b, d} Michael MacAskill^{a, b}

^aNew Zealand Brain Research Institute, Christchurch, New Zealand; ^bUniversity of Otago, Christchurch, New Zealand; ^cPsychology Department, University of Canterbury, Christchurch, New Zealand;

^dDepartment of Neurology, Christchurch Public Hospital, Christchurch, New Zealand

Keywords

Cognitive impairment · Parkinson's disease · Parkinson's disease dementia · Neuropsychological testing · Saccades

Abstract

Background: The evaluation process of the performance of the symbol-digit modalities test (SDMT) has focused much on numerical scores paying only little attention to the qualitative aspects of performance. Incorporating the gaze analysis technique, we aimed to investigate the performance of Parkinson's disease (PD) patients on the written SDMT task. **Methods:** Twelve patients with PD and normal cognition (PD-N), 11 with PD and mild cognitive impairment (PD-MCI), and 13 healthy participants (NC) controlled for age, sex and education were recruited. **Results:** PD-MCI participants achieved significantly lower scores than NC and PD-N participants. Eye-movement parameters, however, did not differ among the study groups, and were not correlated with

task performance. **Conclusions:** Impaired performance on the SDMT by PD-MCI participants despite relatively preserved oculomotor performance indicates that lower SDMT scores are not due – even in part – to visuomotor impairments otherwise seen in PD patients. © 2018 S. Karger AG, Basel

Introduction

The symbol-digit modalities test (SDMT) is a symbol substitution neuropsychological test that examines a person's attention and speed of processing. This test requires a person to substitute geometric symbols for numbers while scanning a response key [1]. However, oculomotor

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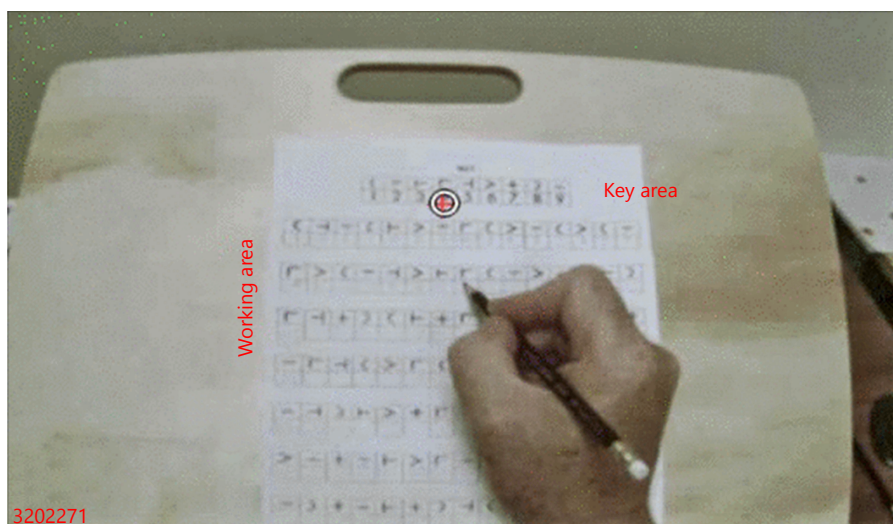


Fig. 1. Scene video from the head-mounted eye-tracker, showing a participant's gaze position (red plus-sign) whilst completing the SDMT. Here, gaze is directed at the number in the Key below the symbol the participant is currently attempting to match. The participant is about to write the number associated with the given symbol in the Working Area.

scanning, working memory, motor persistence and visuomotor coordination are also required for getting a good score on the test [1].

The SDMT has been used in the assessment of many neurological disorders, including Alzheimer's disease [2], Huntington's disease [3], and Parkinson's disease (PD). For example, Hansch et al. [4] found a significant direct relationship between SDMT score and P₃₀₀ latency (used to evaluate cognitive function independent of specific motor responses). In addition, lower SDMT scores are associated with poorer driving safety in PD patients [5].

Traditionally, performance on the SDMT and other pencil-and-paper-tests focuses on numerical scores and only little attention is paid to the qualitative aspects of the performance. With the help of eye-movement tracking techniques, insights into participants' oculomotor scanning patterns and visuomotor coordination may be gained. Tracking the participant's eye movements can also allow for a deeper analysis of the quality of and the pattern behind a response – data that is otherwise not obtainable when using current standards of neuropsychological testing. Therefore, we aimed to explore the performance of PD patients (with normal cognition and mild cognitive impairment) on the written SDMT task.

Methods

Participants

Volunteers from the PD database at the New Zealand Brain Research Institute (Christchurch, New Zealand) were invited to participate. PD participants included patients who met the Movement Disorders Society criteria [6] for mild cognitive impairment

(PD-MCI), and those who did not (PD-N); a group of healthy controls (NC), matched for age, sex and education was also recruited. The study was approved by the Upper South B Regional Ethics Committee, New Zealand (reference URB/11/06/010).

Eye Tracking System

Participants wore the *iView X HED*TM, a head-mounted device that recorded movements of the left eye, while the participant performed the SDMT (SensoMotoric Instruments, Berlin). The *iView X HED*TM has a 200 Hz sampling rate, a tracking resolution of <0.01° and gaze position accuracy of 0.5° – 1°. The focal length of the camera lens for the present study was 3.6 mm, giving horizontal and vertical viewing angles of ±31° and ±22° respectively. The *iView X HED*TM eye-tracking system superimposed a red cross-hair indicating gaze position on each scene video frame, while the participant completed the task (not visible to the participant; Fig. 1).

Procedure

The motor function of PD patients was assessed by the Unified PD Rating Scale (UPDRS)-part III (no disability 0, severe disability 56) and Hoehn and Yahr stage (minimal functional disability 1, confinement to wheelchair/bed 5).

To explore the visuomotor coordination during task performance, the written SDMT was utilised. A printed version of the SDMT was rested on an angled wooden board (as shown in Fig. 1). After fitting the eye-tracking system and gaze calibration, the test was revealed and participants were instructed to complete the task by following standardised instructions [1]. Although no time limit was set, analysis was limited to the first 90 s. Fixation positions (as generated by BeGazeTM) are shown in Figure 2.

Statistical Analysis

One-way analysis of variance was used to test the differences between the study groups; post hoc analyses were carried out using Fisher's least significant difference. Correlations were examined using regression analysis. Statistical significance was determined if type I error rate was <5%. Analyses were performed using SPSS Statistics[®] software package (version 22.0.0.0).

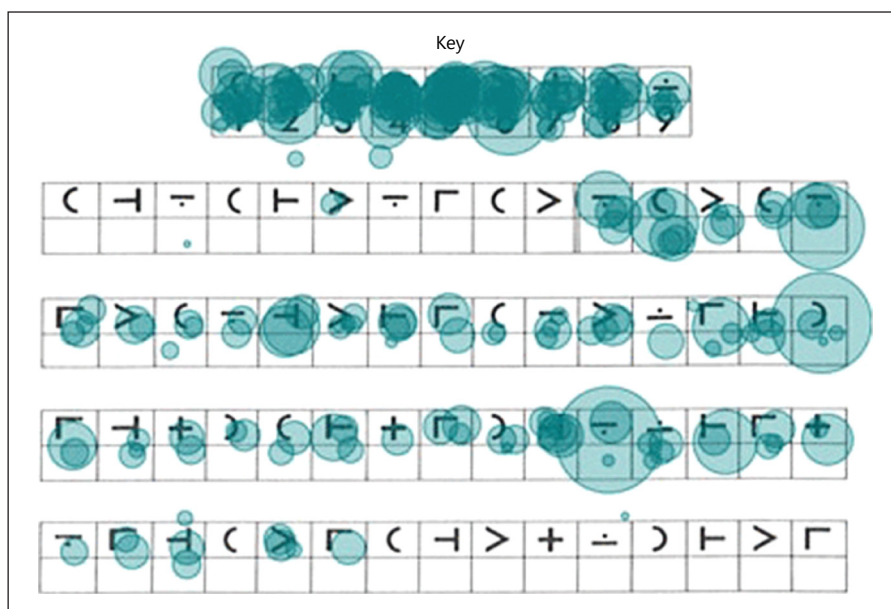


Fig. 2. Fixation position image generated in BeGaze™ for one of the participants. Circles indicate the locations of fixations; and the diameter of each circle indicates the fixation duration, so that the larger the diameter, the longer the duration. Fixations during the practice phase (i.e., the first 10 boxes) are not shown.

Results

Sample Characteristics

Demographic and clinical characteristics of participants are summarised in Table 1. All participants – except 1 ambidextrous PD-MCI patient – were right-handed as assessed by the Edinburgh Handedness Inventory [7].

SDMT Raw Scores

The number of correctly identified digits (raw scores) for the SDMT task ($F_{2,35} = 4.0$) was significantly lower only in PD-MCI patients (25.8 ± 4.9 points) compared to that of NC participants (35.4 ± 11.5 points, $p = 0.01$) and PD-N patients (33.4 ± 7.5 points, $p = 0.04$).

The mean scores were comparable between male and female participants. In all participants, age was negatively associated with SDMT scores ($r = -0.55$, $p < 0.001$), whereas education was positively associated with the scores ($r = 0.45$, $p < 0.001$). For PD patients, SDMT scores were correlated with UPDRS-III scores ($r = -0.47$, $p = 0.02$) but not disease duration ($r = 0.21$, $p = 0.34$).

Eye Movement Data

Eye movement parameters are summarised in Table 2.

Scores on the SMDT were not correlated with the proportion of fixations on the Key Area to the Working Area ($r = 0.2$, $p = 0.28$). Additionally, no significant correlation was found between the SDMT score and the mean fixation duration in the Key Area ($r = 0.1$, $p = 0.4$) or the Working Area ($r = 0.1$, $p = 0.4$).

Table 1. Demographic and clinical characteristics of the study sample

	NC	PD-N	PD-MCI
Age, years	69.5±9.4	66.4±9.3	69.3±10.2
Male/female	12/1	9/3	8/3
Education, years	13.2±3.3	13.9±3.2	12.6±2.3
Time since diagnosis, years	N/A	8.1	7
UPDRS-III	N/A	35.4±12.1	36.5±10.8
Hoehn and Yahr stage	N/A	2.1±0.7	2.1±0.6

N/A, not applicable; NC, healthy control; PD-N, Parkinson's disease with normal cognition; PD-MCI, Parkinson's disease with mild cognitive impairment; UPDRS, Unified Parkinson's Disease Rating Scale.

Discussion

The present study investigated the performance of PD participants and matched controls on the SDMT while recording eye movements. PD-MCI participants achieved significantly lower scores than NC and PD-N participants. Eye-movement parameters, however, did not differ among the study groups, and were not correlated with the task performance. Therefore, impaired performance on the SDMT by PD-MCI participants despite relatively preserved oculomotor performance indicates that lower SDMT scores are not due – even in part – to visuomotor impairments otherwise seen in PD patients [8].

Table 2. Summary of eye movement data stratified by group

	NC	PD-N	PD-MCI
Fixation number			
Mean	226	228	212
SD	58	40	64
ANOVA	$F_{2,33} = 0.60, p = 0.55$		
Fixation duration, ms			
Mean	287	326	289
SD	77	75	52
ANOVA	$F_{2,33} = 0.28, p = 0.76$		
Saccade amplitude, degree			
Mean	5.3	3.9	4.7
SD	2.0	1.0	2.2
ANOVA	$F_{2,33} = 2.1, p = 0.14$		

NC, healthy control; PD-N, Parkinson's disease with normal cognition; PD-MCI, Parkinson's disease with mild cognitive impairment; ANOVA, analysis of variance.

In accordance with a number of previous findings from healthy [9] and multiple sclerosis populations [10, 11], younger age and higher education were found to be significantly associated with better performance on the SDMT.

The mean SDMT score of the PD-N group was similar to that of the NC group, indicating comparable performance on the SDMT, despite PD-related motor deficits. This may support the use of the written SDMT *early* in the course of the disease in patients with PD. Among PD participants, higher UPDRS-III scores had a modest correlation with lower SDMT scores – a finding that could favour the use of the verbal SDMT in patients with advanced motor symptoms. However, even with similar UPDRS-III scores, PD-MCI participants scored significantly lower on the SDMT compared with PD-N participants. This emphasises the contribution of cognition – in addition to the general motor ability – to the deficit evident in the PD-MCI group, and corroborates previous findings of lower SDMT scores in PD patients in general [12].

Despite strong differences in task performance, the analysis of eye movement data yielded few differences in eye movement measurements between the groups. Although no prior similar studies have been undertaken in PD, our eye movement findings are different from those reported by Elahipanah et al. [13] in a group of patients with schizophrenia performing the SDMT. Compared with controls, schizophrenia patients were observed to make more visits to the Key Area per response, and to spend more time in the Key Area per

visit [13]. Direct comparison between the 2 studies, however, may be problematic due to 2 caveats; the pathologies studied (PD vs. schizophrenia) involve different pathophysiological underpinnings. Moreover, Elahipanah et al. [13] used a computerised verbal version of the SDMT in which completed responses were immediately obscured so that participants could only refer to the Key Area for guidance on symbol-digit pairings. In contrast, there was no impediment to participants in our study looking at previously completed symbol-digit pairs – rather than the Key Area – to retrieve the correct response.

A few limitations to our study ought to be acknowledged. The low number of participants in the study is a potential limitation. Matching PD participants with each other (i.e., PD-N with PD-MCI), as well as with NC participants – for age, education and sex – severely limited the pool of participants available for the study. Furthermore, our participants were required to wear the head-mounted eye tracker which may have caused distraction, thus impairing performance – although NC and PD-N participants showed similar performance, which may argue against PD participants being differentially impacted by such influence.

Conclusion

The present study found no association between the performance on the SDMT and participant eye movement parameters. This implies that the cognitive aspects of the SDMT task are valid and are not overly impacted by oculomotor control. More detailed eye movement analyses, perhaps with the addition of a PD-dementia group and utilising both the written and verbal SDMT, may provide answers to uncertainties raised by our study.

Disclosure Statement

The authors have no conflicts of interest to disclose.

Author Contribution

M.P. collected and analysed the data and reviewed the paper. Y.A. designed the study, collected the data and wrote the paper. J.D.-A. supervised the study and reviewed the paper. T.A. supervised the study and reviewed the paper. M.M. designed the study, supervised the study and reviewed the paper.

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