Deficits on the Clock Drawing Test in Parkinson’s Disease

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Parkinson’s Disease (PD) is a progressive neurodegenerative disorder that affects 1% of the world population over the age of 65—anywhere from four to six million people (National Parkinson Foundation, 2010). Although most people identify PD as a movement disorder, cognitive deficits are also present. Poor performance on tasks such as set shifting, internal control of attention, and sequencing is commonly reported by PD patients (Stout & Johnson, 2005), as are visual and verbal memory impairments (Moody, Bookheimer, Vanek, & Knowlton, 2004). Visuospatial skills are also problematic, including depth perception, spatial orientation, and spatial organization (Bowen, Burns, Brady, & Yahr, 1972).

For years, researchers have argued that all of the noted cognitive problems observed in PD patients are due to deficits in the frontal lobes (Dubois & Pillon, 1997). Although it is well known that verbal and visual memory abilities primarily involve the temporal lobes and that visuospatial performance involves the parietal lobes, many argue that deficiencies in the frontal lobes and their connections with these other lobes are responsible for the noted impairments. Only recently have researchers acknowledged that perhaps pathology exists in other areas of the brain, mainly the parietal lobes, and that the frontal lobes are not the only areas affected (Amick, Schendan, Ganis, & Cronin-Golomb, 2006). Perhaps, indeed, pathology in the parietal lobes is in fact responsible for the noted deficits in visuospatial function.

One assessment that has been primarily used to examine visuospatial function in a variety of populations is the Clock Drawing Test (CDT; Goodglass & Kaplan, 1972). The test requires participants to draw a clock, including the face, numbers, and hands (set to a specific time). PD participants have been shown to perform poorly on the numbers portion (correct placement of the numbers on a clock face) of the CDT, most frequently by placing the numbers distant from the rim of the clock, rather than bordering it (Sandyk, 1995). It has been argued that poor number placement on the CDT by PD participants may be indicative of visuospatial dysfunction (Sandyk, 1995) and not frontal lobe pathology, which is a more commonly adopted view. Through recent studies at the Vision and Cognition Laboratory at Boston University, we noticed that PD participants and normal control participants vary in the manner in which they draw a clock. As mentioned earlier, some participants use a planning strategy and some do not. The type of strategy used may relate to frontal lobe involvement in completing the task.

The aim of the current study, therefore, was to compare PD participants to normal control participants on the CDT, both in terms of approach (planned/unplanned drawing of the numbers), and the physical placement
of the numbers, to see if the groups differ in performance. We expected to replicate previous findings that have shown that PD patients exhibit deficits in number placement scores compared to normal control participants. Moreover, given that PD patients tend to exhibit frontal lobe deficits, more PD patients than NC participants should have adopted an unplanned strategy if the strategy one chooses is frontally mediated.

In addition to examining group differences on the CDT, both strategy and number placement scores from this assessment were compared to performance on a number of classic frontal lobe and parietal lobe assessments, respectively, in the PD group. The thought was that if PD participants who did not plan performed more poorly on other frontal lobe mediated assessments (e.g., FAS, Trails A and B, Digit Span, and the Stroop) than those who did plan, then the approach one takes on the CDT (planned or unplanned) is related to frontal lobe functioning. On the other hand, if number placement is related to parietal lobe involvement, those PD participants with poorer number placement scores should perform worse on other parietal lobe mediated assessments (e.g., Money Road Map, Judgment of Line Orientation, and the Landmark task) than those with better number placement scores. The hypotheses of this project were as follows: 1a) When comparing PDs and normal control participants, we expected significant differences in the number placement scores, with the PD group exhibiting poorer number placement scores; 1b) We expected to see differences in clock planning strategies between groups, with the PD participants adopting an unplanned strategy more frequently than NC participants. 2a) Based on previous literature, we expected PD participants to exhibit deficits on the frontal lobe assessments when compared to NC participants; 2b) PD participants who plan and PD participants who do not plan were expected to show differences on the frontal lobe assessments if the strategy one adopted was frontally mediated. If the two PD groups did not differ in performance, we believed it would have suggested that the clock strategy one adopts is not frontally mediated. 3a) Based on previous literature, PD participants were expected to exhibit deficits on the parietal lobe assessments when compared to NC participants; 3b) PDs with poorer number placement scores were expected to perform worse on the parietal lobe tasks if number placement is related to visuospatial functioning. If number placement scores did not relate to visuospatial functioning, the results would suggest that performance was not parietally mediated.

METHOD

Participants
Participants included 24 adults with PD (12 males and 12 females) and 40 normal control adults broken into two groups, NC1 and NC2 (NC1: 4 males and 12 females; NC2: 8 males and 10 females) due to the fact that the neither group had been given all necessary tests. Independent Groups t-tests were used to ensure that both NC groups matched the PD participants on both age and education. Participants provided informed consent approved by the Boston University Charles River Campus Institutional Review Board.

Measures and Procedures
The Clock Drawing Test. (Goodglass & Kaplan, 1972). Participants were provided with a blank 8.5 x 11” sheet of white paper and the following instructions: “I would like you to draw a clock, including the numbers, and set the hands to 10 after 11." The order that each section (face, hands, and each number) was drawn in was recorded by the test administrator. The numbers were either drawn in a planned (e.g., sequential “1, 2, 3, 4, 12” or anchor “12, 6, 3, 9...”) or unplanned (such as “10, 4, 7, 3...”) order. All clocks were analyzed as described below by using principles of the Boston Process Approach (Milberg, Hebben, & Kaplan, 1986) and the Rouleau Method (Rouleau, Salmon, Butters, Kennedy, & McGuire, 1992).

The Boston Process Approach. The Boston Process Approach (Milberg et al., 1986), in regard to Clock Drawing, refers to closely watching and recording how a participant draws a clock, and in this case, the order in which they place the numbers on the clock. It is believed that individuals who place the numbers in a sequential (1, 2, 3, etc.) or anchored (e.g., 3, 6, 9, 12 etc.) manner are utilizing a more planned approach compared to those individuals who adopt a more random method (e.g., 3, 1, 5, etc.). Two scorers were trained on how to read and identify the approach each participant used. Their inter rater-reliability on identifying the approach used was 100%.

The Rouleau Method. The Rouleau Method (Rouleau et al., 1992) looks at the clock not only as a whole, but also assesses the drawing of the individual parts (the face, numbers, and hands). The clock face is scored according to the severity of distortion on a 0-2 point scale with a 2 indicating a gross distortion. A 0-4 point scale is used for judging the clock numbers and clock hands (both placement and length).

Frontal lobe assessments. FAS. For the FAS the examiner asks the participant to say as many words as they can think of that begin with the letter F, then A, then S, for one minute. The total number of words is recorded, along with any errors and repetitions, which are subtracted from the total. The higher the score, the better the performance, with a combined F, A, and S score of 53 or higher considered superior and a score of 10-16 considered severely deficient. Test-retest reliability for NC participants on the
visuospatial abilities, including mental rotation in space and

The Money Road Map measures

Parietal lobe assessments

Money Road Map. The Money Road Map measures visuospatial abilities, including mental rotation in space and

left-right discrimination. This test requires the participant to follow the examiner's finger as it traces a map and to tell the examiner to go left or right every time they make a turn. There are no time limits to the task. Errors are circled and counted for the final score.

 Judgment of Line Orientation (JLO). The JLO measures the ability of the participant to determine angular relationships between line segments by visually matching angled line pairs to 11 numbered radii formatting a semicircle. The test consists of 30 lines to be matched to the semicircle of radii on a sheet in front of the participant. The score on the JLO is the number of items the participant gets correct, so the score range is 0-30.

Landmarks (Line Bisection Test). The Landmark Test is a non-motor line bisection test developed at the Vision and Cognition laboratory at Boston University. Line bisection tests measure visual attention. A horizontal line is shown on a computer screen with a vertical cursor intersecting it. The examiner will gradually move the cursor towards the middle and the participant must say “Stop!” when it is in the middle. On a response sheet, the examiner marks when the participant perceived the cursor to be in the middle.

RESULTS

Performance on the Clock Drawing Task

Hypothesis 1a. When comparing PD to NC1 participants, differences in number placement scores were expected, with the PD group exhibiting poorer performance. Significant differences between groups were not expected on the face and hands portions of the CDT. Using an Independent Groups t-test with group (PD, NC) as the independent variable and number placement scores as the dependent variable, the PD participants (M = 3.69, SD = 0.40) exhibited significantly worse performance on the number placement portion of the CDT than the NC1 participants [M = 3.27, SD = 0.66; t (38) = 2.26, p < .03, partial $\eta^2 = .12$]. There were no group differences in performance on the face [t (38) = .82, p = .42] or hands [t (37) = 1.31, p = .20] sections of the CDT.

Hypothesis 1b. When comparing the PD group to the NC1 group, the former group was expected to adopt an unplanned strategy more frequently than the latter group. To investigate this hypothesis, a Pearson Chi Squared test statistic was used to compare those who planned and those who did not plan across the PD and NC1 groups. Results revealed no significant differences between groups [$\chi^2 (1, N = 40) = .44, p = .51$; planned N = 14, unplanned N = 10], indicating that both groups used similar strategies when completing the clock drawing test.
Performance on the Frontal Lobe Assessments

**Hypothesis 2a.** Based on previous literature, PD participants were expected to exhibit deficits on the frontal lobe assessments. To examine this hypothesis, an Independent Groups t-test was performed to compare PD participants to NC participants on the frontal lobe assessments. Alpha was adjusted to .008 (.05/6) to account for significant correlations between the six frontal lobe assessments. PD participants performed significantly worse than NC participants on the FAS \( t (35) = 4.49, p < .001, \) partial \( \eta^2 = .37 \), Trails A \( t (20) = 3.10, p < .006, \) partial \( \eta^2 = .33 \), and the Stroop task \( t (35) = 3.29, p < .002, \) partial \( \eta^2 = .24 \). There was a trend toward worse performance on Trails B \( t (20) = 2.45, p = .024 \). No significant differences between groups were found for Digit Span Forward \( t (36) = 1.25, p = .22 \) or Digit Span Backward \( t (36) = 1.78, p = .09 \). See Table 1 for the means and standard deviations for each group on each assessment.

**Hypothesis 2b.** PD participants who planned and PD participants who did not plan were expected to show differences on the frontal lobe assessments if the strategy one adopted is frontally mediated. If the two PD groups did not differ in performance, it was thought to suggest that the clock strategy one adopted may not be frontally mediated. To investigate this hypothesis, a nonparametric statistic (Independent Samples Mann Whitney U Test) was used to compare the planned PD group and the unplanned PD group across the six frontal lobe assessments (FAS, Digit Span Forward, Digit Span Backward, Trail Making Test parts A and B, and the Stroop Test). A nonparametric statistic was chosen due to the extremely small sample sizes that resulted from dividing the PD group into subgroups. Because all six frontal lobe assessments tap into similar functions (i.e., they are correlated), a more conservative alpha level (.05/6 = .008) was adopted. No significant differences were noted between the planned and unplanned PD groups for any of the six assessments (all \( p \)'s > .04). See Table 2 for the median, ranges, and \( p \) values for each assessment for the two PD groups. These results suggest that the strategy one adopts is most likely not frontally mediated.

Performance on the Visuospatial Assessments

**Hypothesis 3a.** Based on previous literature, it was hypothesized that PD participants should have exhibited deficits on the parietal lobe assessments. To address this hypothesis, an Independent Groups t-test was performed to compare PD participants to NC2 participants on the parietal lobe assessments. Alpha was adjusted to .017 (.05/3) to account for the correlations between the three parietal lobe assessments. PD participants performed significantly worse than NC2 participants on the JLO \( t (36) = 2.45, p < .019, \) partial \( \eta^2 = .14 \). No significant differences between groups were found for the Money Road Map \( t (36) = .06, p = .96 \) or Landmarks \( t (36) = 1.25, p = .22 \). See Table 3 for the means and standard deviations for each group for each assessment.

**Hypothesis 3b.** PD participants with poorer number placement scores were expected to perform worse on the parietal lobe tasks than NC2 participants if number placement was related to visuospatial functioning. If number placement scores did not relate to visuospatial functioning, it suggests performance was not parietally mediated. Due to small sample sizes, a nonparametric statistic (Spearman's rho correlation) was used to compare PD participants’ number placement scores with the three parietal lobe assessments (Money Road Map, Landmarks, and the JLO). As all three of the assessments tap into parietal lobe functions, the alpha level was adjusted to be more conservative (.05/3 = .017). None of the parietal lobe tasks correlated with the number placement scores \( [N = 20; \) Money Road Map: \( r (18) = .12, p = .62; \) Landmarks: \( r (18) = .40, p = .08; \) JLO: \( r (18) = .03, p = .89 \].

After finding no significant correlations between number placement scores and performance on the parietal lobe assessments, additional analyses were conducted to examine other factors that may be related to number placement performance. First, we examined whether the number placement scores were being driven by frontal lobe performance. To examine this question, Speaman's rho correlations were computed comparing number placement scores to performance across each of the six frontal lobe assessments. No significant correlations were observed (all \( p \)'s > .16), thereby ruling out frontal lobe involvement. We then examined whether number placement scores were related to disease duration. Perhaps those that had PD for longer periods of time were more susceptible to number placement errors. Duration of illness, however, did not correlate with number placement scores \( [r (22) = .32, p = .13] \), ruling out this hypothesis. Finally, we examined the relation between number placement scores and severity of impairment as measured by the UPDRS. A significant correlation was found \( [r (20) = .47, p < .03 \). Specifically, those participants that performed the best on the number placement portion of the CDT had less disease severity. In light of this finding, we examined whether UPDRS scores were related to performance on our other dependent measures. We found that the UPDRS did not relate to any of the frontal or parietal lobe assessments (all \( p \)'s > .09).

**DISCUSSION**

**Hypothesis 1a.** When comparing PDs to NCs, differences in number placement scores were expected, with the PD group exhibiting poorer performance. Significant differences between
groups were not expected on the face and hands portion of the CDT. Results of the current study indicated that the PD participants did perform significantly worse on the numbers portion of the CDT, but not the face or hands portions, thereby lending support for this hypothesis. Poor number placement on the CDT is commonly seen in PD, with participants usually placing the numbers distant from the rim of the clock, but performance on the hands and face portions of the CDT is relatively unimpaired (Sandyk, 1995).

**Hypothesis 1b.** When comparing the PD to the NC group, it was predicted that the former group would adopt an unplanned strategy more frequently than the latter group. Results showed no significant differences between groups, indicating that a difference in planning could not be detected. Recall that participants were placed into the categories of planned (sequential: 1, 2, 3, etc.; or anchor sequential: 3, 6, 9, 12, 1, etc.) and unplanned (random, or any other pattern), based on the order in which they placed the numbers on the clock. This is a fairly new method developed by researchers at Boston University’s Vision and Cognition laboratory and is based on the Boston Process Approach. A limitation of this method is that the categories for the planned group were very strict. For instance, if a participant filled in the anchor points (12, 3, 6, 9), but then continued to put in the remaining numbers in backwards order (i.e. 11, 10, 8, 7, ..., 1), they were placed into the random category. Redefining the groups to allow for slight differences may reveal different results, and is something future research should address.

**Hypothesis 2a.** Based on previous literature, it was predicted that PD participants would exhibit deficits on the frontal lobe assessments. In the current study, PD participants performed significantly worse than NC participants on the FAS, Trails A, and the Stroop Test, and there was a trend toward worse performance on Trails B, which supported our hypothesis. Frontal lobe dysfunction is considered the primary cognitive issue arising from PD (Muslimovic, Post, Speelman, de Haan, Schmand, 2009). In previous studies, PD participants have shown deficits on various frontal lobe assessments, including the Stroop Test (Woodward, Bub, & Hunter, 2002), Digit Span Forward (Siegert, Weatherall, Taylor, & Abernethy, 2008), Digit Span Backward (Siegert et al., 2008), the Trail Making Test (Trails A: Taylor, Saint Cyr, & Lang, 1986; Trails B: Amick, Grace, & Ott, 2007), and the FAS (Taylor et al., 1986).

**Hypothesis 2b.** PD participants who planned and PD participants who did not plan were expected to show differences on the frontal lobe assessments if the strategy one adopted was frontally mediated. If the two PD groups did not differ in performance, it suggests that the clock strategy one adopted may not be frontally mediated. No significant differences were noted between groups for any of the six frontal lobe assessments, indicating that it is possible that the method in which one draws the clock may not be frontally mediated. Planning is a function of the frontal lobes, so if the participants used a planning strategy that helped them adequately complete their clocks, it is assumed that they would also be able to successfully complete tests of frontal lobe function. However, it has been proposed that if the categories were less strictly defined (as mentioned in Hypothesis 1b), different participants may be categorized into the planned and unplanned categories and perhaps significant differences in frontal lobe tests may be noted (i.e., those that plan more score significantly higher on the frontal lobe tests).

**Hypothesis 3a.** Based on previous literature, PD participants were expected to exhibit deficits on the parietal lobe assessments. In the current study, significant differences were found between the PD and NC groups on the JLO, but no significant differences were found on Landmarks (Line Bisection) or the Money Road Map. Many researchers believe that in addition to frontal lobe dysfunction, PD patients also experience visuospatial impairments, which result from parietal lobe dysfunction (Cronin-Golomb & Braun, 1997). In previous studies, PD participants have shown deficits on parietal lobe tests including Line Bisection (Lee, Harris, Atkinson, & Fowler, 2001), JLO (Montse, Pere, Carme, Francesc, & Eduardo), and the Money Road Map (Cronin-Golomb & Braun, 1997). In the present project, a combination of small sample size and the grouping of all PD participants together, rather than examining subgroups based on side of onset or initial symptom, may have led to the lack of significant differences on the Landmark and the Money Road Map assessments.

**Hypothesis 3b.** PD participants with poorer number placement scores were expected to perform worse on the parietal lobe tasks than NC participants if number placement was related to visuospatial functioning. If number placement scores did not relate to visuospatial functioning, it suggests performance was not parietally mediated. PD participants’ number placement scores were compared with the three parietal lobe assessments. None of the parietal lobe tasks correlated with the number placement scores, indicating that number placement is not parietally mediated. However, a limitation to the current study is that there was a small sample size. Also, there are methods to scoring number placement other than the one used in the current study (the Rouleau Method), leaving the possibility open that if a different method was used, correlations may have existed. As demonstrated through correlations, disease severity may have played a significant role in the number placement errors noted in the PD participants.
Conclusion. This study examined whether deficits exhibited by PD participants on the CDT were parietally mediated, or whether there was influence from the frontal lobes as well. Results revealed that neither the frontal nor the parietal lobe determined number placement scores and planning strategy on the CDT. Number placement scores did, however, correlate to disease severity. The worse the disease severity according to the UPDRS, the lower the number placement scores. This may simply indicate that number placement errors derived from motor disability. However, the sample size in this study was small, and further research is needed to support this claim.

References


