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# Clock-Drawing in Neurological Disorders

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Clock-drawing is a widely used bedside test of constructional ability, but it has never been systematically studied or standardized. We examined 87 clocks drawn by neurologically impaired patients and age-matched controls, and propose a set of criteria for scoring clocks. Patients with probable Alzheimer's disease and other dementias have gross impairments in clock-drawing. These deficits include poor spatial arrangement of numbers, incorrect numerical sequence, insertion of stray lines, and addition of extra numbers. In Alzheimer's disease, the total score on the clock-drawing test correlates with the score on the Modified "Mini-Mental State" Examination. Non-demented patients with Parkinson's disease showed only defects in the spatial organization of the numbers, and non-demented patients with other diseases perform as well as controls.

## Introduction

Clock-drawing is an easy constructional task often used to examine the mental state at the bedside. Despite its widespread use, the test is not standardized, nor has there been a systematic study of the types of abnormalities observed. Hemi-neglect is easily recognized on a drawn clock face, but more subtle disturbances of clock-drawing may easily remain unnoticed. Patients who draw abnormal clocks will usually have other neurological signs or neuropsychological deficiencies; an abnormal clock may be ascribed to the underlying disorder with little attention given to the nature of the specific abnormality.

We obtained 87 clocks drawn by patients with a variety of neurological diseases seen in consultation and by age-matched controls we contacted. We propose a set of criteria for clock-scoring based on the abnormalities observed. The patterns on the clock-drawing test in two well-defined groups of patients, non-demented patients with Parkinson's disease (PD) and patients with probable Alzheimer disease (pAD) were correlated to other neuropsychological assessments. A qualitative analysis of the errors made by patients with specific disorders was used to formulate a concept regarding their etiology.

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## Methods and subjects

Subjects were patients seen in consultation on the Medical, Surgical, or Neurological Services or the Outpatient Department. Neurologic diagnoses were confirmed by examination and for dementia the Diagnostic and Statistical Mental Disorders (revised third edition: DSM-III-R) was used as a guide (American Psychiatric Association, 1986). For Alzheimer's disease, NINCDS-ADRDA criteria (McKhann *et al.*, 1984) were used and the chart was reviewed to qualify the diagnosis. For Parkinson's disease (PD), the presence of at least two of the following clinical signs was required: resting tremor, bradykinesia, simian posture, rigidity or shuffling gait. For stroke, computed tomography of the lesion was required. Patients with other neurological diagnoses were also tested. These subjects were grouped as nondemented neurological controls and most had disorders not affecting mental function. Controls were either spouses or hospitalized patients without neurologic disease, but within the same age range as the subjects. Eighty-seven subjects were tested. The following groups were examined: controls (CTL, $n=16$), AD ($n=24$) PD without dementia ($n=13$), cerebrovascular disease ($n=13$: multi-infarct dementia $n=4$; posterior cerebral artery stroke $n=1$; right parietal stroke $n=1$; left parietal stroke $n=1$; asymptomatic right frontal arteriovenous malformation $n=1$; right pontine hemorrhage $n=1$; left middle cerebral artery stroke $n=4$), other neurodegenerative diseases ($n=8$: PD with dementia $n=1$; Huntington's disease with dementia $n=1$ and without dementia $n=3$; chorea acanthocytosis $n=2$; unknown $n=1$), and other neurologic disease ($n=13$: radiculopathy $n=3$; seizures $n=3$; atypical motor neuron disease $n=1$; benign senescent forgetfulness $n=1$; basilar artery migraine $n=2$; Wernicke's encephalopathy $n=2$; multiple sclerosis $n=1$). The three principal groups (CTL, PD, and pAD) comprised 53 subjects who were similar in age: CTL = 61·25 (±9·13), AD = 62·71 (±9·51), PD = 64·23 (±8·95), F (2,50) = 0·19.

### *Clock Test*

Subjects were given a plain white sheet of paper with a circle (diameter = $4\frac{1}{2}$ in. printed on it, and instructed to fill in numbers, as if the circle represented a clock. The subjects were not timed.

Criteria for scoring the clocks are summarized in Table 1. A score of "1" is assigned to each of criteria 1 through 4 if the criterion is met; a score of "0" is assigned if the criterion is not met. For each of criteria A and B, a score of "−1" is assigned if the criterion is met, and a score of "0" is assigned if the criterion is not met. The total score is the sum of the scores of the 6 criteria. However, a total score less than zero is recorded as zero. The highest possible score is 4, the lowest is 0.

The clocks were evaluated by 3 examiners, all familiar with neuropsychological testing, none of whom received any information about the subjects. When a discrepancy arose as to whether a criterion was met or not, the decision of 2 scorers overruled the decision of the third. This occurred in 23 of 522 cases.

TABLE 1. *Criteria for Scoring Clocks*

Score 1 point for each of the following:

1. The symbol or marking used by the patient is recognized as a number.
2. The numbers are within the circumference of the circle, and are around its perimeter.
3. The numbers are in correct numerical order.
4. The numbers are placed symmetrically within the circle, in correct standard clock order. The distance between any two numbers is approximately constant throughout the clock.

Subtract 1 point for each of the following:

A. Stray lines (except for clock-hands) are present. (Not all patients were instructed to insert hands, so do not subtract a point if no hands are present.)
B. Extra numbers are present. The only acceptable numbers are the integers 1 through 12.

The total score is the sum of the above 6 subscores. However, a score of zero or less should be counted as zero.

The *Maximum* score is *four.*
The *Minimum* score is *zero.*

### *Neuropsychological Testing*

Scores on the Modified Mini-Mental State Examination (mMMS) (Mayeux *et al.*, 1981) were obtained retrospectively for 27 patients with pAD or PD; the Rosen Drawing Test (Rosen, 1981), the Block Design and Picture Completion subtests of the Wechsler Adult Intelligence Scale-Revised (Wechsler, 1981) were similarly obtained for twelve patients with AD.

### *Data Analysis*

We first compared the performance of the pAD and PD groups with controls. For each of these 2 groups we compared the total clock score with mMMS performance. In the pAD group, we also compared the total clock score with performance on the Rosen Drawing Test and the Block Design and Picture Completion subtests of the WAIS-R. In the second part of the analysis, we compared the performance patterns of the other neurologically impaired patients with the patterns observed in the AD, PD and CTL groups.

Comparison of the total clock score among the 3 diagnostic groups (CTL, pAD, PD) was determined by the Kruskal-Wallis H test (dKW). The *a posteriori* method in Kirk (1968) was used to test the significance of pairwise comparisons. Data were further analyzed by examining the fraction of each diagnostic group which met a given criterion. Comparison of these proportions among the groups with regard to a given criterion was determined by Fisher's exact test and the Chi-square test (Bailey, 1964). Correlation between the total clock score and the neuropsychological testing was determined by Spearman's rank correlation test (Colton, 1974).

## Results

### *Controls*

Controls performed uniformly well on all parts of the test (see Tables 2 and 3). Of 16 controls, 15 had a perfect score (i.e. met each of criteria 1 through 4 and failed to meet either criteria A or B). Only 1 control failed to meet criteria 2 and 4. No control inserted either stray lines or extra numbers. Controls also perform better than either the pAD and PD groups. With respect to total clock score, the 3 groups do not perform equally ($H=31{\cdot}3$, $p<0{\cdot}001$). In pairwise comparisons, the CTL group performs better than both the pAD group ($d=27{\cdot}81 > dKW=18{\cdot}53, p<0{\cdot}001$) and the PD group ($d=14{\cdot}65 > dKW=14{\cdot}10, p<0{\cdot}05$). The distribution of the PD scores and the pAD scores also was significantly different ($d=13{\cdot}15 > dKW=13{\cdot}01$, $p<0{\cdot}05$).

### *Alzheimer's Disease and Other Dementias*

Of the 31 patients with dementia tested, 24 met criteria for pAD. The other 7 patients included 4 with multi-infarct dementia, 1 with PD and dementia, 1 with Huntington's disease and the patient with an unknown degenerative disorder. All of these subjects performed as well as controls with respect to criterion 1 but failed on the other 5 criteria (see Table 4).

TABLE 2. *Distribution of total clock score in 3 diagnostic groups*

| *Total Score* | *CTL (n=16)* | *pAD (n=24)* | *PD (n=13)* |
|---|---|---|---|
| 0 | 0 | 7 | 0 |
| 1 | 0 | 8 | 2 |
| 2 | 0 | 6 | 4 |
| 3 | 1 | 2 | 4 |
| 4 | 15 | 1 | 3 |

(CTL = control, pAD = probable Alzheimer's disease, PD = Parkinson's disease)

TABLE 3. *Proportion of each diagnostic group fulfilling a given criterion*

| *Criterion* | *CTL (n=16)* | *pAD (n=24)* | *PD (n=13)* | *chi-square* | |
|---|---|---|---|---|---|
| 1 | 16/16 | 21/24 | 13/13 | 3·65 | $p<0.10$ |
| 2 | 15/16 | 7/24 | 5/13 | 16·86 | $p<0{\cdot}001$ |
| 3 | 16/16 | 14/24 | 13/13 | 15.13 | $p<0{\cdot}001$ |
| 4 | 15/16 | 4/24 | 4/13 | 24.38 | $p<0{\cdot}001$ |
| A | 0/16 | 9/24 | 1/13 | 10.21 | $p<0{\cdot}01$ |
| B | 0/16 | 8/24 | 0/13 | 11.39 | $p<0{\cdot}01$ |

(CTL = control, pAD = Alzheimer's disease, PD = Parkinson's disease)

TABLE 4. *Fraction of control (CTL) and dementia groups fulfilling a given criterion*

| *Criterion* | *CTL (n=16)* | *Dementia (n=31)* | *chi square* |
|---|---|---|---|
| 1 | 16/16 | 27/31 | 2·25 $p>0·10$ |
| 2 | 15/16 | 21/31 | 16·03 $p<0·001$ |
| 3 | 16/16 | 14/31 | 10·29 $p<0·01$ |
| 4 | 15/16 | 26/31 | 16·32 $p<0·001$ |
| A | 0/16 | 12/31 | 8·32 $p<0·01$ |
| B | 0/16 | 8/31 | 4·98 $p<0·05$ |

Patients with pAD performed as well as controls on criterion 1 (21/24 fulfilling the criterion vs. 16/16). However, with respect to the other 5 criteria, the pAD group's performance does not equal that of the control groups (for criteria 3 and 4, $p<0·01$; for criteria 2, A and B, $p<0·05$).

Of the 24 patients with pAD, performance data on the mMMS were available for 20 patients. The total clock score correlated well with the total score on the mMMS ($r=0·695$, $p<0·01$). In 12 patients with pAD, the total clock score did not correlate with Block Design, Picture Completion, and the Rosen Drawing Test.

### *Parkinson's Disease*

The pattern of performance of the PD group differed somewhat from that of the pAD group (see Table 3). Patients with PD perform as well as controls with respect to criteria 1, 3, A, and B. However, with respect to criteria 2 and 4, patients with PD did not perform as well as controls ($p<0·001$).

For 7 patients with PD, the mMMS did not correlate with the total clock score.

### *Other Neurologic Disease*

The performance pattern of the remaining 34 patients appeared to depend on the presence or absence of dementia. Those patients with disease confined to the spinal cord performed as well as controls. Similarly, those patients with focal cerebral disease but without dementia (e.g. 1 patient with basilar artery migraine, 1 with right frontal arteriovenous malformation, 1 with a left parieto-occipital arteriovenous malformation, 1 with temporal lobe seizures, etc.) also performed as well as controls.

## Discussion

Patients with pAD, as well as those with other dementias, demonstrated diffuse abnormalities in clock-drawing abilities. While they were able to use numbers appropriately, they exhibited severe difficulty in placing the numbers within the circle's border, made frequent sequence errors, and were unable to place the numbers in a symmetric fashion. Patients with pAD also

had a tendency to insert stray lines into their clocks and frequently used extra numbers. The cases below illustrate these features.

*Case 1: (Fig. 1A)*

Seventy-nine-year-old woman with pAD (mMMS = 23, Clock score = 1). She used numbers as appropriate symbols. Although the numbers are within the boundary of the circle, they do not border the perimeter closely. The numbers are in correct numerical sequence, but are not in standard clock order (the 12 is not at the top, nor is the 6 at the bottom). There is poor symmetry: the numbers appear stacked one on top of the other in two columns. Stray lines are present, which serve to segment the clock.

*Case 2: (Fig. 1B)*

Sixty-seven-year-old woman with pAD (mMMS = 33, performance on WAIS-R Block Design and Picture Completion is normal, Clock score = 1). Her clock reveals two features we observed frequently in other pAD patients: extra numbers are present (the correct numerical sequence of the numerals suggests that this may be a form of preservation), and extra lines have been inserted (note that not every number along the circumferences of the circle has a line corresponding to it). However, she was able to place her numbers relatively symmetrically.

*Case 3: (Fig. 1C)*

Seventy-two-year-old man with pAD (mMMS = 36, Rosen Drawing Test, WAIS-R Picture Completion and Block Design subtests are all very poor, Clock score = 1). This clock exhibits some of the patterns commonly seen in patients with pAD: Numbers are used appropriately, but the numerical sequence is incorrect (12–1–13–15–230–330, etc.). Only one hand of the clock has been drawn, and that hand does not point directly to one of the numbers. While all the numbers fall within the circumference of the circle, they are not arranged symmetrically. Although this pattern suggests hemi-neglect, the patient was aware of the left side of space because he wrote the incorrect date in the lower left-hand corner of the page which fell outside the boundary of the circle. This is not shown in the figure, however.

*Comment.* The strong correlation between total clock score and the mMMS suggests that it is generalized impairment in intellectual function which gives rise to abnormal clocks in pAD, and not an isolated deficit in constructional ability. The abnormalities noted in the clocks above (lack of organization and presence of stray lines in Fig. 1A, perserveration and stray lines in Fig. 1B, incorrect numerical sequence, extra numbers, and possible neglect in Fig. 1C) all point to gross impairments in intellectual function. These cannot all be attributed to isolated constructional deficits.

Constructional deficits occur in pAD and the Block Design Test (WAIS-R) and the Rosen Drawing Test are both defective (Rosen, 1983). Clock-drawing is also a constructional task, so it is not surprising that clock-

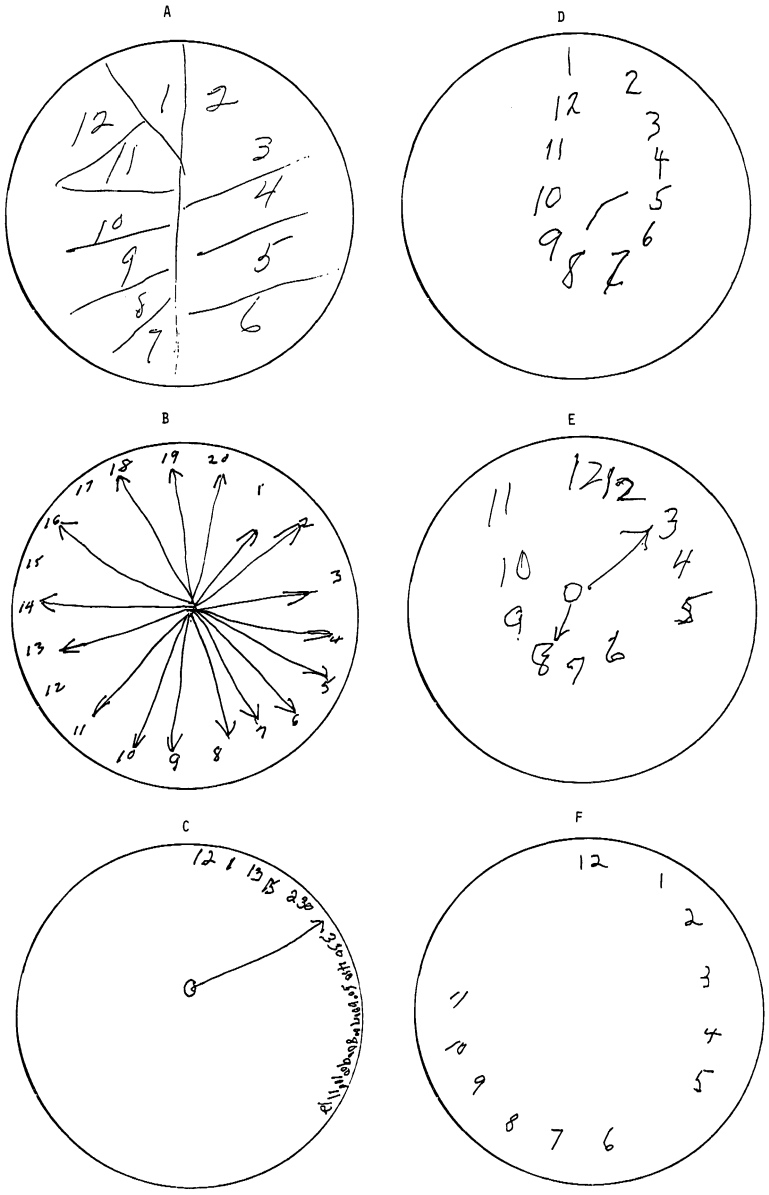


FIG. 1. Clocks drawn by patients with pAD or PD.
A. Clock drawn by a 79-year-old woman with pAD. The numbers are not bordering on the perimeter, the symmetry is poor, and stray lines are present.
B. Clock drawn by a 67-year-old woman with pAD. Extra numbers and stray lines are present.
C. Clock drawn by a 72-year-old man with pAD. The numerical sequence is incorrect, and the symmetry is poor.
D. Clock drawn by a 76-year-old man with PD. The numbers are crowded toward the center of the clock and appear stacked in two columns.
E. Clock drawn by a 74-year-old man with PD. The numbers are grouped in distinct clusters.
F. Clock drawn by a 64-year-old woman with PD. There is a wide gap between the 5 and 6, and between the 11 and the 12.

drawing is severely impaired in pAD. The lack of correlation between the total clock score, the Rosen Drawing Test, the Block Design and Picture Completion subtests of the WAIS-R may indicate that a different aspect of construction ability is involved in drawing a clock. Clock drawing may require planning, conceptualization and organization that simple copying tasks do not. However, the lack of correlation may also be due to the small number of pAD patients studied and the scores on the neuropsychological tests were well below average and spanned only a small part of those tests' scales.

The pattern of diffuse abnormalities in clock-drawing observed in pAD is also seen in patients with dementias of other etiologies. This finding suggests that generalized intellectual impairment gives rise to these deficits.

Non-demented patients with PD demonstrate a distinct pattern of abnormalities. They are able to use numbers correctly, and they place numbers in correct numerical sequence. They do not insert stray lines, nor do they add extra numbers. Their deficits are limited to the placement of the numbers within the circle. While patients with PD place the numbers within the boundaries of the circle, they have difficulty in keeping the numbers along the circumference of the circle. Additionally, they encounter difficulty in placing the numbers symmetrically within the circle, tending to crowd groups of numbers in one place. The following cases illustrate these points.

*Case 4: (Fig. 1D)*

Seventy-six-year-old man with PD (mMMS = 44, Clock score = 2). He was able to use numbers appropriately and in correct numerical order, but was not able to keep the numbers along the perimeter of the circle. In addition to the crowding, there is also a degree of asymmetry to the clock (for example, the 1 is directly above the 12). Note that the hands of the clock, while equal in length, point approximately to the "twenty past eight" position, with respect to the numbers as he has placed them.

*Case 5: (Fig. 1E)*

Seventy-four-year-old man with PD (mMMS = 41, Rosen Drawing Test is normal, but Block Design test is markedly abnormal, Clock score = 2). He used numbers appropriately and sequentially. Like the previous patient, he was unable to keep the numbers around the perimeter of the circle, and tends to crowd them toward the center of the circle. The 12, 1 and 2 are grouped together at the top of the clock, the 3, 4, and 5 form a second cluster of numbers, while the numbers 6 through 10 form their own separate grouping. The 11 is not grouped with any other number. He uses neither extra lines nor extra numbers.

*Case 6: (Fig. 1F)*

Sixty-four-year-old woman with PD (Clock score = 3). She was better able to keep the numbers along the perimeter of the circle. Like the previous patient she placed the 12 in the correct position, but was unable to place the numbers 1 through 5 equidistant from each other. The result is a more subtle form of crowding than was noted in either of the previous 2 clocks. The first 6 numbers (12–5) have been crowded together. The patient realized this error, and attempted to compensate by placing the 6 in the correct position (note that there is no over-compensation). This self-correction leads to a wide gap between the 5 and 6. As she filled in the numbers 6 through 11, the same form of crowding occurs, resulting in a large space between the 11 and the 12. Variations of this pattern were seen in several clocks drawn by patients with PD.

## Comment

In contrast to what was found in pAD, there is no correlation between total clock score and the mMMS in PD. The lack of correlation between the mMMS and the total clock score should not seem surprising in light of the qualitative findings outlined above: the errors in PD are not suggestive of intellectual impairment (the numerical sequence is intact, there are no stray lines or extra numbers, the underlying organization of the clocks is essentially normal). While the abnormalities in pAD may be ascribed to generalized intellectual impairment as well as to poor constructional ability, the abnormalities seen in PD clocks may reflect more specific deficits of perceptual motor coordination. For example, the tendency to crowd the numbers near the center of the circle may actually represent a form of micrographia, while the poor spacing of numbers observed in Fig. 1F may be the result of an inability to plan and monitor one's movements properly.

Much has been written about the role of perceptual motor dysfunction in the constructional deficits observed in patients with PD (Mayeux and Stern, 1983). Current theory about the role of the basal ganglia in intellectual function assigns to them a role in the planning, sequencing, modulating and modifying of behavior (Stern, 1983). It is conceivable that the abnormalities seen in the clocks of PD patients represent an inability to plan, sequence and modulate behavior.

Clock-drawing is impaired in a variety of neurologic diseases. The types of abnormalities noted differ depending on the specific neurologic condition involved. Specifically, only those patients with dementia, regardless of the etiology, exhibit diffuse abnormalities of clock drawing. This finding suggests that if the clock-drawing test were to be used as a screening test, the finding of a diffusely abnormal clock may be suggestive of a dementia. On the other hand, a clock face with limited abnormalities may indicate either a dementing or a non-dementing neurologic condition. The nearly perfect performance of the control group in all aspects of clock-drawing suggests

that any abnormality in clock-drawing may indicate some type of neurologic disease. However, patients with psychiatric disorders would need to be examined before clock drawing could be recommended as a screening test.

The data presented here are retrospective. A prospective study of clock-drawing, in which a randomly selected group of subjects is given the clock-drawing test, followed by both a neurologic and neuropsychologic evaluation may confirm our hypothesis. If such a study shows that an abnormal clock is both specific and sensitive for neurologic disease (or that a diffusely abnormal clock is specific and sensitive for a dementing disease), then the clinician may have a rapid screening test at his or her disposal in the evaluation of a patient in whom dementia or other intellectual impairment is suspected.

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