The Digital Clock Drawing Test (dCDT) - I: Development of A New Computerized Quantitative System

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BACKGROUND

The Digital Clock Drawing Test (dCDT) is a computerized quantitative system that provides standardized, operationally defined scoring with minimal effort and unparalleled precision.

Traditional clock drawing tests are widely accepted cognitive screening tools that measure constructional apraxia, perceptual and executive dysfunction, visuospatial and memory deficits, and general deficits in the conception of time. They are unfortunately subject to significant variation in variables measured, require labor-intensive scoring systems, and rely on subjective judgments and broad qualitative properties (e.g., is hand placement correct, slightly in error, significantly in error, etc.), resulting in classification errors. There is a clear need for a standardized, operationally defined, automatic scoring system.

SUBJECTS AND METHODS

Patients draw command and copy clocks using paper with a faint dot pattern (Fig. 1) and a digitizing pen (Anoto Inc) that works as an ordinary ballpoint while capturing pen position 80 times/second at ±.002". The pen stores data as the user draws; data is later downloaded to the computer when the pen is docked (Fig. 2). Our program analyzes the data, classifying each pen stroke as a clock face, digit, etc. The program's color-coded display makes the classifications clear to the user; its drag-and-drop interface facilitates classification error correction (Fig. 3).

Fig. 1. Dot pattern, detected by pen camera, indicates pen position on the paper.

(Figure by Anoto)

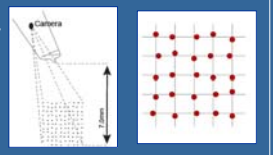


Figure 2. Digital Pen & Cradle

- Pen can store hundreds of clock drawings
- Data automatically transferred to computer when the pen is docked

(Picture provided by Anoto)

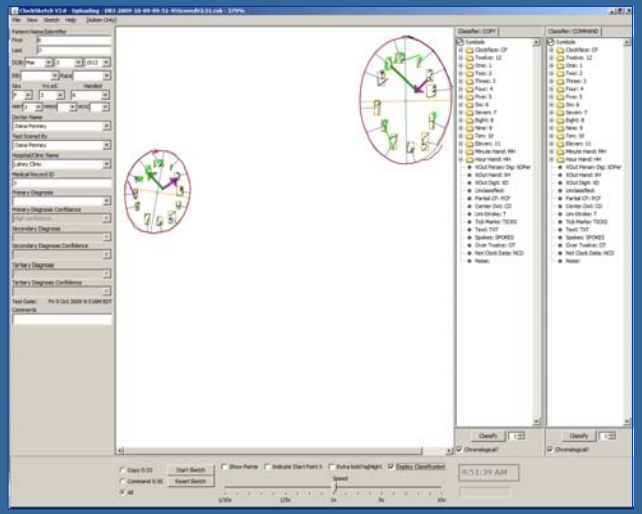
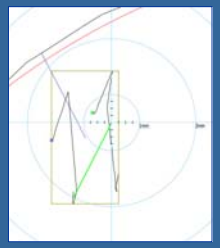


Figure 3: dCDT display – three panels
Left: Patient demographic data, entered via drop-down menus
Middle: Resizable views of the clocks.
Right: Current analysis, easily modifiable via drag and drop.



What is a "*Hooklet*" ?

- sharp turn at end of a stroke that heads toward the next stroke
- detected automatically
- shown in green on the display
- may indicate executive functioning, motor preparatory set planning

Figure 4. Digit 11, zoomed 10x, revealing details not normally visible, including hooklet on the first "1", indicated by a green line.

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RESULTS

- The program's initial classifications can be up to 84% accurate (e.g., on healthy controls), making test interpretation fast and easy.
- Because pen strokes are digitized, hundreds of measurements operationally defined in our software are carried out instantly, with no additional effort by the clinician, including, e.g., total drawing time; time taken to draw each clock hand and each digit; degree of symmetry of the clock face; average distance of the digits from the clock face; count of digits outside the clock face; and accuracy of digit placement.
- The data is time-stamped, capturing representations of behavior and enabling the program to run a movie of the drawing, assisting in making sometimes-difficult clinical judgments.
- The spatial resolution of the pen enables enlarging the drawing by up to 100x, making apparent phenomena fractions of a millimeter in size (Fig. 3), not otherwise visible on the paper. We hypothesize that some of these previously invisible variables captured by the dCDT may be valuable early diagnostic markers. Data are easily exported for consultation, re-analysis, or inclusion in electronic medical records.

CONCLUSIONS

The dCDT is fast and easy to use, delivers precise measurements that can be used to improve diagnostic accuracy, to monitor cognitive change and treatment efficacy. Electronic form is easy to transmit and use in research, improves communication and is readily placed in electronic medical records. The dCDT automates the capture of the drawing process, analysis, and reporting of results for the clock drawing test, providing the foundation for operationally defined test analysis.

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