

The test of time: a history of clock drawing

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Objective: The clock drawing test (CDT) has become one of the most widely used cognitive screening instruments in clinical and research settings. Its effectiveness, acceptability, and quick and easy administration have made it a staple for cognitive screening in dementia and a wide range of brain disorders. Despite a spike in popularity since the 1990s, its origins are relatively unknown. The goal of this review is to chronicle its saga and chart its usage over time.

Methods: PsycInfo, Medline, and PubMed literature searches were performed from earliest record to June 2016, in addition to manual cross-referencing of bibliographies, with a focus before 1990. Summary of relevant articles and books up until 1989 is included, as well as clinical applications and surveys that track CDT usage over time.

Results: While MacDonald Critchley's well-known textbook from 1953, *The Parietal Lobes*, is often cited as the first mention of the CDT, its recorded use actually stretches back more than a century to 1915. A review of the literature shows that the CDT began as a test for aphasia-related disorders and constructional apraxia until its entry into contemporary cognitive screening in the 1980s when it primarily became a cognitive screen. Its usage took off in 1989 with over 2000 publications since.

Conclusions: Despite a fairly obscure existence for decades, the CDT has emerged as an effective and ideal cognitive screening instrument for a wide range of conditions. Its use continues to increase, and it has been incorporated into several widely used cognitive screening batteries. Copyright © 2017 John Wiley & Sons, Ltd.

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Introduction

The clock drawing test (CDT) has become one of the most commonly used cognitive screening instruments (Rabin *et al.*, 2005; Shulman *et al.*, 2006; Ismail *et al.*, 2010). An ideal cognitive screening instrument has the following characteristics: (a) quick administration; (b) acceptable to patients; (c) easy to score; (d) relatively independent of culture, language, and education; (e) good inter-rater and test–retest reliability; (f) high levels of sensitivity and specificity; (g) correlation with measures of severity and other dementia rating scores; and (h) predictive validity (Tuokko *et al.*, 1992; Shulman, 2000; Ismail *et al.*, 2010; Wagner *et al.*, 2011). The CDT satisfies all of

these criteria and also tests a wide range of cognitive skills including comprehension, planning, visual memory and reconstruction, visuospatial abilities, motor programming and execution, numerical knowledge, abstract thinking, inhibition of pull by perceptual features, concentration, and frustration tolerance (Mendez *et al.*, 1992; Royall *et al.*, 1998; Shulman, 2000).

The CDT has primarily been used for screening of cognitive impairment in Alzheimer's disease and other dementias (Kitabayashi *et al.*, 2001; Wiechmann *et al.*, 2010). It has also been utilized with patients suffering from other brain disorders including postoperative delirium (Manos, 1998), Huntington's disease (Rouleau *et al.*, 1992), Parkinson's disease (Saka and

Elibol, 2009), stroke (Cooke *et al.*, 2010), traumatic brain injury (Wagner *et al.*, 2011), schizophrenia (Herrmann *et al.*, 1999), and metabolic syndrome (Viscogliosi *et al.*, 2015).

Despite its widespread use, there is no standardized approach to administration and scoring of the CDT. Clinicians and researchers may require the patient to draw the entire clock face, known as free-drawn (Freedman *et al.*, 1994), while some may provide the patient with a pre-drawn circle (Shulman *et al.*, 1986). Some clinicians may also include what is known as a clock copying task, whereby patients copy a model (Royall *et al.*, 1998); a clock setting task, whereby patients manipulate or draw in just the hands on a clock face (Goodglass *et al.*, 1983); or a clock reading task, whereby patients state the time displayed on a clock model (Tuokko *et al.*, 1992). Although many different studies have used a variety of different time settings, the time of “10 after 11” has emerged as the most popular because of its ability to assess a variety of errors, most notably what is called the frontal pull, a stimulus bound phenomenon whereby one of the hands may be pulled towards the “10” (Kaplan, 1990; Mainland and Shulman, 2013). The instructions given to a patient may vary, but the paradigm usually follows:

In the case of a pre-drawn CDT: ‘This circle represents a clock face. Please put in the numbers so that it looks like a clock and then set the time to 10 minutes past 11.’

In the case of a free-drawn CDT: ‘Draw the face of the clock. Put in the numbers and set the time to 10 after 11.’

More than 20 different scoring systems have been developed with variable emphasis on the different cognitive functions that the CDT can assess (Pinto and Peters, 2009; Mainland and Shulman, 2013). Many of these scoring systems have also been tailored specifically to detect impairment related to specific disorders (Mendez *et al.*, 1992; Rouleau *et al.*, 1992). Some scoring systems follow a set of clear quantitative guidelines that outline certain components of the CDT that should be scored individually (i.e., number placement and number spacing) (Mendez *et al.*, 1992), while some follow a more abstract qualitative guideline for scoring (i.e., minor visuospatial errors and severe level of disorganization) (Shulman *et al.*, 1993). Despite the variability in scoring systems, it has been shown that simpler scoring systems are often better (Mainland and Shulman, 2013). Some also argue that the CDT may be used most appropriately

as a qualitative visual display of cognitive ability that can be tracked longitudinally (Shulman, 2000; Mainland and Shulman, 2013).

Methods

A literature review was conducted to determine the origins of the CDT. An electronic search in PubMed, Medline, and PsycINFO from 1860 to July 2016 using the keywords “clock drawing” returned 1962 results after duplicates were removed. Three articles were published before 1989, five articles were published in 1989 alone, and another 58 subsequently from 1990 to 1995. Thus, we decided to focus on publications before 1989, as we determined this to be the point where the CDT entered mainstream usage, and therefore, they would be considered part of the origins of the CDT. In addition to the three publications prior to 1989, we manually cross-referenced the bibliographies of these articles as well as books pertaining to the CDT. After determining the relevance of the publications to the history of the CDT, we were left with 12 publications, all published prior to 1989. These publications are all included in this review.

Clinical beginnings

In 1926 (Head, 1926), Sir Henry Head (1861–1940), a British neurologist, one of the pioneers of early 20th century neurology, authored *Aphasia and Kindred Disorders of Speech*, a work that has been called the magnum opus (Ashendorf *et al.*, 2013) of his decorated career. He reviewed what was known about aphasia and speech disorders and included many of his own analyses and clinical cases. Head conducted a battery of tests that assessed the drawing, reading, writing, and spatial abilities of the patients, particularly those suffering from aphasia. Contained within his battery are the “clock tests.” This is the first documented mention of clock tests in the literature. Head’s reasoning behind using the clock tests was that they required the execution of meaningful speech, an almost impossible task for people with aphasia. This is similar to the notable neurologist Karl Kleist’s (1879–1960) definition of constructional apraxia, which he described as impairment in the ability to convert visuospatial information into motor acts (Kleist, 1934). Some have suggested that this is where the connection between the two conditions was established and how clock drawing found its eventual niche in the screening for both of these conditions

(Ashendorf *et al.*, 2013). Head laid out a clear set of organized and standardized tasks involving clock reading, setting, and copying to be used clinically. Patients were asked to: copy the time of a clock onto another clock by manipulating the hands, state the time of this same clock, set a clock to verbal and written commands, verbally state the time shown on a clock, and write down the time as well. They were asked to do all of these tasks for as many as 15 different times including: 11:45, 12:50, 5:40, 7:10, 4:20, 1:30, 8:05, 1:55, 9:20, 2:30, 8:10, 8:45, 2:35, 11:20, and 5:40. Head elaborated on several clinical cases and his testing methods and results for each. Many of these cases included the administration of the clock tests with varying times selected from the aforementioned 15. He noted many different issues seen in patients including stating the correct time but writing down an incorrect time, slow completion, and overly focused attention when having to encode the time into a written form. Head recognized the value in the clock tests, at one point even referring to them as “a splendid method of revealing [a patient’s] disabilities” (Head, 1926). The earliest documented clinical case by Head that included the clock tests appears to be from 1915 highlighting the more than century-long history of the CDT.

From its first appearance in 1915 up until the 1970s, the CDT or “clock test” was used solely in a clinical setting. The first example following the publication of Head’s textbook was a clinical case from 1934 (van der Horst, 1934). Van der Horst wrote that constructional apraxia was a condition that was not well known but was beginning to be studied. He described a patient with difficulty judging the spatial positioning of objects. Van der Horst administered a clock reading task, and the patient could not tell the time. This was considered a result of his inability to interpret the positioning of the clock hands. He used this test, in addition to a battery of others, to suggest that as an individual’s spatial sense deteriorates, it may lead to apraxia.

One year later, Mayer-Gross (1889–1961), a German trained psychiatrist, described six patients with constructional apraxia (Mayer-Gross, 1935). In all cases, the problems began with the loss of their directional awareness, decreased motivation as well as memory impairment. He administered several tasks to the patients, including clock reading and setting tasks. In four out of the six cases, the patients were unable to read the clock face, set the time on a clock on verbal command, or set the time on a clock to copy another.

In 1938, Muncie described a 56-year-old man who had been admitted to the Henry Phipps Psychiatric Clinic in Baltimore because of repeatedly striking himself on the head with a newspaper (Muncie, 1938). Muncie administered a set of tasks that assessed speech, reading, writing, and copying as well as praxis. He used the CDT to assess constructional apraxia specifically, referencing the work of Mayer-Gross. He administered clock reading and setting tasks. He noted that the patient “[told] time poorly,” and when asked to set a clock model, he only appeared to recognize the hour hand while ignoring the minute hand.

In this same year, Lyman *et al.* presented the case of a middle-aged Chinese man with a left occipitoparietal brain tumor (Lyman *et al.*, 1938). This case was interesting because of the patient’s fluency in both Chinese and English. The clinicians believed this would allow them to assess alexia and agraphia in both languages. When assessed before the operation to excise the tumor, the patient made a few errors on each of the clock reading, setting, and copying tasks. The clinicians re-administered their battery of tests to the patient postoperatively, and the patient was slow to complete the clock tasks and made mistakes initially, although he usually corrected them fairly quickly. The clinicians also administered a clock setting task with written commands in both languages. No difference was found in the results between the languages. This paper is the first time the clock tests were used to track patient improvement longitudinally, in this case, to assess preoperative and postoperative cognitive changes. The use of the clock test to track patient progression would later become a central feature of the CDT.

Stengel recounted the case of a woman in 1944 with eclampsia and seizures (Stengel, 1944). He used this example to explore the relationship between loss of spatial orientation, constructional apraxia, and Gerstmann’s syndrome which includes right–left disorientation, finger agnosia, acalculia, and agraphia caused by lesions in the left parietal lobe (Critchley, 1953). Despite recovering certain abilities in the months following her eclampsia, she continued to have seizures and sometimes walked into objects. Stengel administered a set of tests to screen for apraxia including a battery of spatial awareness tasks that incorporated clock reading. The patient made errors that were characterized as “mirror-mistakes,” whereby she misinterpreted the set time, such as “12:55” being read as “5 to 11.” Stengel hypothesized that constructional apraxia and Gerstmann’s syndrome may be “united ... [by] a common denominator ... the loss of orientation in space” (Stengel, 1944).

In 1953, famed British neurologist MacDonald Critchley (1900–1997) penned his most well-known work, *The Parietal Lobes* (Critchley, 1953). This expansive volume covered nearly all medical conditions known to relate to the parietal lobe. It included the first comprehensive review of the often mentioned constructional apraxia. He cited the work of Kleist, Lyman, Mayer-Gross, Muncie, Stengel, van der Horst, Mcfie, and Zangwill to help describe the condition and the various tests performed to screen for it. These included reading, writing, drawing, and other spatial tasks. One of these is the clock test in which he assessed both clock setting and clock drawing tasks. He mentioned a previously uncited clinical case of a patient with a right temporo-parietal glioblastoma who was unable to complete a clock setting task. He stated that this was an example of the time-telling difficulties commonly seen in those suffering from constructional apraxia. He showed several clocks drawn by patients and noted commonly made errors such as mirror reversals, number crowding, and symbol omission. This section is particularly notable as it is the first mention of a free-drawn clock drawing task, a test that later became one of the most popular clock tests (Mainland and Shulman, 2013). This expansive chapter on constructional apraxia is often cited by contemporary papers as the first mention of clock drawing; but as noted, Critchley himself drew from sources that preceded his work by several decades.

Mcfie and Zangwill's paper from 1960 outlined a series of clinical cases involving patients with left cerebral lesions who had "visual-constructive disabilities" (Mcfie and Zangwill, 1960). In the first case, the patient's performance on visual-constructive tasks was impaired. Included in these tasks was a clock setting exercise with which the patient struggled. Interestingly, even though this paper was published in the 1960s, the literature cited is primarily restricted to a narrow spectrum of works by Head, Mayer-Gross, and Critchley.

Eddy and Sriram's, 1977 letter to the editor in *Neurology* took a more conceptual approach to the understanding of clock drawing and time, including a case (Figure 1) that displayed the stimulus-bound errors commonly made during clock drawing (Eddy and Sriram, 1977). They also reinforced the commonly held belief that clock drawing had been used primarily by "pragmatic neurologists" for a long time, perhaps "since higher cortical function became a legitimate object of medical attention."

These works all showed the clock test being used to test for visuospatial impairment and more specifically



Figure 1 (Pending permission) The clock drawn by the patient in the second case discussed by Eddy and Sriram. The patient drew a clock with numbers and names of days (e.g., Mon., Wed., and so on). As it turns out, the wristwatch that the patient wore displayed the day of the week. This suggested that a patient's clock drawing may be influenced by the clock face that they are most commonly exposed to—perhaps a stimulus bound phenomenon or conceptual problem. Adapted from Eddy and Sriram (34).

constructional apraxia. Nearly all of these articles cited the same authors and publications demonstrating how limited the research was in the field of both constructional apraxia and clock drawing up until the 1980s.

Edith Kaplan and the rise of the clock drawing test until 1989

Edith Kaplan (1924–2009), a pioneer in neuropsychology, along with her colleague Harold Goodglass (1920–2002) co-authored *The Assessment of Aphasia and Related Disorders* in 1972 while working at the Boston VA Medical Center. Subsequently revised multiple times, this book was a systematic review and outline of their comprehensive tests for aphasia—including the Boston Diagnostic Aphasia Examination, Boston Naming Test, and Parietal Lobe Battery, later renamed the Spatial Quantitative Battery (Goodglass *et al.*, 1983). These three tests were meant to provide an all-encompassing picture of a patient's verbal and visuospatial abilities. The Spatial Quantitative Battery was a set of "spatial-quantitative tasks" that primarily screened for agnosia, acalculia, right–left confusion, and constructional apraxia. Contained within this battery were clock drawing and clock setting tasks. In the first clock drawing task, patients were instructed to "draw the face of a clock showing the numbers and the two hands, set to ten after eleven" (Goodglass *et al.*, 1983). This task was scored on a scale of 0 to 3 with a point given for the contour of the face, symmetry of number placement, and correctness of numbers.

“Ten after eleven” was the time setting deemed most effective by Kaplan herself (Kaplan, 1990). Then, the examiner asked the patient to copy an already drawn clock. This clock is scored in the same way the previously drawn clock was scored. The drawing and copying tasks were strongly correlated with each other (Goodglass *et al.*, 1983). The third task, an exercise in clock setting, presented the patient with four clock faces with short lines denoting where the numbers would appear. They are asked to set the times on the respective clock faces to 1:00, 3:00, 9:15, and 7:30. Each clock is scored on a scale of 0 to 3 with one point awarded for the correct placement of each hand and one point for drawing the appropriate length of the

hour and minute hands. Interestingly, performance on the clock drawing tasks correlated only with spatial-quantitative tasks; however, performance on the clock setting task correlated not only with spatial-quantitative tasks but also with language tasks. Because hand placement was only scored on the clock setting task and not the clock drawing tasks, they suggested that errors in hand placement may be sensitive to impairment that goes undetected by clock drawing alone.

Goodglass and Kaplan also collected data from people with aphasia for all three tests and each of the subtests contained within (Goodglass *et al.*, 1983) and built the first ever dataset of quantitative clock test

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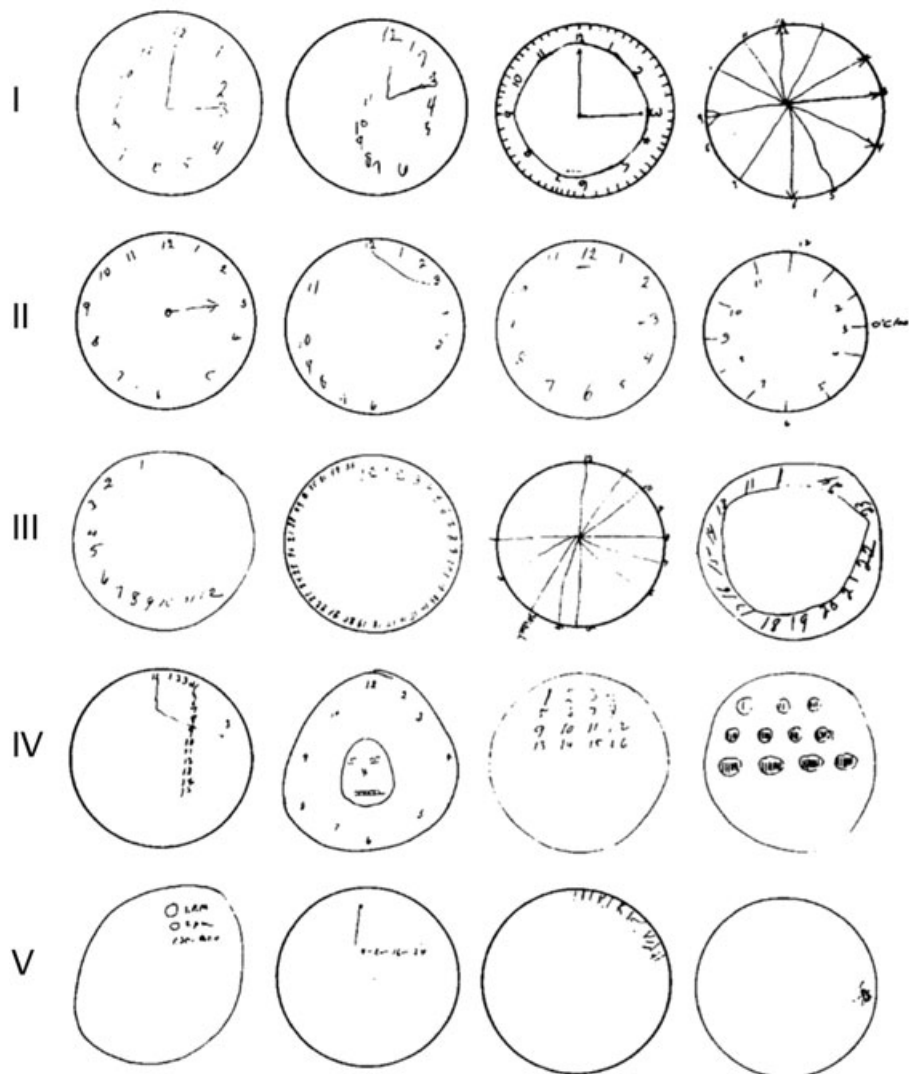


Figure 2 (Pending permission) Clinical examples of clocks drawn by patients that were sorted into each of Shulman’s scoring categories. A variety of errors is evident including issues with the presence and placement of both numbers and hands. Adapted from Shulman *et al.* (18).

results. The clock drawing and copying tasks were part of the “drawing to command” section, which included several other drawing tasks. This whole section was assessed with one blanket score making it impossible to discern the scores specific to clock drawing and copying. However, clock setting was its own individual section, and data specific to this task are therefore available.

It is of particular interest that clock drawing was the favorite test of Edith Kaplan (Ashendorf *et al.*, 2013). She was so fond of the CDT that if she only had a brief period of time with a patient, she would administer a free-drawn CDT with the hands set to her signature “10 after 11” followed by a clock copying task using the same time setting. Her love of the CDT was “based not so much on how well patients performed but on the variety of errors made by patients” (Ashendorf *et al.*, 2013). This is reminiscent of Head’s sentiment that clock drawing was a remarkable way to expose patients’ disabilities (Head, 1926). Kaplan’s work brought clock drawing

into the contemporary sphere of cognitive screening starting in the 1980s.

Ken Shulman was exposed to the clinical use of the CDT while training in geriatric psychiatry at the Institute of Psychiatry in London, England, with Felix Post and Raymond Levy. He began to incorporate the CDT regularly into his assessments of older adults. In 1986, after his return to Toronto, Canada, Shulman and colleagues conducted the first systematic validation of the CDT (Shulman *et al.*, 1986). They created a scoring guideline that classified errors into five levels of severity with 1 representing least impaired and 5 representing most severely impaired (Figure 2). They selected 75 elderly subjects, composed of individuals with cognitive disorders, major affective disorders as well as a group of “normals.” They administered the CDT as well as the Mini-Mental State Exam (MMSE), Short Mental Status Questionnaire (SMSQ), and the Geriatric Depression Rating Scale. They found significant correlations between the: MMSE and SMSQ, CDT

Table 1 Summary of all surveys tracking clock drawing test usage until the present

Study authors	Year published	Target audience	Surveys returned	Findings
Freedman <i>et al.</i> (17)	1994	International Neuropsychological Society and the Behavioral Neurology Society	335	63% of respondents stated that they used the CDT, 98% clinically and 40% in research.
Bush <i>et al.</i> (36)	1997	Family practitioners and GP’s in Ottawa, Canada	368	85% of respondents cited lack of time as a barrier to cognitive screening. 90% stated that they would be likely to use the CDT if proven effective, in large part because of its quick administration.
Reilly <i>et al.</i> 2004 (37)	2004	Geriatric psychiatrists in England and Northern Ireland	331	95% of respondents used the MMSE, 52% used the GDS, 50% used the CDT, and 31% used all three tests.
Shulman <i>et al.</i> (2)	2006	International Psychogeriatric Association, American and Canadian Academies of Geriatric Psychiatry	334	100% of respondents used the MMSE, 72% used the CDT, 56% used delayed word recall, 35% used the verbal fluency test, 27% used similarities, and 25% used the trail-making test.
Milne <i>et al.</i> (38)	2008	Primary care practices in Southeast England	138	51% of respondents used the MMSE, 50% used the CDT, and 8% used the two tests together.
Iracleous <i>et al.</i> (39)	2010	College of Family Physicians of Canada	249	76% used the MMSE, 52% used the CDT, 52% used delayed word recall, 13% used alternating sequences, and 5% used the MoCA.
Ismail <i>et al.</i> (40)	2013	Canadian Academy of Geriatric Psychiatry	155	91% of respondents stated that they were familiar with the CDT, 90% stated that they were familiar with the MMSE. 75% of respondents used the CDT routinely, 71% used the MMSE routinely. Respondents also associated the CDT with the following characteristics: (a) quick to administer; (b) easy to administer; (c) well tolerated; and (d) effective. The MMSE was only associated with the following characteristic: (a) easy to score.

CDT, clock drawing test; GP, general practitioner; MMSE, Mini-Mental State Exam; MoCA, Montreal Cognitive Assessment.

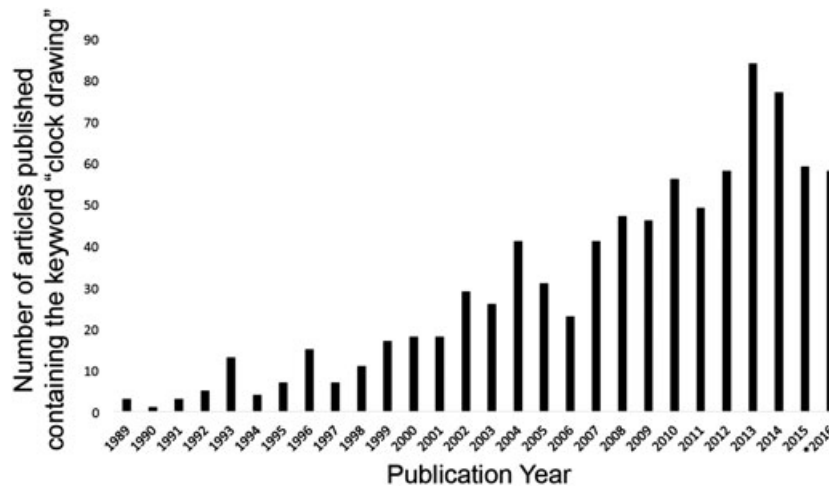


Figure 3 The year by year results of a literature search from the PubMed/Medline database for articles containing the keywords “clock drawing” from January 1, 1989 to June 30, 2016. A total of 847 publications were returned. *Only includes results from January 1 to June 30.

and MMSE, and CDT and SMSQ. Overall, 40% of clocks was assessed as reflecting cognitive impairment on their scoring system. They hypothesized that because their scoring system yielded a low false negative rate and a significant correlation with the MMSE, while also being easy to administer and acceptable to patients, the CDT could be a useful clinical screening instrument for dementia. Shulman and colleagues were more interested in screening for dementia than in documenting constructional apraxia or other visuospatial deficits. Their work, building on Kaplan’s enthusiasm for the CDT and recognition of its unique value, took this task out of the somewhat rarefied area of localized brain lesions that fascinated neurologists and neuropsychologists and into the larger clinical arena of dementia.

Usage of the clock drawing test by clinicians and researchers since 1989

Shulman’s 1986 study (Shulman *et al.*, 1986), in tandem with the work of Kaplan, seemingly sparked usage of the CDT as a screen for dementia or cognitive impairment. In 1986, Roth *et al.* (1986) incorporated the CDT into their comprehensive cognitive examination, the Cambridge Cognitive Examination (CAMCOG), and starting in 1989, a spike in literature involving the CDT is apparent. Three independent scoring systems were published in 1989 alone with six more appearing before 1995 (Mainland and Shulman, 2013). In the subsequent years since the CDT emerged in the mainstream of cognitive screening, there has been an increase in its usage as outlined in Table 1.

Recent findings suggest that the MMSE may lack sensitivity, be susceptible to biases and may have even “outlived its purpose” (Iraclous *et al.*, 2010; Nieuwenhuis-Mark, 2010). This may be contributing to the shift away from it and towards the CDT and other cognitive screens. The CDT can now be found as a part of several more recently developed and validated cognitive assessments: (a) the Montreal Cognitive Assessment (Nasreddine *et al.*, 2005), (b) the Mini-Cog (Borson *et al.*, 2000) (c) the 7 Minute Screen (Solomon *et al.*, 1998), and (d) the Kaplan–Baycrest Neurocognitive Assessment (Leach *et al.*, 2000).

A review of literature published on the CDT using the PubMed/Medline database, within the date range of January 1989–June 2016, returned a total of 847 publications containing the keywords “clock drawing”, 441 of those articles were published between January 1, 2010 and June 30, 2016 (Figure 3). When searching for articles containing the keywords “clock drawing” in the article title for the same time period, 244 publications were found, 99 of those articles were published between January 1, 2010 and June 30, 2016.

Conclusion

Despite its widespread use in cognitive screening, the CDT remained relatively obscure and untapped for a significant portion of its early existence. It was restricted to the clinical domain and was largely utilized as a screen for constructional apraxia. Although Edith Kaplan and a few other early pioneers facilitated the CDT’s entry into the realm of

contemporary cognitive screening, it was not until 1989 that the CDT began its ascent towards becoming one of the most widely used neuropsychological assessment instruments (Rabin *et al.*, 2005; Shulman *et al.*, 2006; Ismail *et al.*, 2010).

With an aging population, particularly the “baby boomer” cohort, it is expected that by 2029, more than 20% of the US population will be older than 65 (Colby and Ortman, 2014). This increase in the elderly population will also come with a higher prevalence of brain disorders, including Alzheimer’s disease and other dementias. Thus, a quick and effective cognitive screening tool is needed now more than ever to allow physicians to keep pace with this forthcoming increase in brain disorders. The CDT is an ideal cognitive screening instrument with high predictive validity and a quick, cost-effective administration (Shulman, 2000). These characteristics allow it to assist in fulfilling this need for a cognitive screening tool that can handle this increasing workload. Its ability to screen for mild cognitive impairment (Umidi *et al.*, 2009) is also valuable as this condition can often serve as a precursor to Alzheimer’s and other dementias, conditions in which early detection is key for monitoring the long-term changes related to these disorders (Levey *et al.*, 2006; Small *et al.*, 2007).

Although many attribute the first mention of the CDT to Critchley in 1953 (Lam *et al.*, 1998; Mainland and Shulman, 2013), its history actually stretches back more than a century to Sir Henry Head’s *Aphasia and Kindred Disorders of Speech*. While there have been concerns regarding its long-term use due to the advent of digital clocks (Clarfield and Bergman, 1990), we predict that it can remain an effective screening instrument for decades to come (Shulman, 2000). Future research should further assess the correlation between the CDT and other cognitive screening batteries so that it can be determined if it is valuable both on its own and as a supplement to these instruments.

The rise of the CDT from a scarcely used test for aphasia and constructional apraxia to one of the most widely utilized and versatile cognitive screening instruments makes its history a topic of interest for clinicians, researchers, and medical historians. A century later, it is clear that the CDT has stood, and will continue to stand, the test of time.

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Conflict of interest

None declared.

Key Points

- History of clock drawing test usage, evolution of the clock drawing test

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