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Clock Face Drawing in Children with Learning Disabilities: An Old Problem Revisited

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Although clock drawing as a neuropsychological measure has proven to be sensitive to the executive functioning of graphomotor skills, visual–spatial perception, and verbal reasoning, its discriminatory pattern in learning disabilities (LDs) is unclear. Therefore, the present study aims to investigate the clock-drawing test (CDT) performance as a screening measure in children with LDs. The population of this descriptive study includes all students who have been diagnosed with a specific LD in Ahvaz, Tehran, and Yasooj, in Iran. The convenience sampling method was used to select 104 participants, aged 8–12 years, matched for age and type of LD. The primary data was collected using the CDT and the data analysis procedures included frequency, percentage, and mean. The test results showed that the most common problems of the students with LDs involved neglect in placing quadrant numbers, stemming from attention deficiency as well as cognitive distortion; the least common problem was drawing both the hour and the minute hands on the clock face. Moreover, the findings indicated that there is the possibility of frontal, temporal, and parietal injuries among these students. It can, therefore, be concluded that the CDT is useful for the early prediction of brain injuries. Clock drawing is thus recommended to be used as a screening method for the prediction, assessment, and treatment of children with LDs.

Keywords**:** learning disabilities, clock face drawing test, diagnosis

The generic term 'learning disability' (LD) refers to a heterogeneous group of disorders present in psychological or neurological processes involved in the understanding or usage of oral and written languages. These disorders may be manifested in an imperfect ability to think, listen, speak, read, spell, write, and perform arithmetic calculations, indicating complications such as perceptual handicaps, minimal brain dysfunction, brain injury, mild aphasia, and dyslexia. In fact, learning problems that are primarily due to hearing, visual, and motor handicaps, mental retardation, and emotional disturbances, or economic, cultural, and environmental deprivation have been excluded from this definition (Lerner, 1997).

Many children have difficulty with reading, writing, and mathematical calculations at some point, but this does not mean they have LDs. A child with an LD often has several related symptoms that persist over time. The symptoms of LDs vary among individuals; these include difficulty with reading and writing, problems with math skills, paying attention, poor coordination, and concepts related to time. It is noteworthy that these symptoms alone are not enough to determine that an individual has an LD. A professional assessment is, therefore, necessary to diagnose a specific LD. For example, dyslexia or reading disorder is characterized by reading problems in children, despite their normal intelligence. Problems may include difficulties in spelling words, reading quickly, writing words, pronouncing words when reading aloud, and understanding what one is reading. Neuroimaging results support a neurophysiological model of reading skill acquisition disorder; according to this, dyslexia is associated with an atypical structural and functional development of posterior brain systems (Xu, Yang, Siok, & Tan, 2015). Previous studies indicated lower activity in the left hemisphere of the brain regions and disruption of posterior brain systems in dyslexic individuals (Im, Raschle, Smith, Grant, & Gaab, 2015). Further evidence of neuroimaging studies indicated that proficiency in word recognition is associated with the integrated performance of the left hemisphere posterior systems. Compared to typical readers, readers with disabilities rely more on the functions of the posterior right hemisphere and the inferior frontal regions to compensate for the disruption in their posterior left hemisphere systems; in normal people, the parietal-temporal and occipitotemporal areas are responsible for word analysis and recognition (Quercia, Feiss, & Michel, 2013).

Another LD called 'dyscalculia' is the defective representation or processing of numerical information that might be a result of numerical processing deficits, rather than deficits in other cognitive abilities (Landerl, Bevan, & Butterworth, 2004). Various studies, however, found specific deficits in the working memory (Geary, 2004, 2010), numerical sense (Geary, Hoard, Byrd–Craven, Nugent, & Numtee, 2007), and visual–spatial functions (Hecht, Torgesen, Wagner, & Rashotte, 2001) that have an influence on the development of dyscalculia. The involvement of the posterior part of the left and the right hemispheres, and some subcortical distributions, account for dyscalculia. These conclusions are based on studies conducted among adults with developmental calculation disorders. The defects are thus basically associated with brain lesions. Some neuroimaging findings reported structural disorders in the brains of adults with dyscalculia (Butterworth, Varma, & Laurillard, 2011), suggesting that the lower brain activity in children with dyscalculia is likely the result of anatomical changes. These studies showed significant differences in the activities of the prefrontal and the parietal regions in children with dyscalculia and these regions in normal children (Kucian et al., 2006).

Research conducted on dysgraphia, or the inability to write coherently, demonstrated deficiencies in fine motor skills, structural functions, visual memory, visual–motor integration, short-term memory, eye–hand coordination, and organizational ability (Rosenblum, Aloni, & Josman, 2010; Schmalzl & Nickels, 2006). Sakurai (2011) investigated the location of lesions associated with writing and reading disabilities, and concluded that the posterior occipital region (inferior occipital gyrus/posterior fusiform) lesion is associated with reading disabilities, whereas the posteromedial temporal region and the angular gyrus lesions are associated with writing disabilities. Although Sakurai, Mimura, and Mannen (2008) specifically emphasized the role of the left posteromedial temporal gyrus lesions in writing disabilities, the left angular gyrus plays a critical role in writing and dictation, and the left angular gyrus lesion is associated with writing disorders. In addition, the results confirmed the left posterior inferior temporal activation during spelling and writing. Therefore, writing and spelling disorders are associated with damage to the aforementioned areas (Rapcsak & Beeson, 2004).

Silver et al. (2006) stated that neurological evaluations not only involve clinical interviews with children and their parents, and the examination of their medical and educational reports, but also a series of tests that can be used to identify the areas of the brain which are associated with attention, executive functions, memory, language, visual–spatial abilities, sensory–perceptive functions, motor skills, educational activities, mental abilities, and emotional-behavioral functions (e.g. Edinburgh Handedness Inventory, Frostig developmental test of visual perception (DTVP), Illinois Test of Psycholinguistic Abilities, clock drawing test, etc.).

The clock drawing test (CDT), as one of the examples of the aforementioned tests, is a cognitive paper-pencil test to identify the extent of brain lesions (Serber et al., 2008). More than a decade ago, Eden, Wood, and Stein (2003) found that the test was a useful screening tool to detect visuospatial impairments in children with dyslexia. They concluded that many children with dyslexia exhibited significant left neglect as measured by the distribution of figures drawn on the left clock face. They observed spatial construction deficits attributed to the right posterior parietal hemisphere dysfunction. In another study conducted by Kibby, Cohen, and Hynd, (2002), the clock face drawing was tested in children with attention deficit hyperactivity disorder (ADHD). The obtained results indicated that errors attributed to poor planning during task execution, consistent with executive dysfunction, were common among children with ADHD. They concluded that a neuropsychological measure of executive functioning was predictive of clock construction performance in children with ADHD.

The CDT test performance requires several cognitive functions (e.g. executive and visual–spatial functions, and construction ability) and multiple interacting brain areas. Examining the probable relationship between CDT performance and the density of gray matter in the brain indicated that the gray matter density in cortical areas (frontal, temporal, parietal, and cerebellar) and subcortical areas (thalamus and basal ganglia) decreases in congruence with the poor performance on CDT. The CDT performance also depends on the integrity of the cortical and the subcortical areas, which are widely distributed in both hemispheres of the brain. The findings of several studies (Kim, Lee, Choi, Sohn, & Lee, 2009; Thomann, Toro, Dos Santos, Essig, & Schröder, 2008) showed that the combination of executive dysfunctions and the frontal subcortical cluttering as well as memory disorders resulted in worse CDT performance; the executive-cognitive functions were significantly associated with CDT performance. The main constituents of frontal-parietal cortical networks to draw the clock are the posterior-parietal cortex and the dorsal pre-motor regions (Ino, Asada, Ito, Kimura, & Fukuyama, 2003). Based on a study conducted by Friedman (1994, cited in Eden et al., 2003), patients who were suffering from right hemisphere damage tended to ignore the left half of the clock, thereby cramming all the numbers into the right side or omitting the numbers after six. Overall, it can be concluded that the more incomplete the drawing is, the more severe the injury seems to be.

Although the CDT is the second-most-used test in the world for the screening of specific disabilities, there is no consensus among scientific experts over its sensitivity, accuracy, interpretation, and application in LD diagnosis (Aprahamian, Martinelli, Neri, & Yassuda, 2010). To date, most of the literature on CDT is based on studies conducted in the American and European contexts, with limited research having been performed in Asian countries. Therefore, the present study attempts to fill a part of this gap by exploring the potential and identifying the challenges of the CDT to diagnose students with LDs in the Iranian context. Ganji, Zabihi, and Khodabakhsh (2013) found that CDT was an appropriate screening tool for the neuropsychological assessment of children with developmental dyslexia. Hooman, Ganji, and Farajolahi (2011) concluded that the reliability coefficient of the test was .765 using Cronbach's alpha. Moreover, its validity and test-retest reliability were .95 and .90, respectively. It can thus be concluded that the CDT enjoys appropriate reliability and validity levels for the cognitive assessment of children. This test requires a minimum amount of material and usually takes up to five minutes for the testers to administer. While simple tasks may not show its overall benefit, the processes used to draw a clock as well as the errors made by the examinees provide valuable sources of information for comprehensive assessment (Friedman, 1994, cited in Eden et al., 2003). Previous research showed that CDT was an appropriate instrument to assess the parietal performance of the right hemisphere, but defective clock drawing can reflect both cognitive and spatial neglect. Although much theoretical research on LDs has been conducted, very few studies have empirically addressed their different aspects (Soltani-Kouhbanani & Soltani-Kouhbanani, 2014). Expanding on this line of research, the CDT was used in the present study to examine the clock drawing pattern for the early diagnosis, evaluation, and treatment of children with LDs. In contrast with previous studies, the current study attempted to investigate reading, writing, and math-learning disabilities, and discuss them from a neuropsychological viewpoint.

Method

The population of the current descriptive study consisted of all the 8–12-year-old students with LDs in Tehran, Ahvaz, and Yasooj, Iran, who were studying in LD centers in the academic year 2014–15. The sample consisted of 104 students with LD. To select the sample of the study, the convenience sampling method was used. All patients who referred to the learning disorder centers of Tehran, Ahvaz, and Yasooj within the year were tested; those diagnosed with LD were included in this study. The inclusion criteria were thus having the common symptoms of the so-called LD, and the exclusion criterion was a lack of these symptoms. Table 1 presents the LDs, the name of the city, and the number of participants.

Table1
The LDs, the Name of the City, and the Number of Participants

City / Disorder	Ahvaz (N)	Tehran (N)	Yasooj (N)
Reading	1	1	1
Math	2	13	9
Writing	9	5	3
Math-writing	4	4	6
Reading-writing	6	11	4
Math-reading	2	1	2
Reading-writing-math	3	6	11
Total	27	41	36

After explaining the logic of the test, the researcher explained that participation was voluntary and refusal to participate would not result in any consequences or loss of benefits. The written consent forms were then received from the parents. Clocks and watches were removed from view, and children with LD were asked to complete the CDT developed by Cohen, Ricci, Kibby, and Edmonds (2000) as part of an extensive neuropsychological battery. The students were asked to draw a clock and set the time to read exactly '11'; they were not allowed to move the sheet or use an eraser to make corrections during the drawing period as we wanted their immediate response.

Although various scoring systems have been provided for clock drawing tasks since 1983, the scoring system of this study was based on the one provided by Cohen et al. (2000). Clock drawing tasks were thus scored for clock construction and the ability to set the time accurately, and the errors made by the examinees were investigated later based on the method provided by Kibby et al. (2002). This method included the following failures: errors in demonstrating the equidistant spacing between numbers, incorrect numerical sequences, omission or repetition of numbers, rotation or reversal of numbers, the inappropriate ratio of the hour hand length to minute hand, drawing the wrong hand for a given time, the neglect of any quadrant(s), a failure to draw the numbers '3, 9' and '6, 12' in front of each other, omission of the clock hands, and perseveration. Two raters, blind to our classifications, independently scored all the clocks for both construction and time. The results from the two raters suggested high inter-rater reliability for form (r =.94) and time (.98). After scoring, the two raters discussed and settled the discrepancies with the help of the researcher.

Results

Instructions for clock test implementation were given to the instructors of the LD centers of Ahvaz, Tehran, and Yasooj during a training session, and they were asked to administer the test on the sample. The data analysis procedures utilized in this study included a relative frequency percentage. A frequency percentage is a display of data that specifies the percentage of observations that exist for each data point or the grouping of data points. It is a particularly useful method of expressing the relative frequency of the errors made during the CDT. The relative frequency number is converted into a percentage by the following formula: $p = fi / N \times 100$, where p is the relative frequency percentage, fi is the absolute frequency, and N is the number of frequencies. Table 2 shows the type and relative frequency percentage of the errors made by the participants.

As discernible from Table 2, the highest error rate belongs to neglect in placing the quadrant numbers, which stems from attention-deficit disorder, and the lowest error rate belongs to drawing none of the clock hands. Table 3 indicates the type and relative frequency percentage of the errors made by the participants based on the different LDs of math, reading, writing, and their combinations.

Table 2
The Type and Frequency Percentage of Errors on the Clock Drawing Test

Type of Errors	Frequency percentage
1. Attention deficit and neglect in placing the quadrant numbers	91.*82*
2. Incorrect hand setting and wrong denotation of time	*50.64*
3. Drawing clock hands of equal length	*11*
4. Drawing only one of the clock hands	*10*
5. Drawing none of the clock hands	*0*
6. Perseveration	*5.76*
7. Clock hands (dotted) extension	*2.88*
8. Numbers crowded together	*36.77*
9. Incomplete numbering	*12*
10. Distorted numbering	*10*
11. Placing extra numbers	*1.92*
12. Numerical rotation	*45.54*
13. Distortion	*65.38*
14. Incorrect numerical sequence	*18.26*
15. Repetition of the numbers	*4.80*
16. Rotation of the clock screen	*20.26*
17. Drawing additional lines	*25.77*
18. Misplacing the numbers on the clock face	*42*.36

Table 3
The Type and Frequency Percentage of Errors based on Different LDs

Learning Disability / Type of Errors	Math	Reading	Writing	M-R	M-W	R-W	M-R-W
1	87.17	100	92.11	100	94.03	84	87.17
2	61.63	0	49.19	59.16	64.17	52.14	64.36
3	9.43	0	0	20.29	0	25.65	21.82
4	9.53	0	7.88	0	16.68	9.69	25.97
5	0	0	0	0	0	0	0
6	10.36	0	0	0	0	12.53	17.49
7	4.06	0	0	0	14.28	0	0
8	31.86	33.33	36.49	20	18.28	35	78.45
9	17.66	0	11.76	0	22.42	15	16.78
10	9.23	33.33	13.15	0	19.04	5.02	0
11	3.98	0	0	0	0	4.18	4.76
12	37.59	33.33	47.23	60	21.42	50	66.66
13	59.73	33.33	66.70	100	59.13	65	73.66
14	11.33	0	36.29	0	36.71	25	18.28
15	0	0	0	0	8.14	12	11.52
16	16.14	0	14.71	25	32.71	15	37.57
17	14.56	0	33.59	45.76	47.85	13.49	24.89
18	49.83	0	53.72	60	36.93	40	54.75

M=Math, R=Reading, W=Writing

As the aforementioned table indicates, neglect in placing the quadrant numbers has the highest frequency among the students suffering from reading and a combination of reading and math disability (100) in comparison to other disabilities. In addition, drawing none of the clock hands has the lowest error rate among the students with the three stated LDs (0).

Discussion

It is hypothesized that the errors made by the participants are valuable sources of information for a comprehensive neurological assessment. In the current study, besides the expected errors of the scoring system proposed by Cohen et al.

(2000), other errors were identified and classified by the researcher under the supervision of expert staff in the field (See Appendix for the samples of errors made by the children with and without LD). The errors are as follows:

1. Neglect of any quadrant(s), meaning that at least one of the following conditions exists:

a. Placing at least one and at most three numbers in a specific quadrant or the other quadrants (attention deficit)

b. Failure to observe equidistant spacing between numbers in a specific quadrant or the other quadrants (attention deficit)

c. Failure to place all the numbers within a quadrant or the other quadrants (inattention)

2. Clock hands (dotted) extension
3. Placing extra numbers
4. Inappropriate numerical organization on the clock face

These results are consistent with literature that suggest that children with LDs present deficits in executive functioning, particularly in the area of planning and organizational skills, during task execution (Kibby et al., 2002). Although the underlying neuropsychological mechanisms that predict successful clock drawing performance in children are not definitely known, previous studies have indicated that attention is related to the frontal-temporal and parietal lobes function; distortion is related to the cerebellum, parietal, and temporal function; and incorrect hand setting and wrong denotation of time as well as numerical rotation are related to the parietal and frontal lobes, and the cerebellum. Errors in number positioning (i.e. equidistant spacing) are commonly considered to be representative of frontal lobe development in children. Errors in hand position (i.e. setting the hands to the correct time) is commonly found in children with frontal lesions (Cohen et al., 2000). Hence, it can be concluded that there is the probability of damage to these areas, particularly the frontal, temporal, and parietal lobes, considering their prominent role in attention disorders.

Furthermore, comparing error frequency among different LDs showed that neglect in placing the quadrant numbers had the highest frequency among students suffering from reading and a combination of reading and math disability in comparison to other disabilities. Conversely, drawing none of the clock hands had the lowest error rate among the students with the three stated LDs. Previous research indicated that the clock drawing ability is sensitive to temporal and parietal lobe dysfunction (Freedman et al., 1994). Dyslexia is usually associated with left-hemisphere dysfunction because the skills that are impaired in dyslexia, such as verbal working memory and phonological processing, are known to primarily depend on this hemisphere. The current study provided research-based evidence which shows that children with dyslexia neglect the left side of the image when they draw clock faces; this suggests a dysfunction of right-hemisphere mechanisms in addition to those dysfunctions frequently reported in the left hemisphere. This is consistent with the findings of previous studies, suggesting that children with reading disorders or dyslexia suffer from impairments in temporal-parietal regions (Banai & Kraus, 2007; Hadzibeganovic et al., 2010) as well as the posterior parietal-temporal cortex, and the left and the right frontal regions (Schulte–Korne & Bruder, 2010), which were reflected in their clock construction performance. It is also commensurate with research findings that state that children with dyscalculia suffer from visual–spatial perception impairments (Price, Holloway, Räsänen, Vesterinen, & Ansari, 2007). It was found that children with poor math performance placed all numbers on the right half of the clock face or they were unable to place the numbers ‘12’, ‘3’, ‘6’, and ‘9’ in the correct positions (See Appendix), which accounted for their visuospatial neglect, stemming from temporal and parietal cortex lesion. As such, these results are consistent with those of other researchers who found that children with dysgraphia suffer from impairments in the medial posterior temporal area and the left posterior inferior temporal (Rapcsak & Beeson, 2004). The results indicated that children with poor writing performance were more prone to neglect the lower left quadrant, causing major spatial distortion in the clock face. These are considered common errors among children with damage to the occipital–temporal–parietal junction but also in some cases of frontal and subcortical damage (Sakurai, 2011; Sakurai, Mimura, & Mannen, 2008). Finally, drawing both the hour and the minute hands on the clock face was found to be the least common problem among children with LDs—this was a surprising finding. Perhaps, this can be attributed to the potential differences in the development of the knowledge of time as compared to the development of constructional abilities and organizational skills.

Since there are no established norms regarding the frequency of the errors made by students with LDs, the results were compared with the findings of Cohen et al. (2000), who investigated the development of clock face drawing in normal children and found a stepwise progression in skill development from ages 6–8 years with regard to the ability to record time and from 6–10 years with regard to the ability of constructing a clock face. Moreover, they reported that children aged eight years performed better than those who were seven years of age; and children who were seven years of age performed better than those who were six years of age in terms of setting the time. A similar progression was found in the clock face construction, meaning that children who were 10 years of age performed better than those who were eight years of age. When performance was assessed qualitatively, it was found that most children aged eight and above could correctly indicate the requested time, whereas clock construction performance continued to gradually improve through to age 12—i.e. the maximum age assessed. One possible explanation for these types of common errors among the specific age groups is that neglect in young children might be developmental in nature, rather than neuropathological. Conversely, the results of this study indicated that all the 8–12-year-old participants with LDs continued to demonstrate poor number positioning, spacing, and hand setting. Such errors cannot be considered solely developmental; rather, they appear to be neuropathological in nature. They are usually associated with frontal dysfunction as opposed to neglect associated with parietal development.

To sum up, it is confirmed throughout the study that CDT is an appropriate and valuable tool for the neuropsychological assessment of cognitive disorders; it deserves to be accentuated in future studies. Considering that the sample of our study had mild forms of LDs, it is likely that the observed problems would have been different had our sample consisted of children with more severe forms of the disabilities. Future studies can, therefore, longitudinally investigate the developmental progression of clock face drawing in children with a more severe form of disability as compared to normal control groups. Regarding the generalizability of the results, it should be noted that when it is not possible to choose a random sample, any generalizations drawn are tentative at best. However, as this project involved a small number of participants, it allowed for an in-depth exploration of the CDT and its possible implications. The limitations, therefore, included small sample size and the lack of a control group. A small sample size might limit the generalizability of the findings to children with LDs in other contexts. Moreover, the lack of a normal control group resulted in the lack of reliable baseline data to compare with the results. Any generalization must thus be made very cautiously and a larger sample size is recommended for future studies.

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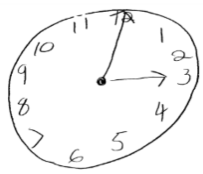
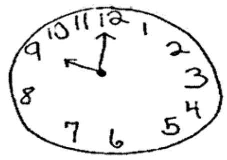
Appendix
Examples of Clock Construction Ability for Children with and without LDs

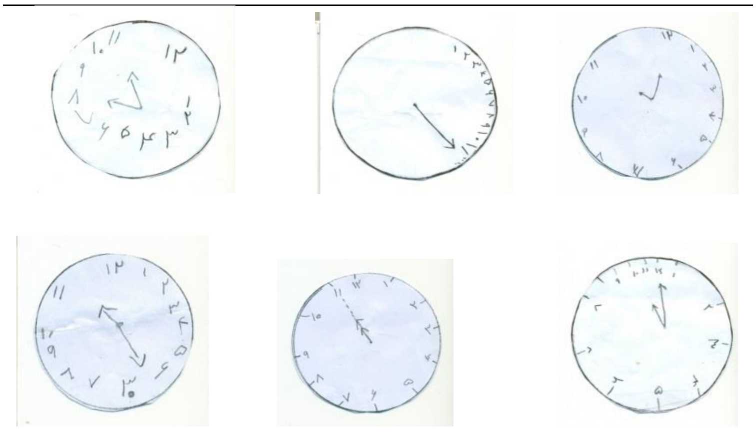


A 9–year–old normal child
Kibby, Cohen, and Hynd (2002)



A 10–year–old normal child
Eden, Wood, and Stein (2003)

A 11–year–old normal child
Eden, Wood, and Stein (2003)



6–12–year–old children with LD