

Normative Performance on an Executive Clock Drawing Task (CLOX) in a Community-Dwelling Sample of Older Adults

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Abstract

The CLOX is a clock drawing test used to screen for cognitive impairment in older adults, but there is limited normative data for this measure. This study presents normative data for the CLOX derived from a diverse sample of 585 community-dwelling older adults with complete cognitive data at baseline and 4-year follow-up. Participants with evidence of baseline impairment or substantial 4-year decline on the Mini-Mental State Examination were excluded from the normative sample. Spontaneous clock drawing (CLOX1) and copy (CLOX2) performances were stratified by age group and reading ability from the Wide Range Achievement Test, 3rd edition (WRAT-3). Lowest mean CLOX scores were observed for the oldest age group (75+ years old) with the lowest WRAT-3 reading scores. For all groups, average scores were higher for CLOX2 than CLOX1. These normative data may be helpful to clinicians and researchers for interpreting CLOX performance in older adults with diverse levels of reading ability.

Keywords: Normative data; Clock drawing test; Reading ability; Older adults; Aging

Introduction

Clock drawing tests (CDTs) are popular clinical tools widely used in screening for cognitive disorders and dementia (Shulman, 2000). To date, there are several versions of CDTs that incorporate numerous scoring systems focusing on various quantitative and qualitative error scoring types (Freedman et al., 1994; Libon, Malamut, Swenson, Prouty Sands, & Cloud, 1996; Mendez, Ala, & Underwood, 1992; Royall, Cordes, & Polk, 1998). The CLOX is one of these measures that has a quantitative scoring system (Royall et al., 1998), and is divided into two parts. CLOX1 involves spontaneous (unprompted) clock drawing more closely tied to executive function than CLOX2, which is a copy task (Royall, Chiodo, & Polk, 2003).

Despite the widespread clinical use of CDTs, there are limited published data regarding clock drawing performance in representative community-based samples of older adults (Hubbard et al., 2008). This is particularly true of the CLOX measure, for which cutoffs to determine impairment are based on performance in a sample of 62 college students (Royall et al., 1998). In general, data on representative samples are important for establishing boundaries of normal performance within a population before extrapolating that data to the determination of clinical impairment (see Lezak, Howieson, & Loring, 2004, or Strauss, Sherman, & Spreen, 2006 for detailed discussion on the need for normative data to interpret cognitive performance). One of the problems with using cognitive performance of younger adults to judge impairment in older populations is highlighted by findings from the Seattle Longitudinal Study, one of the few studies that has been able to adequately examine cohort differences in

cognitive performance by using a sequential design (Shaie, 1994). Adults from more recently born cohorts show better performance across a number of different cognitive tasks than previously born cohorts (Shaie, 1994). Thus, using performance of younger adults to determine impairment in older adults would be likely to lead to overestimation of cognitive impairment in older people.

Of the few community-based studies describing performance on CDTs in larger samples of older adults, older age and fewer years of education are typically associated with poorer CDT performance (Bozikas, Gaizkoulidou, Hatzigeorgiadou, Karavatos, & Kosmidis, 2008; Ravaglia et al., 2003; von Gunten et al., 2008). Similar associations with age and education have also been found specifically for CLOX performance (Crowe, Clay, Sawyer, Crowther, & Allman, 2008; Schillerstrom et al., 2007). In addition, several studies have highlighted the concern that quantity of educational experience (i.e., years or level of education) fails to capture quality of educational experience, which can vary widely across cohorts, states, and even counties within states (Dotson, Kitner-Triolo, Evans, & Zonderman, 2008; Manly & Echemendia, 2007). This idea of accounting for quality of education is especially important for interpreting performance on cognitive tests among older African Americans, since those who attended segregated schools were more likely to have experienced a poorer quality of education due to factors such as inferior funding, greater number of students per classroom, and shorter length of school year (Manly, Jacobs, Touradji, Small, & Stern, 2002).

Several studies have demonstrated that despite comparable years of education, older African Americans show lower scores than Caucasian older adults on a variety of different standardized neurocognitive tests (Baird, Ford, & Podell, 2007; Boone, Victor, Wen, Razani, & Ponton, 2007; Manly et al., 2002; Pedraza & Mungas, 2008). It is important to note that many of these discrepancies are reduced to non-significance when reading level is used as a covariate (Manly et al., 2002). Reading level is thought to be a proxy measure for educational quality. In analyses specific to CLOX, African American race was found to be associated with poorer CLOX performance, even after adjustment for years of education (Crowe et al., 2008). However, after controlling for reading ability, racial differences on CLOX1 scores were eliminated. Overall, age and reading ability were the two factors that were most strongly related to CLOX1 and CLOX2 performance in multiple regression models including race, gender, urban/rural residence, and level of education (Crowe et al., 2008).

Similar to other cognitive tests, the concern with using CDTs as markers of cognitive dysfunction in older adults is that without a comprehensive understanding of the natural variability of test performance across a variety of older adult populations, there is a potential for over- or underestimation of impairment (Manly, 2008; Pedraza & Mungas, 2008). Pinto and Peters (2009) provided a recent comprehensive literature review on CDTs in clinical screening and found that several CDT versions exhibited good ability to discriminate between moderate/severe dementia and controls, but displayed much more limited sensitivity/specificity values in distinguishing between milder dementia cases and controls. These studies highlight the need for further examination of CDT performance in cognitively healthy older adults.

The current study builds on earlier work from the University of Alabama at Birmingham Study of Aging that examined CLOX performance among community-dwelling African American and Caucasian adults 65 years old or older living in urban and rural central Alabama (Crowe et al., 2008; Schillerstrom et al., 2007). Our finding that CLOX performance differences between the African American and Caucasian older adults were largely explained by differences in reading ability (Crowe et al., 2008) suggests that normative data for CLOX based on reading ability would be a valuable addition to the literature for both clinicians and researchers using this measure. Normative data for CLOX were previously presented for a continuing care retirement community sample, for two older adult age groups (Royall, Chiodo, & Polk, 2003). Thus, the present study adds to existing literature by providing normative data from community-dwelling older adults, by using multiple groups for both age and reading ability, and by excluding participants with evidence of global cognitive decline during the 4-year follow-up period.

Materials and Methods

Participants

Study participants were adults over the age of 65 from the UAB Study of Aging (SOA; Allman, Sawyer, & Roseman, 2006), a longitudinal study of older adults recruited from a list of Medicare beneficiaries obtained from the Centers for Medicare and Medicaid Services (CMS). Recruitment was from three rural and two urban counties in central Alabama and was stratified by race (African American/Caucasian), gender, and county (rural/urban). Community-dwelling older adults able to schedule their own appointments were invited to participate in an extensive in-home baseline interview and were followed by telephone contacts at 6-month intervals. Four years after the baseline in-home visit, an additional in-home assessment was scheduled for participants who remained community-dwelling. The overall goal of the UAB SOA was to examine the factors that influence everyday function and mobility. The study protocol was approved by the UAB Institutional Review Board and in-home

interviews were conducted by trained interviewers after obtaining informed consents. A detailed description of the study design and measures has been previously published (Allman et al., 2006).

Participants for the current study were those who completed cognitive testing at baseline and at 4-year follow-up. A standardized reading test was administered at the 4-year in-home visit only. At baseline, there were 910 participants with complete cognitive data. At the time of follow-up, 178 of the initial 910 participants were deceased and 11 were in nursing homes, leaving a total of 721 individuals with baseline cognitive data who were eligible for the 4-year in-home interview. A total of 593 of these participants (82%) agreed to be interviewed in their homes again. Data on the cognitive and reading measures at 4 years were available for 585 participants. Non-participants were slightly older, had lower education levels, and had lower baseline cognitive screening scores ($p < .05$).

Measures

Global cognitive status was measured with the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). MMSE scores range from 0 to 30, with higher scores indicating better cognitive function. The MMSE was administered at both baseline and 4-year follow-up in-home visits.

The CLOX (Royall et al., 1998; Royall, Mulroy, Chiodo, & Polk, 1999) was employed as an additional cognitive screening measure completed at baseline and 4-year follow-up. The CLOX is a quantitative clock-drawing test divided into two parts. CLOX1 was designed to be sensitive to executive function deficits and involves instructing participants to draw a clock set to 1:45 without further prompts or cues. CLOX2, which involves copying a clock that has already been drawn, reflects visuospatial construction skills but is less dependent on executive control function. The test has demonstrated good inter-rater reliability and internal consistency, as well as better sensitivity to executive control function than several other scoring systems (Royall et al., 1999; Royall, Espino, et al., 2003; Schillerstrom et al., 2007). Participants can earn up to 15 points for each of the CLOX tests.

Data on reading ability was gathered at the 4-year follow-up in-home visit but not baseline. The reading subtest from the Wide Range Achievement Test, 3rd edition (WRAT-3; Wilkinson, 1993) was used to estimate reading skills. Reading ability measured by WRAT-3 has been found to better account for racial differences on cognitive test performances compared with years of education (Manly et al., 2002). Reading ability has also been found to have high stability and is relatively insensitive to the cognitive effects of mild dementia (Ashendorf, Jefferson, Green, & Stern, 2009; Bright, Jaldow, & Kopelman, 2002; Schmand, Geerlings, Jonker, & Lindeboom, 1998).

Procedure

Normative data were derived from baseline data collection of the study. To ensure that the normative sample comprised cognitively healthy older adults, we excluded participants from our sample with evidence of the following: baseline global cognitive impairment; subsequent 4-year global cognitive decline; or report of dementia diagnosis. Cutoffs for significant baseline impairment and decline on the MMSE were derived from prior work examining MMSE performance in a community-based sample of 3,513 older adults (Tangalos et al., 1996).

Tangalos and colleagues (1996) reported that the traditional cutoff score of 23 or less on the MMSE yielded adequate sensitivity and specificity for detection of dementia in a community-dwelling sample of older adults irrespective of age and education. While the authors did provide alternate cutoff scores stratified by age and education groups, no data were provided for individuals with less than 6 years of education. Given that a substantial proportion (17%) of the 585 participants in the current sample had 0–6 years of education and the relatively modest improvement in sensitivity to be gained, we chose to use the cutoff of 23 or less on MMSE for excluding participants with baseline global cognitive impairment. We also excluded participants who declined four or more points on the MMSE over the 4-year follow-up period, which was recommended as the cutoff indicating substantial deterioration rather than chance fluctuation (Tangalos et al., 1996). This cutoff also corresponded to 1 *SD* above the mean MMSE decline in the current sample.

We additionally excluded participants from the normative sample who had a reported diagnosis of Alzheimer's disease or other dementia. Dementia was ascertained by self-report of diagnosis, presence of diagnosis on physician questionnaire, or record of diagnosis on hospital discharge summary at any time from baseline to 4-year follow-up.

Based on our prior research (Crowe et al., 2008), we provided normative data for participants stratified by age and reading ability groups. These two factors were most strongly related to CLOX performance in multiple regression models controlling for race, gender, urban/rural residence, and years of education. Age and reading ability were each categorized into three groups using SAS proc rank to obtain tertiles. Means and SD for CLOX1 and CLOX2 performance were obtained for each of the nine age/reading ability group combinations.

Results

Table 1 presents sample characteristics for the total sample with complete baseline and 4-year data ($N = 585$). Mean age of participants was 74 years, 47% African American, 53% were female, and 48% lived in rural communities. For the criteria used to exclude participants from the normative sample, there were 107 individuals with baseline score of less than 24 on the MMSE, 103 participants who showed a decline of four or more points on MMSE over 4 years, and 44 who had reported Alzheimer's disease or other form of dementia. A total of 210 participants (36% of the sample) were excluded from the normative sample based on these criteria, resulting in a sample size of 375 for inclusion.

Table 1 also shows sample characteristics specifically for participants who were and were not included in the normative sample, as well as statistical comparisons of these groups for demographic and cognitive characteristics. Those who were excluded from the normative sample were older and more likely to be African American, male, and from rural counties of Alabama. However, the normative sample still comprised nearly 40% of African Americans. Differences between the excluded and normative samples were also found for education level, reading ability, and cognitive test scores. The normative sample was more highly educated and had better scores on the WRAT-3, MMSE, and CLOX tests.

Age and reading ability groups were based on tertiles. This strategy produced fairly equivalent sample size representation across the age and reading ability groups. The age groupings consisted of participants who were 65–69, 70–74, and 75 or more years old. For reading ability, scores on the WRAT-3 reading subtest were <38 , 39–46, and >47 for the three groups. Corresponding reading grade level for these groups was 6th grade or less, 7th grade to high school, and high school to post-high school, respectively.

Normative data for the spontaneous clock drawing (CLOX1) and clock copy (CLOX2) are presented for the stratified age and reading ability groups in Tables 2 and 3. There were at least 30 participants in each of the nine age/reading ability groupings. Average CLOX scores differed across the different combinations of age group and reading level, with the lowest mean

Table 1. Characteristics of participants

Characteristic	Complete sample ($N = 585$)	Excluded sample ($n = 210$)	Normative sample ($n = 375$)	Comparison of normative to excluded sample	p
Age, mean (SD), range	73.6 (5.8), 65–92	75.1 (6.3), 65–92	72.8 (5.3), 65–89	$t(583) = 4.7$, $d = 0.39$	$<.001$
African American, %	46.7	61.9	38.1	$\chi^2(1, N = 595)$, $d = 30.6$	$<.001$
Female gender, %	53.3	45.7	57.6	$\chi^2(1, N = 595)$, $d = 7.6$.006
Rural, %	48.4	53.8	45.3	$\chi^2(1, N = 595)$, $d = 3.9$.049
Level of education, %				$\chi^2(3, N = 595)$, $d = 105.4$	$<.001$
0–6 years	17.1	36.7	6.1	$\chi^2(1, N = 595)$, $d = 88.6$	$<.001$
7–11 years	25.6	29.1	23.7	$\chi^2(1, N = 595)$, $d = 2.0$.158
12 years	26.0	16.7	31.2	$\chi^2(1, N = 595)$, $d = 14.8$	$<.001$
>13 years	31.3	17.6	38.9	$\chi^2(1, N = 595)$, $d = 28.4$	$<.001$
WRAT-3 reading score, mean (SD), range	38.9 (10.7), 0–57	33.0 (11.5), 0–57	42.2 (8.5), 0–57	$t(583) = -11.1$, $d = -0.92$	$<.001$
CLOX1, mean (SD), range	10.9 (2.8), 2–15	9.6 (3.1), 2–15	11.6 (2.3), 3–15	$t(583) = -8.9$, $d = -0.73$	$<.001$
CLOX2, mean (SD), range	13.0 (1.7), 5–15	12.2 (2.0), 5–15	13.4 (1.2), 6–15	$t(583) = -9.5$, $d = -.79$	$<.001$
MMSE, mean (SD), range	26.4 (3.6), 8–30	23.9 (4.5), 8–30	27.8 (1.9), 24–30	$t(583) = -14.6$, $d = -1.21$	$<.001$
Baseline MMSE <24 (%)	18.3	50.1	0	$\chi^2(1, N = 595)$, $d = 233.8$	$<.001$
MMSE decline from baseline (%)	17.6	49.1	0	$\chi^2(1, N = 595)$, $d = 223.2$	$<.001$
Dementia diagnosis (%)	7.5	21.0	0	$\chi^2(1, N = 595)$, $d = 85.0$	$<.001$

Notes: SD = standard deviation; WRAT-3 = Wide Range Achievement Test, 3rd edition; CLOX = Executive Clock Drawing Test; MMSE = Mini-Mental State Examination; χ^2 = chi-square; d = Cohen's d .

p -values obtained for comparison of those excluded and the normative sample using t -test or chi-square analysis.

Table 2. Normative data for spontaneous clock drawing (CLOX1) by reading ability and age group

	Age group		
	65–69	70–74	75+
WRAT-3 Score			
≤ 38	$n = 31$, $\bar{x} = 11.23$, $SD = 2.33$	$n = 50$, $\bar{x} = 11.06$, $SD = 1.79$	$n = 45$, $\bar{x} = 10.36$, $SD = 2.36$
39–46	$n = 51$, $\bar{x} = 11.75$, $SD = 2.31$	$n = 40$, $\bar{x} = 11.50$, $SD = 2.44$	$n = 33$, $\bar{x} = 12.18$, $SD = 2.34$
≥ 47	$n = 38$, $\bar{x} = 12.63$, $SD = 2.05$	$n = 45$, $\bar{x} = 12.51$, $SD = 1.63$	$n = 42$, $\bar{x} = 11.31$, $SD = 2.89$

Notes: \bar{x} = mean; SD = standard deviation; CLOX = Executive Clock; Drawing Test; WRAT-3 = Wide Range Achievement Test, 3rd edition.

Table 3. Normative data for copy clock drawing (CLOX2) by reading ability and age group

	Age group		
	65–69	70–74	75+
WRAT-3 Score			
≤38	$n = 31, \bar{x} = 13.16, SD = 1.32$	$n = 50, \bar{x} = 12.90, SD = 1.44$	$n = 45, \bar{x} = 12.47, SD = 1.44$
39–46	$n = 51, \bar{x} = 13.76, SD = 0.86$	$n = 40, \bar{x} = 13.58, SD = 0.90$	$n = 33, \bar{x} = 13.72, SD = 0.91$
≥47	$n = 38, \bar{x} = 13.86, SD = 0.91$	$n = 45, \bar{x} = 14.02, SD = 0.83$	$n = 42, \bar{x} = 13.54, SD = 1.21$

Notes: \bar{x} = mean, SD = standard deviation; CLOX = Executive Clock Drawing Test; WRAT-3 = Wide Range Achievement Test, 3rd edition.

score of 10.4 ($SD = 2.4$) on CLOX1 for the 75+ age group who scored <38 on WRAT-3 reading, and the highest mean score of 12.6 ($SD = 2.1$) for those in the age GROUP of 65–69 with WRAT-3 reading score of >47. As expected, average scores were higher across the different groups for the clock copy task (CLOX2) than the spontaneous clock drawing (CLOX1).

Discussion

This study presents normative data for a clock drawing test, CLOX, in a community-based sample of older adults with diverse levels of reading ability and good representation of African Americans. Given the widespread clinical use of various types of CDTs, such as the CLOX, it is important to have normative data available to establish representative performance for populations of interest. The current data are consistent with the assertion that performance on cognitive tests such as the CLOX is likely influenced by factors such as age and educational quality.

The central focus of the current study was to present CLOX performance data using age and reading level as the grouping variables of interest. Several recent studies have highlighted the issue that reading ability may be more closely linked to the estimation of quality of education than number of years of education, an issue that may be particularly salient in understanding and interpreting performance on cognitive measures among older African Americans who may have attended segregated schools (Manly et al., 2002). Differences in cognitive test performance among older members of disadvantaged racial groups may not reflect a higher prevalence of cognitive disorders but disparities in access to better quality of education. Our community-based sample of older adults was relatively unique in representing substantial proportions of persons with low reading levels, African American race, and rural residence.

Based on evidence demonstrating a strong association between reading ability and cognitive test performance, other studies are beginning to present normative test data based upon word reading skills (e.g., Hubbard et al., 2008). In light of the increasing number of studies showing a relationship between better reading ability and higher scores on various cognitive tests, as well as our previous findings specifically related to CLOX (Crowe et al., 2008), we presented normative information by age and reading level categories instead of the more traditionally used years of education. However, it should be noted that not all studies have demonstrated an association between reading level and clock drawing performance. For example, one recent study investigating older African American community-dwelling adults reported that clock drawing performance was not related to reading ability (Johnson, Flicker, & Lichtenberg, 2006).

Previous normative CLOX data were presented for a cross-sectional sample of older adults that was 99% Caucasian and living in a continuing care retirement community (Royall, Chiodo, & Polk, 2003). The current study utilized a more representative sample of older adults, and we were able to exclude individuals from the normative sample who showed substantial global cognitive decline. In addition, our study is the first to our awareness to provide normative data for any clock drawing test for persons with reading levels below 7th grade, given that our lowest reading ability category corresponded to a 6th grade or lower reading level. One recent study (Hubbard et al., 2008) published detailed normative clock drawing data for three other clock scoring systems using a sample of 207 African American and Caucasian middle-aged and older adults (ages 55–98). However, the study sample consisted of persons with higher reading ability, with a mean WRAT-3 reading score of 52, in contrast to a mean WRAT-3 reading score of 42 in this normative sample.

Provision of normative data stratified by reading ability level may assist clinicians and researchers begin to discern the impact of educational quality upon cognitive performance. Using previously reported data on the CLOX task, the current sample would have relatively high rates of impairment as defined by CLOX1 scores of <10, which represents performance below the 5th percentile for young adults attending college (Royall et al., 1998). Approximately one-third of our normative sample in the lowest reading ability category would be classified as having impaired executive function using this cutoff. This is despite the fact that many of our participants with the lowest reading and educational levels were excluded from our normative sample based on low MMSE scores at baseline. These findings highlight the necessity to consider educational

factors in decisions regarding a diagnosis of cognitive impairment, particularly for persons with lower access to educational opportunities indicated by reading scores lower than expected based on the level of educational attainment. Interestingly, while only 6% of the normative sample in the current study had 0–6 years of education, 33% of our normative sample had reading scores at the 0–6th grade level.

In terms of study limitations, we relied upon WRAT-3 reading scores from the 4-year follow-up home evaluation since reading testing was not conducted at baseline. There is, therefore, a potential bias that reading scores may have changed over the 4-year period from baseline to follow-up. However, prior research on stability of reading ability suggests that reading scores are fairly robust measures over time and are relatively insensitive to dementia until later in the disease stages (Ashendorf et al., 2009; McCaffrey, Duff, & Westervelt, 2000). Another limitation is that dementia was not formally assessed in this study. We excluded from the normative sample any participant with identified clinical diagnosis of dementia at either baseline or the 4-year follow-up home assessment, as well as excluded individuals with either low MMSE scores at baseline (<24) or a four-point or more MMSE decline over the 4-year period. On the other hand, the use of a cutoff on baseline MMSE may have excluded individuals with low scores not due to cognitive decline, especially for those with lower levels of education and reading ability. The fact that 36% of the sample was excluded from the normative data gives us confidence that the remaining participants were cognitively healthy overall. However, it is acknowledged that a portion of the study sample may have been clinically characterized with cognitive impairment (i.e., mild cognitive impairment or early stage dementia; Petersen et al., 2009) if formal clinical assessments had been conducted.

There is some controversy in the field of neuropsychology about the use of norms based on demographic factors. An advantage of norms that take demographic factors into account is enhanced specificity (reduced risk of false-positive diagnoses of cognitive impairment), especially among those with lower levels of education or reading levels (Heaton, Miller, Taylor, & Grant, 2004; Lezak et al., 2004; Marcopulos, Gripshover, Broshek, McLain, & Brashear, 1999; O'Connell & Tuokko, 2010; Strauss et al., 2006). However, data also suggest that removing the effects of risk factors for cognitive impairment (e.g., age and education) reduces sensitivity of a test and increases the risk of a false-negative diagnosis (Fastenau, 1998; Morgan & Caccappolo-van Vliet, 2001; O'Connell & Tuokko, 2010; Reitan & Wolfson, 1995, 2005; Sliwinski, Buschke, Stewart, Masur, & Lipton, 1997). Ultimately, the decision of whether to use adjusted norms should be made after considering the context of the evaluation, including the base rate of the disorder in the subgroup, the sensitivity and specificity of the measure, and costs associated with false-positive and false-negative diagnoses (see Strauss et al., 2006). In the context of a clinical evaluation for dementia, the use of norms appropriate for age and reading level is recommended given the potential high costs of a false diagnosis of dementia.

The normative data provided in this study fill a current gap in the literature for the CLOX measure. In general, additional research is needed that focuses on disentangling the effects of factors such as race, quantity of education, and quality of education on cognitive performance and cognitive decline in older age. This line of research will hopefully improve identification of cognitive impairment and the prediction of dementia and functional decline among older individuals of diverse ethnic and educational backgrounds.

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Conflict of Interest

None declared.

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