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ARTICLE

Qualitative analysis of the Clock Drawing Test by educational level and cognitive profile

Análise qualitativa do Teste do Desenho do Relógio por faixas de escolaridade e perfil cognitivo

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ABSTRACT

The use of a qualitative scale for the Clock Drawing Test (CDT) may add information about the pattern of errors committed. **Objective:** To translate and adapt the Modified Qualitative Error Analysis of Rouleau into Brazilian Portuguese and to examine the pattern of errors according to educational level and cognitive profile. **Method:** 180 adults (47-82 years) completed the CDT. Participants were stratified into age and educational levels and separated between those with and without changes in cognitive screening tests (Mini-Mental State Examination, Verbal Fluency). **Results:** No significant differences were found in CDT scores among age groups. Among participants without cognitive impairment, those with lower education often presented graphic difficulties, conceptual deficits and spatial deficits. Participants with cognitive deficits, demonstrated more frequently conceptual and spatial errors. **Conclusion:** The qualitative analysis of the CDT may contribute to the identification of cognitive changes. Education level has to be taken into consideration during the analysis.

Keywords: Clock Drawing Test, cognitive screening, dementia, elderly, education.

RESUMO

O uso de uma escala qualitativa para o Teste do Desenho do Relógio (TDR) pode trazer informações adicionais sobre o perfil dos erros cometidos. **Objetivo:** Realizar a tradução e a adaptação da Análise Qualitativa de Erros de Rouleau Modificada para o português e analisar o padrão de erros por faixas de escolaridade e perfil cognitivo. **Método:** 180 adultos (47-82 anos) completaram o TDR. Os participantes foram estratificados em faixas etárias, faixas de escolaridade e separados entre aqueles com e sem alterações cognitivas em testes de rastreio (Mini-Exame do Estado Mental, Fluência Verbal). **Resultados:** Não foram encontradas diferenças no perfil de erros no TDR entre as faixas de idade. Dentre os participantes com cognição preservada, aqueles com menor escolaridade apresentaram com maior frequência dificuldades gráficas, déficits conceituais e déficit espacial. Entre os participantes com alterações cognitivas, foram frequentes as dificuldades conceituais e espaciais. **Conclusão:** A análise qualitativa do TDR pode contribuir para identificar alterações cognitivas. A escolaridade deve ser levada em consideração durante sua análise.

Palavras-chave: Teste do Desenho do Relógio, rastreio cognitivo, demência, idosos, educação.

The Mini-Mental State Examination (MMSE), the Verbal Fluency test (FV) and the Clock Drawing Test (CDT) are the cognitive screening tests most frequently used in the world[1,2,3,4]. Studies suggest that a combination of brief cognitive tests can increase the diagnostic accuracy for detecting dementia, in particular Alzheimer's disease (AD), even among illiterate elderly[5]. The CDT is a screening test that is easy and fast to apply[6]. It evaluates visuospatial and visuoconstrutive functions, the ability to use symbolic and graphic representations, language, semantic memory and executive functions[7]. The score of the CDT can be obtained through various quantitative scales. The most frequently used scoring system was developed by Shulman[8]. However, other scales have also been found accurate for early dementia diagnosis[9,10,11,12].

In this context, researchers and clinicians who use the CDT are faced with the issue of choosing the best way to analyze the drawings. In Brazil, Lourenço et al.[17] and Aprahamian et al.[5] found equivalence among the quantitative methods examined. Yet, quantitative scales do not allow

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the description of the error profile of the participant and they do not reveal specific cognitive changes. In Brazil, there are no studies examining the contribution of qualitative scales for the analysis of the CDT.

In 1992, Rouleau et al.[19] proposed the Qualitative Error Analysis of Rouleau. In this initial study, AD patients were compared to patients with Huntington's disease and normal controls. No differences were observed between diagnostic groups in the quantitative analysis, however, the qualitative analysis suggested that patients with AD showed conceptual errors, perseverations and stimulus-bound responses more often than patients with Huntington's disease and normal controls. Later studies reported that the Qualitative Error Analysis of Rouleau could help differentiate AD patients from those with vascular dementia (VD)[20], frontotemporal dementia (FTD)[21] and healthy patients[22].

More recently, Parsey and Schmitter-Edgecombe[23] demonstrated the accuracy of the CDT to distinguish individuals with mild cognitive impairment (MCI) from AD patients and normal controls. The authors used the original Qualitative Error Analysis of Rouleau scale and a modified version proposed by the authors. In this new version, an error was added, namely Numbers out of order or missing, in the Conceptual deficit category (see in Appendix the modified scale with the error added by the authors). The results indicated that the modified scale was more sensitive for detecting individuals with MCI than the original scale. The authors suggested that the qualitative analysis of CDT errors can help increase the sensitivity for identifying MCI.

Considering the contribution of the CDT for the early identification of cognitive changes and the lack of Brazilian studies on qualitative strategies to analyze the CDT, the aim of the present study was to translate and adapt the Modified Qualitative Error Analysis of Rouleau (with the additional error proposed by Parsey and Schmitter-Edgecombe)[23] scale to Brazilian Portuguese. Additionally, we aimed to examine the CDT error profile of cognitively unimpaired participants with different age and educational levels, in order to verify whether errors in the CDT could be related to age associated changes or to limited educational experience. Finally, we compared the CDT error profile of participants with and without cognitive impairment in screening tests (MMSE and/or VF) in order to identify errors in the CDT that could signal early pathological changes.

METHOD

Participants

The study involved the retrospective review of the cognitive assessment protocol of 180 independent adults who completed cognitive screening tests one week before they began their participation in a memory workshop offered consecutively between 2007 and 2010, in the Third Age University program of the *Universidade de São Paulo*, East Campus. The sample was divided into three levels of schooling (1-4 years, 5-8 years, >8 years), three age groups (younger than 60 years, 60-74 years, 75 and over) and sex. Additionally, participants were divided between those who had scores above the education adjusted cut-off scores on the MMSE and animal category FV[24,25], (defined as normal controls – NC), and those with changes in both tests or in just one of them (defined as participants with cognitive decline – CD). The CDT was not used to classify the groups according to cognitive performance.

Materials and procedures

The cognitive assessment lasted about 30 minutes and it was performed individually in a silent room. All participants were informed about the research activities developed during the evaluations and the memory workshop and signed an informed consent form.

To determine cognitive impairment according to the MMSE, education adjusted cut-off scores were as follows: 17 points for illiterates, 22 for 1 to 4 years of schooling, 24 points for 5 to 8 years of schooling and 26 for 9 or more years of schooling. The cut-off score represented the means for each educational level reported in Brucki et al.[24] minus one standard deviation.

VF was applied at its usual format, when the participant is asked to say names of animals in one minute. The cut-off points were as follows: nine animals for illiterate participants, 12 animals for those with 1 to 7 years of schooling and 13 animals for individuals with 8 or more years of education[25].

During the application of the CDT, participants were asked to make a circle, put the numbers of the clock inside the circle and indicate 11 hours and 10 minutes with the pointers. The drawings were analyzed quantitatively by the scales of Shulman[8] and Sunderland[9] and qualitatively with the Modified Qualitative Error Analysis of Rouleau[23].

The Modified Qualitative Error Analysis of Rouleau can be seen in Appendix A. With the additional error, suggested by Parsey & Schmitter-Edgecombe in the modified version[23], it includes 16 possible errors. The maximum possible score is 16 due to the fact that in item 1, errors in clock size – large or small – are mutually exclusive. In item 4 – Conceptual Deficits – the new error that refers to numbers out of order or missing was included. According to the previous authors, this type of error is common among older adults with early cognitive decline. To calculate the score in the modified scale the number of errors in the drawing is subtracted from 16. The higher the score the lower the number of errors made.

In Appendix A, we observe that the Modified Qualitative Error Analysis of Rouleau assesses six aspects of the construction of the clock, including: the size of the drawing, graphic difficulties related to changes in visuoconstructive

Table 1. Means and standard deviations for sociodemographic and cognitive variables for the total sample and with sample divided into NC and participants with CD.

	Min.	Max.	Total (n=180)	NC (n=141)	CD (n=39)	p
Female/Male	-	-	144/36	109/32	35/04	0.086*
Age	47	82	64.98 (6.79)	65.18 (6.69)	64.69 (7.80)	0.700***
Education	01	25	9.04 (4.47)	9.38 (4.50)	7.56 (3.79)	0.028**
Income	01	10 ou +	3.46 (2.20)	3.65 (2.29)	2.62 (1.76)	0.005**
MMSE	18	30	26.87 (2.51)	27.53 (1.97)	24.62 (2.81)	<0.001**
VF	03	28	15.28 (4.07)	16.50 (3.27)	10.90 (3.66)	<0.001***
CDT Shulman	1	5	3.77 (1.21)	3.92 (1.15)	3.21 (1.24)	0.001**
CDT Sunderland	2	10	8.61 (1.72)	8.77 (1.71)	8.05 (1.67)	0.001**
CDT Rouleau	8	16	14.04 (1.53)	14.28 (1.48)	13.21 (1.44)	<0.001**

NC: normal controls; CD: participants with cognitive deficits; MMSE: Mini-Mental Status Exam; VF: verbal fluency; CDT: Clock Drawing Test. Income was assessed in minimum wages. *Chi-square test; **Mann-Whitney; ***t-test for independent samples.

functions, the individual's ability to inhibit response to distracting stimuli, conceptual deficits that may occur due to loss of semantic memory, visuospatial abilities and/or planning deficits and perseveration of responses.

A bilingual researcher (MSY) translated the scale into Brazilian Portuguese. The translated version of the scoring system was discussed and adjusted by a group of students and researchers who investigate cognitive aging (the scale in Brazilian Portuguese is available upon request from the corresponding author). After these adjustments, 20 CDTs were evaluated according to the qualitative scale by two independent raters, trained to use the scale. Disagreements were found to be less than 10% of the scored errors and they were resolved through discussion. Next, one of the authors (ATF) analyzed the remaining protocols. The CDT protocols were also scored according to Shulman and Sunderland scales.

Statistical analysis

The Kolmogorov-Smirnov test was used to assess if the variables presented normal distribution. The Student t-test for independent samples was used to compare NC and CD group means for age and VF, as they presented with normal distribution. The U Mann-Whitney test was used to compare the groups for education, income, MMSE, CDT Shulman, CDT, Sunderland CDT, and Rouleau CDT which did not have normal distribution. For the analyses that involved categorical variables, such as sex, the Chi square test was used. The Kruskal Wallis test was used to compare the three age groups and educational levels. When differences were identified between age groups and education, the means were compared using the Tukey post hoc test.

To calculate the degree of association between sociodemographic and cognitive variables, Spearman correlations were calculated. SPSS version 17.0 was used in the analyses. The level of significance was set at 5%, i.e. $p<0.05$.

RESULTS

The demographic characteristics for the total sample and for the sample divided between NC and CD can be found in Table 1. In addition to impaired cognitive performance in at least one test, CD participants were less educated and had lower income than NC.

Statistical comparisons revealed no significant differences in cognitive performance between the age groups and sex for the total sample. Significant differences were found when the sample was stratified into three levels of schooling, including only participants without cognitive deficits in the MMSE and/or VF (n=141) (Table 2). The results indicated that the least educated groups had comparable performance for the MMSE and VF, and they were different from the group with higher education. For the Shulman CDT, the least educated group was different from the others. For the Sunderland and Rouleau CDT scores, there was a significant difference between the group with the lowest and the highest levels of education.

Table 2. Cognitive performance according to education groups, including only participants without cognitive deficits (n=141).

	1-4 years (n=32)	5-8 years (n=27)	>8 years (n=82)	p-value*
MMSE	26.28 (2.57)	26.89 (1.89)	28.23 (1.34)	<0.001**
VF	15.41 (3.04)	16.07 (3.59)	17.06 (3.16)	0.022**
CDT Shulman	3.25 (1.46)	4.11 (0.97)	4.12 (0.99)	0.008
CDT Sunderland	7.66 (2.43)	8.93 (1.14)	9.15 (1.32)	0.002
CDT Rouleau	13.40 (1.84)	14.40 (1.33)	14.57 (1.22)	0.004

MMSE: Mini-Mental Status Exam; VF: verbal fluency; CDT: Clock Drawing Test. *Kruskal Wallis test, with Tukey post hoc test. **1-4 years is equal to 5-8 years; 1-4 years is different from 8 years and older; 5-8 years is different from 8 years and older; 1-4 years is different from 5-8 years; 1-4 years is different from 8 years and older; 5-8 years is equal to 8 years and older; 1-4 years is equal to 5-8 years; 1-4 years is different from 8 years and older; 5-8 years is equal to 8 years and older.

Table 3. Frequency of errors in the Modified Qualitative Error Analysis of Rouleau for NC subdivided into education groups (n=141).

	1-4 years (n=32)	5-8 years (n=27)	>8 years (n=82)	p
Size of the Clock	18.7	18.5	24.4	
Small	15.6	14.8	14.6	0.991
Large	3.1	3.7	9.8	0.347
Graphic Difficulties	56.3	51.8	28.1	
Mild	50.0	40.7	23.2	0.014
Moderate	6.3	11.1	4.9	0.516
Severe	0	0	0	
Stimulus-Bound Responses	9.4	7.4	3.7	
Pointers tied to stimulus	3.1	3.7	0	0.240
Time in print or digital	6.3	3.7	3.7	0.817
Conceptual Deficits	53.2	22.2	21.9	
Misrepresentation of the clock itself	6.3	0	0	0.032
Misrepresentation of the time	37.5	18.5	19.5	0.100
Numbers out of order or missing	9.4	3.7	2.4	0.254
Spatial/Planning Deficits	78.2	29.6	43.8	
Neglect of the left hemi-space	0	0	0	
Deficit in planning	46.9	29.6	34.1	0.327
Deficit in spatial planning of numbers	21.9	0	1.2	<0.001
Numbers written outside of the clock face	3.1	0	8.5	0.195
Numbers written counterclockwise	6.3	0	0	0.032
Perseveration	37.6	18.5	15.8	
Perseveration of hands	18.8	14.8	7.3	0.184
Perseveration of numbers	18.8	3.7	8.5	0.127

p-value refers to the Chi-square test.

Table 4. Frequency of errors in the Modified Qualitative Error Analysis of Rouleau for NC and CD groups (n=180).

	NC % (n=141)	CD % (n=39)	p
Size of the Clock	22	33.3	
Small	14.9	28.2	0.054
Large	7.1	5.1	0.663
Graphic Difficulties	39	56.4	
Mild	32.6	41.0	0.328
Moderate	6.4	15.4	0.72
Severe	0	0	0
Stimulus-Bound Responses	5.7	10.3	
Pointers tied to stimulus	1.4	2.6	0.62
Time in print or digital	4.3	7.7	0.38
Conceptual Deficits	29.1	71.7	
Misrepresentation of the clock itself	1.4	5.1	0.164
Misrepresentation of the time	23.4	48.7	0.002
Numbers out of order or missing	4.3	17.9	0.003
Spatial/Planning Deficits	49	64.1	
Neglect of the left hemi-space	0	0	0
Deficit in planning	36.2	53.8	0.046
Deficit in spatial planning of number	5.7	5.1	0.895
Numbers written outside of the clock face	5.7	2.6	0.430
Numbers written counterclockwise	1.4	2.6	0.621
Perseveration	21.2	28.2	
Perseveration of hands	9.9	10.3	0.848
Perseveration of numbers	11.3	17.9	0.167

NC: normal controls; CD: elderly with deficit in cognitive screening tests; p-value refers to the Chi-square test.

Scores for the Rouleau CDT were analyzed with the NC group divided into three educational groups (Table 3). There were significant differences in mild graphic difficulties, incorrect representation of the clock, deficit in the display of numbers and arrangement of numbers in a counterclockwise direction. Participants with 1-4 years of schooling made more errors than those with 5 to 8 years who, in turn, made more errors than individuals who studied more than 8 years.

The misrepresentation of the clock and counterclockwise number display occurred exclusively among those in the least educated group. Mild graphic difficulties occurred in all groups. Those with 1 to 4 years of study displayed numbers incorrectly more often than people with 8 years or more. Participants in the second level of schooling did not commit this error. Neglect of the left hemi-space of the clock was not observed in any level of schooling.

NC and CD groups were compared in the six error categories of the Rouleau CDT scale (Table 4). There was a significant difference for misrepresentation of the time on the clock, numbers out of order or missing and deficits in planning, with greater frequency of these errors in the CD group.

Table 5 shows the correlations between the CDT scores, assessed by the three scales, with age, education, income, MMSE and VF. Results showed a significant association between the three CDT scores and sociodemographic variables (except for age) and between CDT scores and other screening tests. Results suggested similar relationships for the three CDT scoring systems.

Table 5. Spearman Correlation between CDT rating scales and sociodemographic and cognitive variables (n=180).

		CDT Shulman	CDT Sunderland	CDT Rouleau
Age	Rho	-0.52	0.054	0.109
	p	0.46	0.443	0.124
Education	Rho	0.269	0.280	0.276
	p	<0.001	<0.001	<0.001
Income	Rho	0.297	0.303	0.266
	p	<0.001	<0.001	<0.001
MMSE	Rho	0.353	0.349	0.375
	p	<0.001	<0.001	<0.001
VF	Rho	0.194	0.194	0.242
	p	0.009	0.009	0.001

MMSE: Mini-Mental Status Exam; VF: verbal fluency; CDT: Clock Drawing Test.

DISCUSSION

In this study, we aimed to describe the performance profile and pattern of errors in the CDT analyzed with a qualitative scoring system among independent participants. Participants were divided into three age and education groups and between those with and without impairment in cognitive screening tests (MMSE and VF). Additionally, qualitative CDT scores were compared to scores on two quantitative scales.

There were no significant differences in cognitive scores between the different age groups. Previous Brazilian studies[26,27,28] indicated that older participants tend to have worse performance on cognitive tasks. For instance, Kochhann et al.[29] studied 963 women aged between 20 and 92 years, in order to assess the independent effect and interactions between age, gender and education on the MMSE and noted that education and age influenced the MMSE scores. It is possible that in the present study no significant age differences were found due to the limited variability in the distribution of age. The sample contained a small number of people over 75 years.

Participants with lower education exhibited performance below education-adjusted cut-off points in the MMSE and VF more frequently. It is possible that the cut-off scores proposed thus far in Brazil are not suitable for all regions of Sao Paulo, which is a huge metropolitan area with heterogeneous sociocultural and economical characteristics. The study was carried out in the Eastern region of Sao Paulo where income and education levels are lower. Alternatively, it is plausible that there is a higher proportion of people with cognitive impairment among the less educated, as suggested by previous epidemiological studies[30,31].

Significant differences were found for the quantitative and qualitative CDT scores between schooling levels. CDT evaluates complex mental functions, such as the symbolic and graphic representation of a clock, auditory language, semantic memory and executive functions[7]. It is expected that these skills are modulated by educational experience, as suggested by Aprahamian et al.[18] and Lourenço et al.[17]. Correlation analyses also suggested a significant relationship between education and income on CDT performance, however, the reported correlations were of modest magnitude.

The qualitative analysis of the CDT enabled a more detailed description of the errors, which is not feasible in the quantitative scoring systems. The most commonly observed CDT errors among participants without cognitive impairment with lower education were: errors in number display, numbers in counterclockwise direction (spatial/planning deficit) and incorrect representation of the clock (conceptual deficit). Participants with less education seemed to have more difficulties with respect to the meaning, interpretation and knowledge of the clock itself. Mild graphic difficulties were also more frequent in this group.

The CDT errors identified in the subgroup of participants with cognitive impairment in the MMSE and/or VF were similar to those found in the group with MCI in the study by Parsey and Schmitter-Edgecombe[23]. Conceptual deficits (misrepresentation of time and numbers out of order or missing) and spatial/planning deficits were the most frequently observed errors in the CD group. In the study by Parsey and Schmitter-Edgecombe[23], the typical error profile for the elderly with MCI was moderate graphic difficulties and conceptual deficits (misrepresentation of time and numbers out of order or missing). Therefore, the present study and the one cited above are in agreement that errors in the representation of time and numbers out of order or missing may be a sign of early cognitive decline.

Conceptual deficits, such as numbers out of order or missing, seem to be particularly informative to identify MCI[23], and these errors may not be evident in quantitative CDT scales. In addition, knowledge of the typical errors of individuals with limited schooling, such as spatial/planning deficits, reported in the present study, may help clinicians to differentiate them from disease associated errors.

Despite the fact that the CDT has been frequently used as a screening tool for the identification of dementia, it has been less used to identify individuals with MCI. Qualitative CDT analysis may possibly contribute to the identification of these cases, as it enables the description of specific errors. An important limitation of the present study is that cognitive impairment was based on screening tests. Another limitation is the fact that the study protocol did not include a complete clinical characterization of participants. Future studies should explore the contribution of the qualitative analysis of CDT in samples with various diseases associated with cognitive changes.

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APPENDIX – MODIFIED QUALITATIVE ERROR ANALYSIS OF ROULEAU

16 POINTS POSSIBLE, *INDICATES ADDED ERROR

SIZE OF THE CLOCK

(1) Small (less than 1.5 inches in diameter) OR
(1) Large (more than 5 inches in diameter)

GRAPHIC DIFFICULTIES

Lines imprecise resulting in distortions of the clock face or resulting in numbers that are difficult to read.

Hands not straight or fail to connect in the middle

Overall performance appears inaccurate or clumsy

(1) Mild: some distortions of the clock face and/or the hands and/or the numbers. Overall performance was adequate.

(2) Moderate: distortions evident, but the overall performance remained interpretable.

(3) Severe: distortions evident and severe, possibly resulting in a non-interpretable drawing.

STIMULUS-BOUND RESPONSES (NOTE: PREVIOUS STUDIES REQUIRED DIFFERENT TIMES TO BE DISPLAYED IN THE CLOCK)

The tendency for the drawing to be dominated or guided by a single stimulus

(1) Time is written (in letters/numbers) beside the 1or between the 4 and the 5

(1) Hands are pointed toward 4 or 5, or hands are absent

CONCEPTUAL DEFICITS

Errors reflect a loss/deficit in accessing the knowledge of the attributes, features, and meaning of a clock

(1) Misrepresentation of the clock itself (clock without numbers, no outer circle)

(1) Misrepresentation of the time (hands absent or inadequately represented, incorrect length of hands or hands the same length, time written on the clock)

*(1) Numbers out of order or missing (starting sequence with 1 in the "12" position, number sequence finishes early or does not reach 12, numbers missing in the sequence)

SPATIAL AND/OR PLANNING DEFICITS

Deficits in the layout of the numbers on the clock face

(1) Neglect of the left hemi-space

(1) Deficit in planning, with gap before 12, 3, 6, or 9

(1) Deficit in spatial planning of numbers, without any specific pattern in spatial disorganization

(1) Numbers written outside of the clock face, or numbers written on the outer circle

(1) Numbers written counterclockwise

PERSEVERATION

The continuation or recurrence of activity without an appropriate stimulus

(1) Perseveration of hands: presence of more than 2 hands

(1) Perseveration of numbers: abnormal prolongation of numbers, (e.g.,writing numbers beyond 12, or repeating the same numbers)

Total Number of Errors =_____ Total Score (16 – number of errors) =_____

Note: The Brazilian Portuguese version of the scale is available upon request from the corresponding author.