The clinical relevance of the use of age-, education- and sex-adjusted normative data for the Montreal Cognitive Assessment; a cohort study

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Abstract

Background: Cognitive impairment is a major source of morbidity. The Montreal Cognitive Assessment (MoCA) is a validated screening instrument to assess cognitive performance. Recent literature introduced an age-, education- and sex-adjusted interpretation method to enhance clinical accuracy of the MoCA. However, its clinical applicability in brain injury patients is currently unknown.

Objective: To evaluate the clinical relevance of the demographic-adjusted MoCA (DA-MoCA) interpretation to detect cognitive impairment among acquired brain injuries patients.

Methods: We studied two brain injury cohorts. Firstly, a data analysis of the Restore4stroke Cohort (n=347) at 2 months post-stroke was performed. Secondly, a prospective cohort including 51 brain injury patients admitted at the University Medical Center Utrecht (UMCU) was studied. We compared cognitive impairment rates between the original- and DA-MoCA interpretation. Differences in patient characteristics in patients with opposite outcome were explored.

Results: We compared cognitive impairment rates between the original- and DA-MoCA interpretation. According to the DA-MoCA cognitive impairment rates dropped by 19.8% (Restore4Stroke) and 7.8% (UMCU), and no participants were newly diagnosed as cognitively impaired. Participants reclassified as not cognitively impaired according to the DA-MoCA were characterized by significantly lower levels of education in the Restore4Stroke cohort and by older age in the clinical brain injury cohort (UMCU).

Conclusion: The DA-MoCA interpretation reduces the number of participants diagnosed with cognitive impairment, primary by correcting for the influence of age and education on cognitive functioning. The DA-MoCA interpretation could particularly be relevant for populations characterized by extremes in age and education.

Abbreviations

CLCE-24-C	Checklist for Cognitive and Emotional Consequences- Cognition subscale
DA-MoCA	Demographically adjusted Montreal Cognitive Assessment
GR	Geriatric revalidation setting
MoCA	Montreal Cognitive Assessment
MR	Medical revalidation setting
NIHSS	National Institutes of Health Stroke Scale
SD	Standard Deviation
UMCU	University Medical Center Utrecht

Introduction

A large proportion of stroke patients experience cognitive changes such as cognitive impairment which is a major source of morbidity in this population [1]. The stroke prevalence in the Netherlands in 2022 was 21.4 per 1000 people [2]. Due to better survival and aging population more people have to cope with the consequences of a stroke [3,4]. A systematic review and meta-analysis showed that approximately 4 out of 10 hospitalized stroke patients, who are capable of undergoing cognitive assessment, have cognitive impairment that does not meet dementia criteria in the first year post-stroke [5]. Post-stroke cognitive impairment is associated with decreased participation [6] and a lower quality of life [7]. It is essential for healthcare professionals to assess and monitor cognitive function, because early detection facilitates timely cognitive rehabilitation interventions which could improve the quality of life in stroke survivors [8].

The Dutch guidelines recommend examining patients within 4 weeks post-stroke for the possible presence of cognitive impairment using the Montreal Cognitive Assessment (MoCA) [8–11]. The MoCA is a validated, simple- to-administer and widely used screening instrument to assess cognitive performance. The MoCA screens on cognitive functioning in 8 different domains: attention and concentration, executive functions, memory, language, visuo-constructive skills, conceptual thinking, arithmetic, and orientation [12,13]. The total possible score is 30 points, with higher scores reflecting better performance. Cognitive impairment is suspected if the total score of the MoCA is <26 [13]. In that case further diagnostic neuropsychological examination >4 weeks post-stroke is recommended [9,10].

A validation study of the MoCA stated that maintaining this cutoff point would result in a sensitivity for detecting cognitive impairment of 90% and a specificity of 87% [13]. Since a wide range of sensitivity (ranging from 50-95%) and specificity (ranging from 67-100%) rates for detecting cognitive impairment, have been reported in the past years, the cutoff point of the MoCA remains a topic of debate [14–17]. One of the hypotheses accounting for these findings is a diversity in demographic variables between the populations studied [13,18].

The MoCA score does not account for demographic variables, such as age, education and gender. In the healthy population, the occurrence of cognitive impairment increases with advancing age [19]. This may lead to an overestimation of the prevalence of cognitive impairment post-stroke among older, and an underestimation among younger individuals [19,20]. Furthermore, higher education might enable people to compensate better for cognitive decline, influencing test score [20–22]. It is therefore suggested that a demographic adjusted interpretation can enhance the diagnostic accuracy of the MoCA.

A recently published study by Kessels et al. 2022 [18], including 820 healthy individuals, developed a new way of interpreting the MoCA scores using age-, education- and sex-adjusted normative data. This led to a regression formula based percentile distribution that aimed to reduce the confounding effects of age, education and sex. This could potentially lead to an increased accuracy of the MoCA as screening tool for cognitive impairment. Accurately identifying patients with cognitive impairment might facilitate appropriate and timely care, such as, cognitive rehabilitation interventions which could improve quality of life.

However, the clinical applicability of this new interpretation among patients with brain injury is currently unknown. The primary objective of this study is to gain insight into the clinical relevance of the renewed demographically adjusted interpretation of the MoCA (referred to as DA-MoCA) as proposed by Kessels et al [18]. We aim to explore the prevalence of cognitive impairment based on the original- and DA-MoCA interpretation in two brain injury cohorts. As well as the characteristics of patients who receive a different diagnoses when demographically adjusted normative data are applied.

Materials and Methods

Study design

We studied 2 brain injury cohorts. First of all, the study represents a secondary data analysis of the Restore4stroke Cohort [23], a multi-center longitudinal cohort study conducted across 6 general hospitals in the Netherlands from March 2011 to March 2013. Secondly, the study represents a prospective cohort study conducted at the University Medical Center Utrecht (UMCU) from July 2023 to August 2023.

Patients' characteristics Restore4Stroke

Participant were included in the Restore4stroke cohort if they were at least 18 years old, clinically diagnosed with a stroke, either ischemic or hemorrhagic and provided informed consent within 7 days following the stroke [23]. Participants were excluded from the study if one of the following criteria were met: [23] 1) interference with the study outcome was expected due to the presence of other comorbidity, 2) they had a pre-existing Barthel Index score of ≤17, indicating dependence regarding activities of daily living [24] 3) pre-existent cognitive decline was suspected assessed by a score ≥1 on the 'heteroanamnesis list cognition'[25] or 4) insufficient knowledge of the Dutch language was suspected.

Patients' characteristics of the clinical brain injury cohort (UMCU)

Consecutive patients who underwent cognitive screening, including a MoCA, as part of a consultation by a rehabilitation physiatrist at the UMCU between 24th July 2023 and 24th August 2023 were included in the prospective UMCU cohort. In the event that the MoCA had been administered multiple times, the first MoCA in the set was retained.

The MoCA

The Dutch MoCA [12] (see Appendix A, Figure A1 and Figure A2, for examples) was used to evaluate cognitive performance at 2 months post-stroke (Restore4Stroke cohort) and during clinical admission (UMCU cohort). The MoCA is a validated screening tool for individuals with a stroke [26]. Test administration and scoring were performed by trained research assistants and clinicians [23,27].

The original interpretation of the MoCA

Cognitive impairment was originally defined as a MoCA score of <26 out of 30. If the MoCA score was ≥26, the participant was classified as 'not cognitively impaired'. If a participant had received 12 years or less of formal education, an additional point was added to the final score to correct for the influence of education [13,18].

The demographically adjusted interpretation of the MoCA

Kessels et al. [18] presented a percentile distribution based on normative data that allowed adjustment of the MoCA score for age, education and sex [18]. The percentile distribution was stratified by age group, education level and sex. Age was divided into the following subgroups: 18-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, 70-79 years and ≥ 80 years. Level of attained education was based on the Verhage classification [28]. This classification comprised seven categories, with level 1 corresponding to 'less than an elementary school diploma' and level 7 to an 'university degree'. Clinicians were instructed to record the highest level of education attained or, if not possible, the occupation of the patient. The researcher translated occupation to the corresponding education level. Education levels were divided in three subgroups: low, corresponding to the Verhage classification 1-4; average, corresponding to the Verhage classification 5; and high, corresponding to the Verhage classification 6-7 [28]. The extra point participants originally received for 12 years or less formal education was not disbursed [18]. The obtained percentile scores were converted into diagnostically meaningful labels based on consensus criteria [29]. Specifically, percentiles were categorized as follows:

≥ 98 percentile was labeled as ‘exceptionally high’, 91-97 percentile as ‘above average’, 75-90 percentile as ‘high average’, 25-74 percentile as ‘average’, 9-24 percentile as ‘low average’, 2-8 percentile as ‘below average’ and <2 percentile as ‘exceptionally low.’

The Checklist for Cognitive and Emotional Consequences

The Checklist for Cognitive and Emotional Consequences, cognition subscale (CLCE-24-C) was used to identify the presence of subjective cognitive problems post-stroke [30]. A higher score corresponds to more symptoms. The questionnaire was scored by an interviewer with a score of “0” corresponding to the absence of complaints, a “1” to possible presence of complaints, and a “2” to the presence of complaints [27].

Statistical analysis

Descriptive statistics were performed to analyze participant characteristics and dependent variables.
For interpreting the MoCA scores we compared the original MoCA and the DA-MoCA method. Original MoCA total scores were dichotomized into ‘cognitively impaired’ (MoCA<26) and ‘not cognitively impaired’ (MoCA≥26). The outcome of the diagnostic labels of the DA-MoCA were dichotomize into ‘cognitively impaired’ (percentile ≤24, corresponding to diagnostic labels ranging from low average to exceptionally low) and ‘not cognitively impaired’ (percentile ≥ 25, corresponding to diagnostic labels ranging from average to exceptionally high). The McNemar test was used to analyze the difference in cognitive impairment rates.

In the subgroup of participants that were classified as cognitively impaired according to the original MoCA interpretation, we compared participants classified as 'cognitively impaired' and participants who were classified as 'not cognitively impaired' according to the DA-MoCA using the Wicoxon rank-sum test and the chi-square test. Normality of distribution was assessed using visual inspection.

Data processing and statistical analyses have been performed using the program IBM SPSS Statistics for Windows, Version 27.0 (Armonk, NY: IBM Corp). A p-value of ≤0.05 was considered statistically significant.

Ethical considerations

The Restore4Stroke cohort study received approval from the Medical Ethics Committees of all participating hospitals (Restore4stroke 14-07-2015;NL34676.100.10) [31].

Results

Participant inclusion

At 2 months post-stroke (Restore4Stroke)

A total of 395 participants were included in the initial Restore4Stroke cohort [23]. For this study we excluded 48 participants from the original cohort (as depicted in Figure 1), due to missing MoCA scores at 2 months post-stroke (n=47) or missing data on the level of education (n=1).

Clinical brain injury cohort (UMCU)

A total of 60 participants were administered a MoCA during hospital stay. For this study, we excluded 9 participants due to various reasons: an incomplete MoCA (n=4), missing data on level of education (n=3), and missing data on age (n=2) (as illustrated in Figure 1).

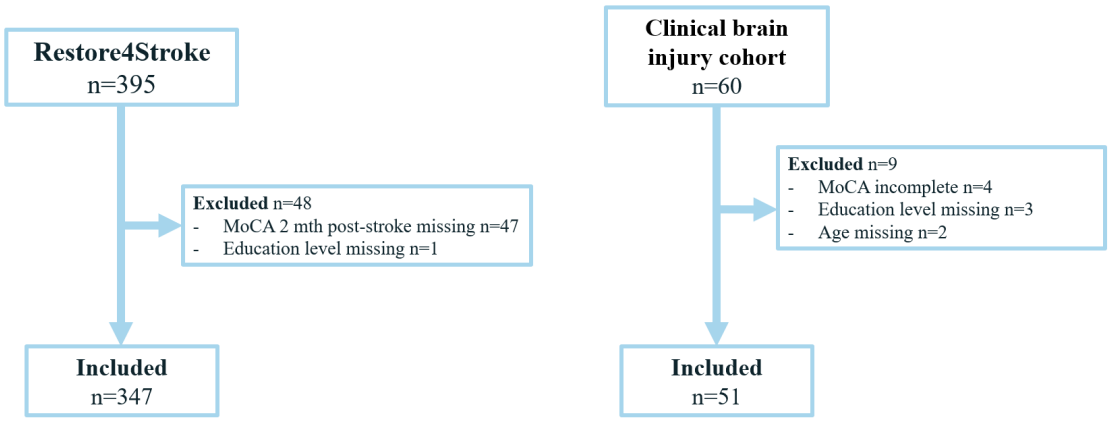

Figure 1: flowchart inclusion 'Restore4Stroke participants' and 'Clinical brain injury participants'.
Abbreviations: MoCA, Montreal Cognitive Assessment

Participant characteristics

At 2 months post-stroke (Restore4Stroke)

Table 1 represents the characteristics of participants at 2 months post-stroke. The age at time of stroke ranged from 24 to 93 years with a mean age of 66.6 years (±12.4). The majority of participants experienced their first stroke (87.3%), mostly of an ischemic character (93.4%) and with minor stroke symptoms (57.9%). Most participants were discharged home after hospital admission (72.9%).

Clinical brain injury cohort (UMCU)

The characteristics of clinical brain injury participants are illustrated in Table 1. The cohort includes patients with various diagnoses, with stroke patients comprising the largest group (54.9%). The ages of participants ranged from 25 to 94 years with a mean age of 63.8 years (±17.1). The minority of participants have attained a low level of education (5.9%).

Table 1: participant characteristics.

	Restore4Stroke Study participants (n=347)	UMCU Study participants (n=51)
Demographic factors		
Sex (% male)	221/347 (63.7)	26/51 (51.0)
Age (mean± SD)	66.6 (±12.4)[a]	63.8 (±17.1)
Education [b] (mean± SD)		
Low (%)	143/347 (41.2)	3/51 (5.9)
Average (%)	109/347 (31.4)	26/51 (51.0)
High (%)	95/347 (27.4)	22/51 (43.1)
Disease-related factors		
Diagnosis		
Stroke (%)	347/347 (100)	28/51 (54.9)
Neuro-oncology (%)	-	7/51 (13.7)
Trauma (%)	-	8/51 (15.7)
Other	-	8/51 (15.7)
Discharge destination		
Home (%)	253/347 (72.9)	24/50 (48.0)
Inpatient GR (%)	46/347 (13.3)	11/50 (22.0)
Inpatient MR (%)	48/347 (13.8)	11/50 (22.0)
Other (%)	-	4/50 (8.0)
Stroke-related factors		
Ischemic stroke (%)	323/346 (93.4)	
Left hemisphere (%)	137/346 (39.5)	
First stroke (%)	303/347 (87.3)	
Severity of stroke		
No stroke symptoms (%NIHSS 0)	85/347 (24.8)	
Minor stroke symptoms (% NIHSS 1-4)	202/347 (57.9)	
Moderate stroke symptoms (%NIHSS 5-12)	55/347 (15.8)	
Severe stroke symptoms (%NHISS >12)	5/347 (1.5)	

Abbreviations: GR, geriatric revalidation; MR, medical revalidation; NIHSS, National Institutes of Health Stroke Scale [32]; SD, Standard Deviation.

[a] At time of stroke.

[b] Education subclasses: low, corresponding to the Verhage classification 1-4; average, corresponding to the Verhage classification 5; and high, corresponding to the Verhage classification 6-7 [28].

Comparison between MoCA interpretation methods

At 2 months post-stroke (Restore4Stroke)

The DA-MoCA interpretation results in significant less participants diagnosed with cognitive impairment (n=69), impairment rates dropped by 19.8% (illustrated in Table 2). There are no individuals newly diagnosed as cognitively impaired according to the DA-MoCA interpretation.

Clinical brain injury cohort (UMCU)

The DA-MoCA interpretation leads to a slight decrease in the number of participants (n=4) diagnosed with cognitive impairment, impairment rated dropped by 7.8% (illustrated in Table 2). There are no individuals newly diagnosed as cognitively impaired according to the DA-MoCA interpretation.

Table 2: Impairment rates of the original- vs. demographically adjusted MoCA interpretation.

	Original MoCA impaired[a] n=(%)	DA-MoCA impaired[b] n=(%)
Restore4Stroke (n=347)	234 (67.4)	165 (47.6)**
UMCU (n=51)	38 (74.5)	34 (66.7)

Abbreviations: MoCA, Montreal Cognitive Assessment; DA-MoCA, demographically adjusted Montreal Cognitive Assessment.

**statistically significance differences ($p<0.01$) between 'original MoCA' and 'DA-MoCA'

[a] Cognitive impairment defined as a total MoCA score <26

[b] Cognitive impairment defined as <25 percentile according to Kessels et al. 2022 [18]

Characteristics of participants classified as cognitive impaired according to the original MoCA

At 2 months post-stroke (Restore4Stroke)

Based on the original MoCA interpretation 234 participants were diagnosed with cognitive impairment at 2 months post-stroke (Table 3), of whom 69 (19.9%) were not cognitively impaired based on the DA-MoCA interpretation. These participants (n = 69) have significantly more often attained a lower level of education (69.6 % vs. 44.2%) than participants diagnosed with cognitive impairment, according to the original MoCA interpretation. Furthermore, these participants were more likely to return home upon hospital discharge (78.3% vs. 69.1%). Additionally, there was no significant difference observed in terms of perceived cognitive complaints between the subgroups, as assessed by the CLCE-C. Finally, woman tended to be diagnosed less frequently as cognitively impaired according to the DA-MoCA interpretation compared to men (34.5% vs. 65.5%).

Clinical brain injury cohort (UMCU)

Based on the original MoCA interpretation 38 participants were diagnosed with cognitive impairment at hospital admission (Table 3), of whom 4 (7.8%) were not cognitively impaired based on the DA-MoCA interpretation. These participants (n= 4) tend to be older, with a mean age difference of 11.0 years, and were more likely to return home upon hospital discharge (50.0% vs. 36.4%), than participants diagnosed with cognitive impairment according to the original MoCA interpretation. No significant difference in education level was observed between the two subgroups.

Table 3: Characteristics of participants originally classified as cognitively impaired divided into subgroups according to DA-MoCA interpretation.

	Restore4Stroke original MoCA impaired[a] (n=234)		**UMCU original MoCA impaired[a] (n=38)**	
	DA-MoCA not impaired[b] (n=69)	**DA-MoCA impaired[b] (n=165)**	**DA-MoCA not impaired[b] (n=4)**	**DA-MoCA impaired[b] (n=34)**
Demographic factors				
Sex (% male)	40/69 (58.0)	108/165 (65.5)	2/4 (50.0)	17/34 (50.0)
Age (mean± SD)	67.2 (±11.3)	69.7 (±11.0)	72.8 (±14.2)	61.8 (±17.6)
Education (mean± SD)				
Low (%)	48/69 (69.6)	73/165 (44.2)**	-	3/34 (8.8)
Average (%)	15/69 (21.7)	55/165 (33.3)	3/4(75.0)	17/34 (50.0)
High (%)	6/69 (8.7)	37/165 (22.4)*	1/4 (25.0)	14/34 (41.2)
Disease-related factors				
Diagnoses				
Stroke (%)	69/69 (100)	165/165 (100)	2/4 (50.0)	15/34 (44.1)
Neuro-oncology (%)	-	-	1/4 (25.0)	5/34 (14.7)
Trauma (%)	-	-	1/4 (25.0)	7/34 (20.6)
Other (%)	-	-	-	7/34 (20.6)
Discharge destination				
Home (%)	54/69 (78.3)	114/165 (69.1)	2/4 (50.0)	12/33 (36.4)
Inpatient GR (%)	11/69 (15.9)	27/165 (16.5)	2/4 (50.0)	6/33 (18.2)
Inpatient MR (%)	4/69 (5.8)	24/165 (14.4)	-	11/33 (33.3)
Other (%)	-	-	-	4/33 (12.1)

Abbreviations: GR, geriatric revalidation; DA-MoCA, demographically adjusted Montreal Cognitive Assessment; MoCA, Montreal Cognitive Assessment; MR, medical revalidation; SD, Standard Deviation.

[b] Education subclasses: low, corresponding to the Verhage classification 1-4; average, corresponding to the Verhage classification 5; and high, corresponding to the Verhage classification 6-7 [28].

[a] Cognitive impairment defined as a total MoCA score <26.

[b] Cognitive impairment defined as <25 percentile according to Kessels et al. 2022 [18].

*statistically significance differences ($p<0.05$) between 'DA-MoCA not impaired' and 'DA-MoCA impaired'.

**statistically significance differences ($p<0.01$) between 'DA-MoCA not impaired' and 'DA-MoCA impaired'.

Discussion

The primary objective of this study was to gain insight into the clinical relevance of age- education- and sex- adjusted normative data for the MoCA, as proposed by Kessels et al [18]. First of all, the study demonstrates that fewer individuals received a diagnosis of cognitive impairment when assessed using the DA-MoCA interpretation compared to the original MoCA interpretation. Secondly, no participants were newly diagnosed as cognitively impaired according to the DA-MoCA interpretation. Participants classified differently based om the DA-MoCA interpretation received significantly more often a lower level of education and less often a higher level of education in the Restore4Stroke cohort and tend to be older in the clinical brain injury cohort.

The cutoff point for cognitive impairment, as determined by the DA-MoCA interpretation, varied from <22 to <27, with percentile scores < 25 indicating cognitive impairment. This is in line with previous literature reporting suggested cutoffs ranging from <21/22 [14,33] to <26 [34], supporting the hypothesis that the diversity in reported cutoff scores may be linked to the demographic heterogeneity of the studied populations [13,18]. The significance of demographic variables in the interpretation of the MoCA is also observed in a recently published systematic review and meta-analysis of studies on MoCA diagnostic test accuracy specific in stroke survivors. This study stated that the optimal cutoff of the MoCA was 21/22 points, since this cutoff yielded the best diagnostic accuracy [33]. This cutoff point might be influenced by the fact that individuals with a stroke are predominantly of older age[4]. De Da-MoCA also demonstrated that the MoCA should be adjusted for older individuals and proposed a cutoff point of <22 for less educated women aged over 70 and less educated men aged over 80. This is in line with

the recently published systematic review and meta-analysis [33]. However, the DA-MoCA suggested a higher cutoff point for participants in the same age groups that attained an average or high level of education. [18]
In conclusion, our study results are largely in line with previous literature on this topic, and highlight the importance of an alteration of the MoCA interpretation for populations primarily comprised of elderly patients to mitigate the occurrence of false-positive diagnoses of cognitive impairment [19].

The DA-MoCA interpretation only increased the cutoff score to <27 points for participants that are aged between 18 to 29 years and have attained a high level of educations, correcting for the influence of young age and high education as described in prior research [19–22]. For all other age groups and education levels, the cutoff remained either the same as the original <26 points or decreased [18]. This probably explains why we did not identify more patients with cognitive impairment using the DA-MoCA interpretation, as we mainly included patients with an older age as a result of the prevalence of stroke in this population [4].

Consistent with the normative data provided by Kessels et al [18] our clinical brain injury cohort showed that older individuals are less frequently diagnosed with cognitive impairment according to the DA-MoCA interpretation. Given that the clinical brain injury cohort not only includes stroke patients but also individuals with other diagnoses, such as those with traumatic brain injury who are predominantly younger, this may potentially account for the difference in cognitive impairment rates between the two cohorts studied.

In addition to a difference in age, which is demonstrated in the clinical brain injury cohort, the level of education appears to mainly influence the classification in the Restore4Stroke cohort. This is in line with previously published studies that indicate that educational level influences cognitive functioning [20–22]. Participants that are, compared to the original MoCA interpretation, no longer diagnosed with cognitive impairment according to the DA-MoCA interpretation have significantly more often attained a lower level of education and significantly less often a high level of education. Originally, only 1 point is applied to correct for the influence of education, on cognitive performance, if less than 12 years of formal education is attended [13]. Observed in the regression formula based percentile distribution is that, with the exception of men between the ages of 70-79, there is an average of 2 points difference between the low-educated and the averagely educated group, suggesting that the original 1 point compensation for a low education appears to be insufficient. The influence of education could clinically be most relevant for populations with a high prevalence of low levels of education such as areas with a low social-economic status.

According to the regression-based percentile distribution, gender is only relevant for interpreting the MoCA scores in low-educated participants aged between 70 and 79 years. Generally, the influence of genders seems to be small. However, a study published in 2019 stated that there seems to be a difference in memory function between men and woman [35]. In our study, no significant sex difference was observed. However, in the Restore4Stroke cohort, woman tended to be diagnosed less frequently as cognitively impaired according to the DA-MoCA interpretation, compared to men.

In summary, changing the original <26 cutoff point to a demographically adjusted percentile distribution could facilitate a more precise interpretation of cognitive functioning after an acquired brain injury and potentially reduce the number of participants that are misclassified as cognitive impaired under current scoring. This may contribute to more targeted rehabilitation interventions and, if individuals identified as not cognitively impaired by the DA-MoCA interpretation do not require cognitive rehabilitation, could reduce the overall costs of the rehabilitation care. However, to determination this requires a comprehensive neuropsychological test battery, since this serves as the gold standard for assessing cognitive functioning [18].

Nevertheless, introducing the DA-MoCA interpretation could increase the administrative burden and the likelihood of calculation errors. An electronic administration and scoring of the MoCA, integrated into the patient records, may enhance its clinical utility. The extent to which the extra administration outweighs the benefits depends on the setting and the population in which the MoCA is conducted. Based on our study results the DA-MoCA interpretation could especially contribute in populations characterized by extremes in age and level of education.

Strengths and limitations

This study is the first to administer and examen the regression formula based percentile distribution in both a large post-stroke cohort (n=347) at 2 months post-stroke, and a clinical brain injury cohort (n=51). This contributes to the clinical applicability of the DA-MoCA interpretation in the hospital phase. It is important to recognize that the majority of individuals in both cohorts have experienced a stroke (94.5% of total participants), and that the prevalence of cognitive impairment tends to be naturally higher in the post-stroke populations. This reduces the generalizability of the results regarding the diagnoses that are in the minority. Furthermore, is the clinical brain injury cohort a small cohort (n=51), resulting in limited statistical power as well as that the results could not be described per diagnosis group, impairing generalizability.

Future research

External validation is recommended for patient populations that were in the minority in this study such as traumatic brain injuries and neuro-oncology patients. Furthermore, longitudinal monitoring of participants who are not cognitively impaired according to DA-MOCA interpretation is recommended to examen whether this group experiences cognitive disorders according to a neuropsychological test battery or complains on cognitive functioning in the long-term.

Conclusion

The DA-MoCA interpretation results in less participants diagnosed with cognitive impairment by primary correcting for the influence of age and education on cognitive functioning. The DA-MoCA interpretation can especially contribute in populations characterized by extremes in age and level of education such as population dominated by elderly or by low levels of education.

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Appendix A

Figure A1: An example of a Dutch MoCA, version 8.1. Total score is 15/30 points corresponding to cognitive impairment. Cognitive dysfunction can be seen in the following domains: executive functioning and visuo-constructive thinking (demonstrated in the alternating trail making and cube drawing), attention (demonstrated in the calculation errors), language (demonstrated in the second sentence and the verbale fluency), conceptual thinking (demonstrated in similarity assignment), postponed memories (demonstrated in the five words task) and orientation (demonstrated in the orientation questions where orientation in time is missing).

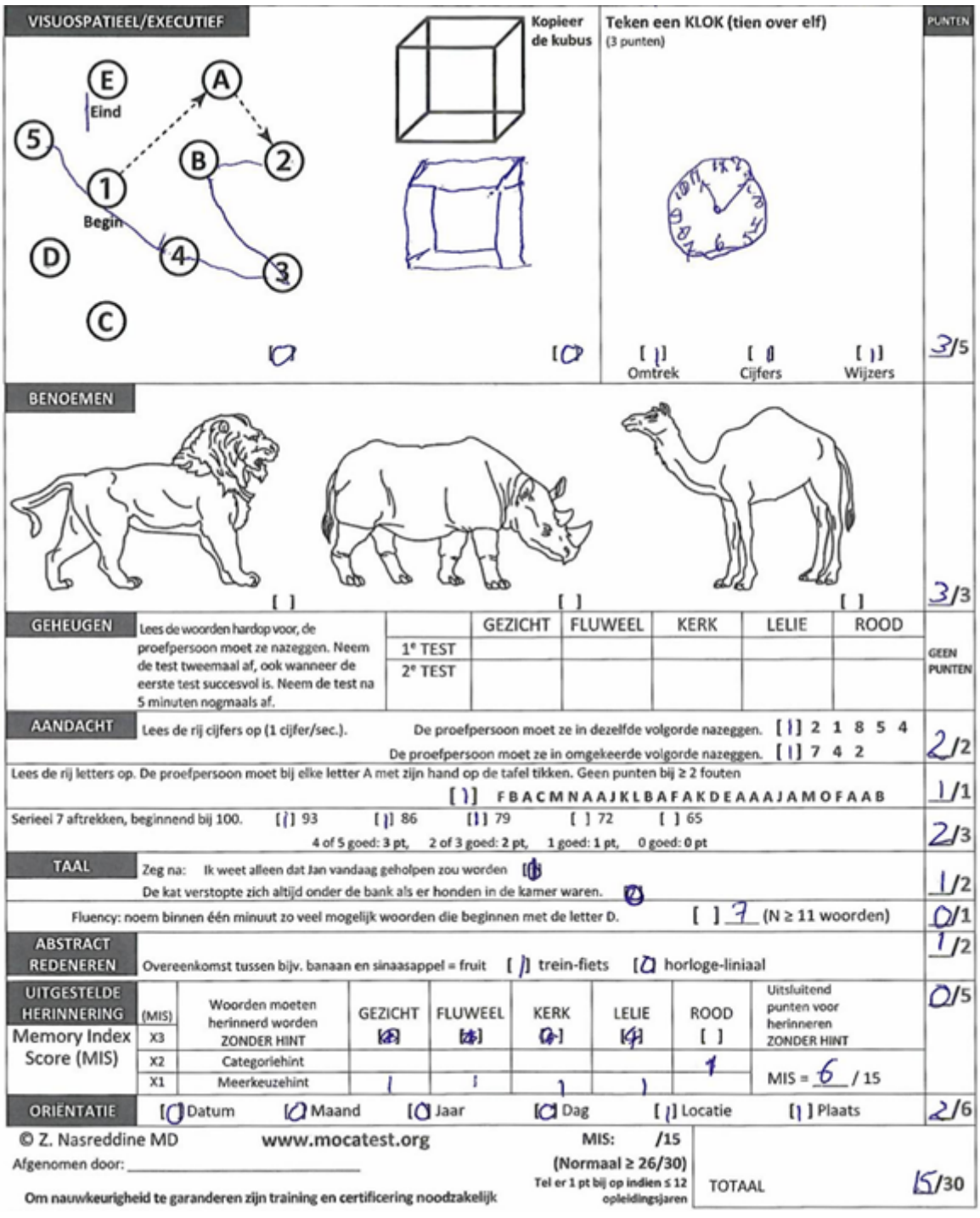

Figure A2: An example of a Dutch MoCA, version 8.1. Total score is 25/30 points corresponding to cognitive impairment according to the original MoCA scoring. This patient could be classified as cognitively not impaired according to the DA-MoCA interpretation based on sex, level of education and age. Cognitive dysfunction can be seen in the following domains: visuo-constructive skills (demonstrated in the cube drawing), conceptual thinking (demonstrated in the animal naming task), attention (demonstrated in the repeat task), language (demonstrated in the second sentence) and orientation (demonstrated in the orientation questions where orientation in location is missing).