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ORIGINAL ARTICLE

Exploring the measurement properties of the Montreal Cognitive Assessment in a population of people with cancer

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Abstract
Background Cancer and cancer-related treatments are associated with a constellation of physical and psychological changes. Treatments associated with noncentral nervous system neoplasms can have short- and long-term effects on cognition, affecting quality of life in people with cancer. Clinical measurement tools specific to cancer-related mild cognitive impairment (MCI) are lacking. The Montreal Cognitive Assessment (MoCA) has been validated in a geriatric population and used in studies assessing MCI in persons with cancer, but no studies have yet shown its psychometric properties when used with this population.
Purpose The purpose of this study is to explore the psychometric properties of the MoCA within a population of persons with noncentral nervous system cancer.
Methods A total of 74 participants were included from persons attending a Cancer Nutrition-Rehabilitation Program at the McGill University Health Centre. Rasch analyses were conducted.
Results The MoCA data fit all the properties of the Rasch model with a person separation index of 1.04 and person reliability of 0.52. The MoCA items were found to measure a unidimensional construct and spanned 6.57 logits, with item difficulty levels between 2.49 and −4.08 logits. However, the MoCA presented a lack of items of higher difficulty, as person cognitive ability levels ranged from −0.51 to 5.17 logits.
Conclusion Within the limits of a small sample size, the results of this exploratory study suggest the possibility that the MoCA, when used within a population of persons with cancer, may meet criteria for unidimensionality and adequate item fit but may present weaknesses when used with participants of higher cognitive abilities.

Keywords MoCA · Rasch analysis · Cognition · Cancer · Mild cognitive impairment

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Introduction

Cancer and cancer-related treatments are associated with a constellation of physical and psychological changes [1–3]. Over the last two decades, research has shown that treatments for noncentral nervous system neoplasms can have short- and long-term effects on cognition, affecting quality of life in persons with cancer [3–5]. Several meta-analyses have shown that cognitive changes associated with cancer may include

impairments in specific domains such as the following: executive function, visuospatial processing, attention, concentration, and processing speed [6–10]. There is evidence to support that mild cognitive impairment (MCI), colloquially referred to as *chemo fog* or *chemo brain,* is prevalent in up to 33 % of cancer survivors and up to 70 % of individuals receiving chemotherapy [11, 12]. MCI may even precede chemotherapy and is sometimes present at diagnosis [13–16]. The importance of considering cognitive changes associated with cancer and its treatments is amplified by rising incidence rates and number of cancer survivors [17]. However, clinical measurement tools specific to cancer-related MCI are lacking [14, 18]. An international expert panel at the Venice cognitive workshop agreed that the assessment of MCI in people with cancer is necessary and should focus on assessing attention, processing speed, memory, learning, retrieval, language, visuoperception, constructional abilities, motor skills, and executive function [14]. Despite the abundance of evidence for cancer and cancer-treatment related MCI, persons often report cognitive changes, such as short-term memory and concentration difficulties, which are not always captured by current neuropsychological evaluations [19]. A systematic review by Hutchinson et al. found that persons' self-reported cognitive changes often did not correlate with results using objective testing [20]. These findings point to a need for psychometric evaluations of currently used measurement tools.

Studies exploring cognition in people with cancer have used extensive and lengthy neuropsychological tests, which can take hours to administer [11, 21]. In a clinical setting, shorter screening tools are often preferred for practical reasons, such as the Montreal Cognitive Assessment (MoCA) [22], which was developed to screen for MCI in an elderly population. It consists of items spanning several cognitive domains including the following: visuospatial/executive functioning, naming, memory, attention, language, abstraction, delayed recall, and orientation. The participant is asked to respond to the following items: tracing a line conjoining letters and numbers in ascending order while alternating between a letter and a number (*trail*), reproducing an illustration of a cube (*cube*), drawing a clock indicating a specific time (*clock contour, clock numbers, clock hands*), naming of three animals (*lion, rhinoceros, dromedary*), forward and backward digit spans, tapping when the letter A is read out amongst a series of other letters (*tapping*), subtractions of 7 from 100 (*serial 7*), sentence repetitions, naming of words which begin with a specific letter of the alphabet (*verbal fluency*), abstractions, delayed recall of five words (*face, velvet, church, daisy, red*), and orientation items (*year, month, exact date, day of the week, place, and city*) [22]. A total score is obtained by summing the scores from each item, and a cutoff score below 26 on 30 is considered an indicator of MCI with a sensitivity of 90 % for elderly populations as compared to 18 % sensitivity for the Mini-Mental State Examination [22]. A study by Olson et al. was the first to explore the feasibility of using the MoCA within a population with brain cancer [23]. The study hypothesized that the MoCA's short administration time would minimize the impact of cognitive testing on people with cancer-related fatigue; they found that the MoCA was well tolerated. In addition, they argued that the MoCA's availability in multiple languages, at nil cost, and its ability to be administered by various health care professionals would allow this measure to be appropriate for clinical use with people with brain cancer and called for further validation studies. In a later study, Olson et al. found the MoCA to be superiorly sensitive to the commonly used Mini-Mental State Exam and found it to be well correlated with patient-reported outcomes [24]. A recent study by Baxter et al. explored the feasibility of using the MoCA to assess MCI in survivors of various cancer types and found it to be an applicable measure [25]. However, the literature lacks psychometric evaluations of the properties of the MoCA in people with noncentral nervous system cancers [20].

Modern psychometric methods are growing in popularity within the research of rating scale performance. Rasch measurement theory (RMT) is a modern psychometric method grounded within a proven mathematical model, which depicts the conditions to be satisfied for a measurement tool to be considered a rating scale. Unlike traditional psychometric evaluations, RMT has the benefit of being sample independent, thus increasing the generalizability of the results. Within the literature, the MoCA has been evaluated in a number of populations using classical test theory. Only a few studies have used modern psychometric methods, such as RMT, to evaluate the MoCA's psychometric properties, mainly within geriatric populations [26–28]. These studies have shown that the MoCA can provide reliable and valid estimates of overall cognitive performance within these populations. However, no study has used RMT to explore the psychometric properties of the MoCA in a population of people with cancer. The objective of the present study is to explore the measurement properties of the MoCA in a population of people with noncentral nervous system cancer.

Methods

Setting The Cancer Nutrition-Rehabilitation (CNR) Program has been established as a research program with the aim of evaluating the effect of such a program on various clinical outcomes (see Gagnon et al. [29] for details) and was approved by the Research Ethics Board of the McGill University Health Centre. All clinical data were collected prospectively and entered in a database. This study is a secondary analysis of the collected clinical data. The MoCA was administered in either French or English by an occupational therapist to some

people attending the program to screen for MCI, using criteria established for the geriatric population [22].

Population and clinical data Participants over the age of 18 enrolled in the CNR program between 2009 and 2012 with noncentral nervous system cancer types with a MoCA assessment (original version) available in their medical chart were included while those with brain metastases were excluded. The following data were extracted from the CNR database: sex, age, cancer site, cancer stage, and treatment status. As the MoCA results were not entered in the database, the itemized MoCA test scores, language of assessment, and years of education were extracted retrospectively from the medical charts.

Statistical analyses RMT was used to evaluate the MoCA's measurement performance against a mathematical model to determine if a priori requirements for it to be considered a rating scale had been met. This theory assumes that the probability of each response is dependent on the interaction between the difficulty level of the item and the ability level of the examinee. The partial credit model was selected to take into account the *serial 7* item which consists of sequentially subtracting 7 from 100 five times. This item is therefore scored on a four-point scale: 3 points are allotted for at least four correct subtractions, 2 points for two or three correct subtractions, 1 point for only one correct subtraction, and 0 for none.

Test-of-fit statistics were used to evaluate targeting of persons and items by comparing ability levels to the difficulty level of each item. Test-of-fit statistics represented as infit and outfit residual statistics provide information about the difference between the score obtained and the expected score according to the Rasch model [30]. Infit residual and outfit residual values between 0.5 and 1.5 were considered suitable fit [30]. Standardized fit residuals ±2 were considered to be representative of misfit [30]. A principal component analysis of the residuals was then conducted to test unidimensionality and to identify the possibility of any dominant secondary factor, which may preclude the important RMT property of unidimensionality [30]. The goal of the principal component analysis was to determine whether one factor was sufficient to explain the variance within the data. To test unidimensionality, Reckase's criterion was used which proposes that unidimensionality is achieved when the variance explained by a measure is at least 20 % [31]. Furthermore, as proposed by Linacre, an eigenvalue of at least 3 in the first contrast was used as a cut-point for multidimensionality [30]. Differential item functioning (DIF) analyses for age, sex, education, cancer stage, language of testing, and chemotherapy status were also conducted to determine response patterns to items which did not fall within the RMT predictions, with a cutoff value of $P \leq 0.05$, and ensure that the MoCA retains its measurement properties regardless of changes in these variables. In keeping with Rasch analytic requirements [30], extreme person scores were omitted from the measurement estimation process. Rasch summary statistics were explored, also with the removal of extreme scores. In order to support a scale's reliability (internal consistency), separation statistics above 2 and reliability above 0.8 were used [30]. Rasch analyses were conducted using Winsteps version 3.81.0 statistical software [32].

Results

Participant characteristics are presented in Table 1. The majority of the 74 participants (74 %) were under the age of 65 with varying cancer diagnoses and stages. Furthermore, 90.5 % of the sample reported having completed over 12 years of education.

As shown in Table 2, the principal component analysis of the residuals demonstrated that the MoCA explained 29.4 % of the raw variance within the observations, meeting Reckase's criterion of unidimensionality, which requires the measure to explain at least 20 % of the raw variance [31]. The unexplained variance in the first contrast was equivalent to an

Table 1 Participant characteristics

		N (%)
Number of participants		74
Participants below 65 years old		55 (74.3)
Participants ≥65 years old		19 (25.7)
Female		46 (62.7)
Male		28 (37.3)
Education ≥12 years		67 (90.5)
Chemotherapy status	During chemotherapy	29 (39.2)
	Post-chemotherapy treatment	45 (60.8)
Cancer stage	Stages I–II	15 (20.3)
	Stages III–IV	50 (67.6)
	N/A	9 (13.5)
Cancer diagnosis	Colorectal	17 (23.0)
	Breast	13 (17.6)
	Lung	8 (10.8)
	Upper gastrointestinal	6 (8.1)
	Leukemia	6 (8.1)
	Ovarian	5 (6.8)
	Head and neck	5 (6.8)
	Pancreatic	4 (5.4)
	Lymphoma	2 (2.7)
	Kidney/bladder	2 (2.7)
	Other	6 (8.1)

N number of participants

Table 2 Results of the principal components analysis

A) Raw observed and expected variance			
	Observed eigenvalue units	Observed % of total raw variance	Expected Rasch model %
Total raw variance in observations	35.4	100.0	100.0
Raw variance explained by measures	10.4	29.4	29.4
Raw variance explained by persons	4.1	11.6	11.6
Raw Variance explained by items	6.3	17.8	17.8
B) Raw unexplained variance			
	Eigenvalue units	% of total raw variance	% of raw unexplained variance
Total raw unexplained variance	25.0	70.6	100.0
Unexplained variance in first contrast	2.6	7.2	10.2
Unexplained variance in second contrast	2.1	6.0	8.4
Unexplained variance in third contrast	1.9	5.5	7.7
Unexplained variance in fourth contrast	1.7	4.9	7.0
Unexplained variance in fifth contrast	1.6	4.5	6.4

eigenvalue of 2.6. As per Linacre, an eigenvalue of at least 3 in the first contrast is required to indicate multiple dimensions [30]. Thus, an eigenvalue of 2.6 is sufficient to support that the MoCA does not measure more than one dimension.

Figure 1 presents a person–item variable map, while Table 3 presents item locations and their fit to the Rasch model. As shown in Table 3, the MoCA items fell along a continuum spanning −4.08 to 2.49 logits, thus covering a total of 6.57 logits. When calibrated ordinally, the *drawing of the cube* item represented the most difficult item in contrast to the *orientation* items (*city*, *place*, and *year*) which represented the least difficult. The *repetition of the second sentence* item was closest to a logit value of 0 (logit value of 0.05), representing an average cognitive ability level. These item characteristic curves are presented in Fig. 2, and all item characteristic curves are presented in Supplementary materials. Test-of-fit statistics demonstrated that the item infit residual values ranged from 0.85 to 1.22 and outfit residuals from 0.41 to 1.43. The items *city*, *place*, and *year* did not fit the model, as they yielded correct responses from 100 % of the sample. Furthermore, the following items fell slightly short of optimal fit: *drawing of the clock contour* item (outfit residuals 0.40), the first *abstraction* and *the oriented to month* items (outfit residuals 0.41), and the *naming of the lion* item (outfit residuals 0.47). However, these items do not represent misfit.

Furthermore, as presented in Fig. 1, the difficulty levels of the items within the MoCA were found to mistarget person cognitive ability levels which spanned from −0.51 to 5.17 logits. This suggests that the MoCA was slightly off-target, as it did not challenge the abilities of participants with higher cognitive abilities.

Table 4 presents Rasch summary statistics. Participants presented a good variability of MoCA scores with a mean total score of 24 (SD 3.1) corresponding to an item difficulty logit value of 1.78 (SD 0.92), with the lowest total MoCA score being 14 (Table 4(A)). A separation index of 1.04 and person reliability of 0.52 indicated lower levels of reliability for the measure as a whole (Table 4(B)).

DIF analyses found that age influenced performance on the *drawing of the clock contour* item, as people ≥65 years old performed at an item difficulty level of 0.36 logits (SE 0.56) in comparison to people <65 years old who performed at an item difficulty level of −3.63 logits (SE 1.81) which demonstrates that people ≥65 years old had more difficulty with this item (DIF contrast of 3.99, $p=0.04$). DIF analyses also found that chemotherapy treatment status impacted responses on the *serial 7* item (five consecutive subtractions). Participants undergoing chemotherapy treatments at the time of assessment performed at an item difficulty level of −2.21 logits (SE 1.01) in comparison to participants having completed chemotherapy treatment who performed at an item difficulty level of 0.05 logits (SE 0.26) which demonstrates that participants post-chemotherapy found this item more difficult (DIF contrast −2.25, $p=0.02$). Lastly, DIF analyses for sex revealed that the *drawing of the cube* item was impacted by sex ($p=0.05$). Women completed the *drawing of the cube* with an item difficulty level of 2.93 logits (SE 0.36) in comparison to men who completed the *drawing of the cube* with an item difficulty level of 1.81 logits (SE 0.41) which demonstrates that this item was easier for men (DIF contrast 1.12; $p=0.05$). DIF for education, language of testing, and cancer stage did not yield any statistically significant results.

Discussion

This study presents the first application of RMT to the MoCA within a population of people with cancer. The results of this study provide preliminary evidence of strengths and

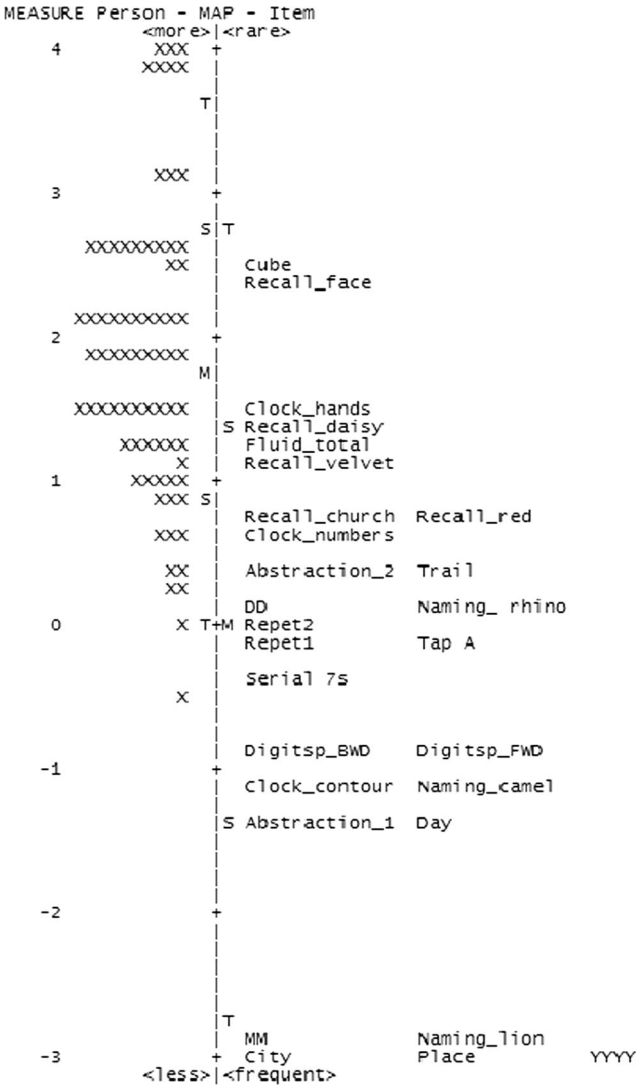

Fig. 1 Person–item map. A variable map of person ability levels in comparison to item difficulty levels. The letter *M* along the vertical axis indicates the mean logit value, the letter *S* indicates one standard deviation from the mean, and the letter *T* indicates two standard deviations. Items are ranked according to their difficulty level, and persons are ranked according to their ability levels. Difficulty levels are represented as logits, where 0 logit indicates an item of average ability whereas items with logit values above 0 represent more difficult items and items below 0 represent less difficult items

weaknesses of using the MoCA in a population of people with cancer.

The first strength is that the MoCA may be considered to be measuring a unidimensional latent construct. Within the present study, the MoCA was found to be measuring one dimension based on a principal component analysis, which revealed an acceptable variance explained by the measure of 29.5 %, as per Reckase's criterion. Another criterion relevant to dimensionality is the eigenvalue in the first contrast, which was found to be 2.6. As per Linacre, an eigenvalue of 3 is usually required to consider the possibility of multiple dimensions [30]. Thus, unidimensionality is supported. As described by Chou et al., eigenvalues are influenced by sample size [33]. Using a larger sample size, unidimensionality of the MoCA has been corroborated by Koski et al., who found the MoCA to be unidimensional, using exploratory and confirmatory factor analysis, albeit in a geriatric population [27]. Furthermore, Freitas et al. also found the MoCA to be unidimensional, using principle components analysis and a cut point of 20 % variance explained by the measure and an eigenvalue below 3 in the first contrast, in an elderly Portuguese population [28]. The second strength of the MoCA found within the present study is that the majority of the items fit the Rasch model. Thirdly, the MoCA items covered a large range of item difficulty levels.

However, the MoCA presents some weaknesses. Its main weakness observed in this present study is that the items mistarget the cognitive abilities of the participants being tested. Specifically, person cognitive ability levels were found to be higher than the most difficult items on the MoCA, such as the *drawing of the cube* and *recall of the word face*. In addition, the finding of three extreme scores and numerous high person scores points to a gap in the higher difficulty item range. Furthermore, items at the lowest end of the continuum, such as *city*, *place*, *year*, and *month*, were also found to be too simple for this population. A scale is considered to be well targeted when the average location score obtained for persons is centered on 0 [30], which was not the case in our study, as the mean of person abilities was 1.78 logits (SD 0.92). This may suggest the possibility of a ceiling effect when using the MoCA in some persons with cancer. This may be because the MoCA has a limited number of items which target areas such as verbal memory, processing speed, and executive function which were found to be impacted by cancer-related MCI in previous studies [34, 35]. In a systematic review, McDougall et al. found that individuals with breast, colorectal, and prostate cancers experienced difficulties in executive function, memory, verbal memory, and recall [36]. Our findings are also supported by a previous study by Bender et al., which found that cognitive impairment in people with cancer tends to be domain specific rather than dispersed [37]. Moreover, differences in the cognitive changes found in people with cancer in comparison to other populations may partially explain the higher cognitive ability levels found in the present study.

Within this present study, DIF analyses revealed DIF for chemotherapy status for the *serial 7* item such that participants post-chemotherapy treatment were at a disadvantage. This finding is supported by longitudinal studies on chemotherapy-induced MCI which have demonstrated cognitive changes even months following the completion of chemotherapy treatment. Deprez et al. correlated these changes with decreases in cerebral white matter at several time points post-chemotherapy [38]. Furthermore, a randomized prospective study by Wefel et al. found that a subset of women who had received chemotherapy for breast cancer continued to

Table 3 Item locations and fit to Rasch model

Item	% of persons with correct response	Item-test correlation	Item difficulty logits (SE)	Infit residuals	Outfit residuals
Drawing of the cube	67.6	0.38	2.49 (0.27)	1.07	1.14
Delayed recall of the word face	74.2	0.44	2.35 (0.28)	0.99	1.01
Drawing of the clock hands	76.1	0.46	1.54 (0.26)	0.94	0.93
Delayed recall of the word daisy	72.7	0.52	1.33 (0.27)	0.85	0.8
Verbal fluency[a]	60.6	0.28	1.27 (0.26)	1.13	1.23
Delayed recall of the word velvet	75.8	0.47	1.18 (0.27)	0.91	0.87
Delayed recall of the word red	74.2	0.38	0.78 (0.27)	0.91	0.87
Delayed recall of the word church	72.7	0.23	0.7 (0.29)	1.14	1.23
Drawing of the clock numbers	73.2	0.35	0.6 (0.29)	1.01	0.93
Trail making[b]	77.5	0.36	0.34 (0.3)	0.93	1.19
Second abstraction[c]	80.3	0.44	0.34 (0.3)	0.87	0.78
Oriented to day of the month	80.3	0.1	0.15 (0.32)	1.22	1.43
Naming of the rhino	80.3	0.25	0.15 (0.32)	1.06	1.12
Repetition of the second sentence[d]	80.3	0.31	0.05 (0.32)	1.03	0.86
Repetition of the first sentence[e]	78.9	0.19	−0.17 (0.34)	1.11	1.22
Tapping A[f]	85.9	0.31	−0.17 (0.34)	0.95	0.94
Serial 7[g]	83.1	0.37	−0.36 (0.25)	0.98	0.89
Forward digit span	91.5	0.24	−0.92 (0.44)	1.01	0.81
Backward digit span	91.5	0.32	−0.92 (0.44)	0.93	0.56
Naming of the camel	93	0.16	−1.13 (0.48)	1.01	1.23
Drawing of the clock contour	93	0.35	−1.13 (0.48)	0.87	0.49
Oriented to day of the week	94.4	0.13	−1.38 (0.53)	1.05	1.15
First abstraction[h]	94.4	0.34	−1.38 (0.53)	0.86	0.41
Oriented to month	97.2	0.04	−1.38 (0.53)	0.86	0.41
Naming of the lion	98.6	0.14	−2.85 (1.01)	1	0.47
Oriented to year	100	0	−4.08 (1.83)	–	–
Oriented to place	100	0	−4.08 (1.83)	–	–
Oriented to city	100	0	−4.08 (1.83)	–	–

SE standard error

[a] Verbal fluency: naming as many words that begin with a specific letter of the alphabet

[b] Trail making: participant is asked to draw a line between numbers and letters in ascending order

[c] Second abstraction: participant is asked to explain how a watch and a ruler are alike

[d] Repetition of the second sentence: participant is asked to repeat the following sentence, "I only know that John is the one to help today"

[e] Repetition of the first sentence: participant is asked to repeat the following sentence, "The cat always hid under the couch when dogs were in the room"

[f] Tapping A: participant is asked to tap each time they hear the letter "A" amongst a series of letters

[g] Serial 7: five consecutive subtractions

[h] First abstraction: participant is asked to explain how a train and a bicycle are alike

show cognitive decline after treatment [39]. A later study by Wefel et al. found that a large proportion of people receiving chemotherapy experienced delayed cognitive changes [40]. Conversely, DIF for chemotherapy status may also be secondary to a selection bias in our sample. Many participants referred to the CNR program post-chemotherapy were referred for severe cancer-related fatigue (data not presented in this study), a symptom which may impact cognitive performance [41].

Furthermore, in comparison to studies exploring the properties of the MoCA using RMT in other populations, the present study begins to demonstrate some weaknesses of using this measure in a nongeriatric sample of individuals. Using RMT, Koski et al. evaluated the MoCA within a geriatric population and found that it can provide reliable and valid estimates of cognition [27]. In a later study, Koski et al. demonstrated that combining the MoCA and MMSE increased measurement precision, thus improving the estimates of

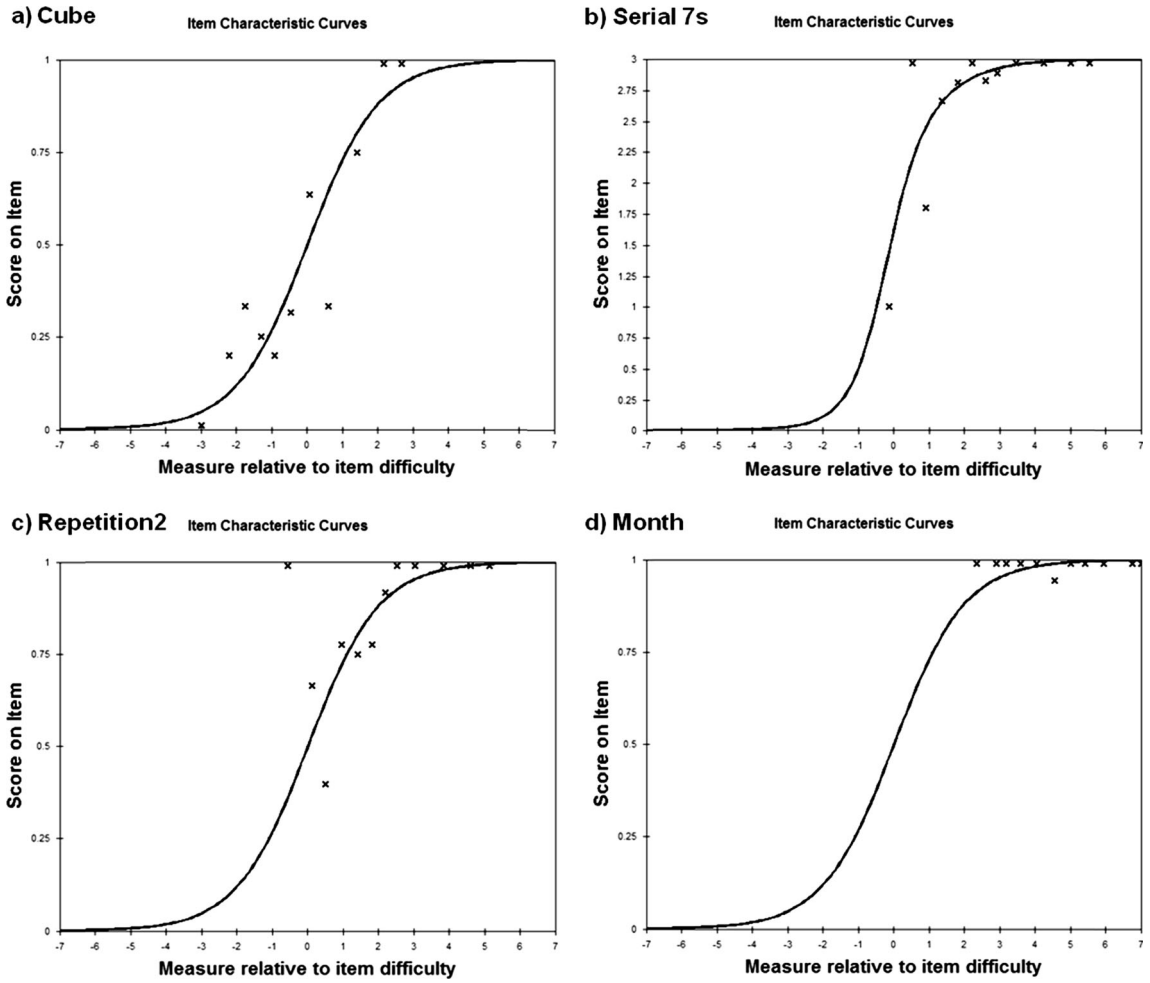

Fig. 2 Selected item characteristic curves (ICC). *Solid lines* represent expected item responses for each person location (ability) as per Rasch estimates. *Dots* represent observed responses from participants. **a** ICC for the *drawing of the cube* item; this item was found to have the highest logit value (difficulty). **b** ICC for the *serial 7* item (five sequential subtractions), scored on a four-point scale. **c** ICC for the *repetition of the second sentence* item with a logit value at the lower end of the continuum. **d** ICC for the *month* item, which obtained perfect scores from the majority of the sample

overall cognition in a geriatric population. Albeit, a limitation of both these studies was that samples were derived from a cognitive specialty clinic [26]. In 2011, Konsztowicz et al. developed a novel method for quantifying overall cognitive impairment in the elderly population through adaptive testing. This simplified approach, known as the Geriatric Rapid Adaptive Cognitive Estimate (GRACE), provides a brief alternative which reduces test-taker burden by administering questions in line with the test-takers' abilities; questions that are too simple are avoided [42]. Studies exploring adapted testing methods may also prove to be useful in people with cancer.

The sample size was a limitation within the present study and may limit the generalizability of results. A recent study by Chen et al. compared the results of Rasch analyses by drawing varying small subsamples of 30, 50, 100, and 250 participants from a sample of 800 participants [43]. They found that the person separation index, a reliability measure, was not significantly influenced by sample size. However, the magnitude of fit residuals (larger samples were able to detect more misfitting items), overall model fit (larger sample sizes provided larger chi-square statistics), and item and person ordering varied with smaller sample sizes. Stability was achieved with sample sizes above 100 [43]. Thus, the results of the present study, with a sample size of 74 participants, should be used with caution, as they provide exploratory psychometric properties as a first step in evaluating the psychometric properties of the MoCA, rather than definitive results.

The current literature is lacking a clear definition of cancer-related MCI. A clearer definition of this construct can help guide further research exploring measurement tools specific to people with cancer. Physiologically, the changes associated with cancer-related MCI differ greatly from those seen in individuals with dementia. A number of studies have hypothesized that physiological and psychosocial mechanisms may contribute to the onset of cancer-related MCI such as inflammatory cytokine dysregulation, DNA damage, genetic

Table 4 Rasch summary statistics

A) Participant performance on the MoCA			
	Mean (SD)	Max	Min
Total MoCA score	24 (3.1)	29	14
Frequency	27.6 (1.3)	28	23
Person ability logits	1.78 (0.92)	3.89	−0.51
Model error	0.59 (0.15)	1.05	0.43
Infit residuals MNSQ	1.00 (0.23)	1.75	0.65
Infit residuals ZSTD	0.1 (0.7)	2.2	−1.3
Outfit residuals MNSQ	0.95 (0.59)	4.13	0.2
Outfit residuals ZSTD	0.1 (0.7)	3.1	−1.3
B) Measure reliability			
	Real	Model	
RMSE (SD)	0.63 (0.66)	0.61 (0.69)	
Separation index	1.04	1.13	
Person reliability	0.52	0.56	

SE person mean=0.11

MoCA Montreal Cognitive Assessment, *SD* standard deviation, *MNSQ* mean-square infit statistic, *ZSTD* Z-standardized, *SD* standard deviation, *RMSE* root-mean-square deviation, *SE* standard error of person mean

predispositions, hormonal changes, and toxins crossing the blood–brain barrier as well as psychosocial mechanisms such as stress and depression [14, 44, 45].

Within the limits of a small sample size, the results of this exploratory study suggest the possibility that the MoCA, when used within a population of persons with cancer, may meet criteria for unidimensionality and adequate item fit but may lack the ability to discriminate levels of cognition in persons of higher cognitive abilities.

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Conflict of interest The authors have no conflicts of interest to declare. The primary author has full control of all data and agrees to allow the journal to review pertinent de-identified data if requested.

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