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Montreal Cognitive Assessment (MoCA): A Convergent validation study in the framework of a Neuropsychological Assessment Consultation

VOLUME 1

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Resumo

Os défices cognitivos são uma grande preocupação de saúde pública no atual contexto de envelhecimento da população. A deteção precoce destes é de extrema importância para a identificação atempada da demência e do declínio cognitivo associado a outras patologias. A avaliação neuropsicológica (ANP), e mais especificamente, os instrumentes de rastreio cognitivo breves, como o *Montreal Cognitive Assessment* (MoCA), mantém-se o melhor método para monitorizar a progressão do declínio cognitivo. Este estudo psicométrico visa examinar a validade convergente do MoCA relacionada com critérios externos através da análise da relação entre os resultados do MoCA e os resultados de testes estandardizados da consulta de avaliação neuropsicológica do "Centro de Prestação de Serviços à Comunidade da Faculdade de Psicologia e Ciências da Educação da Universidade de Coimbra". Os dados foram retirados da base de dados desta consulta (N=79). Foram realizadas análises comparativas com outros instrumentos (testes de rastreio, testes neuropsicológicos e um resultado z compósito de testes neuropsicológicos por domínio cognitivo). Os resultados do MoCA (total e por domínio) demonstraram correlações significativas, positivas, moderadas a altas, com as outras provas e pontuações compósitas analisadas. O estudo reúne evidencias de validade convergente deste teste de rastreio, demonstrando que o MoCA é uma medida breve, fiável e válida da função cognitiva, concordante com os resultados de outros testes neuropsicológicos frequentemente usados na prática clínica.

Palavras-Chave: Montreal Cognitive Assessment; Validade Convergente; Rastreio Cognitivo; Testes Neuropsicológicos

Abstract

Cognitive impairments are a major public health concern in the current context of aging population, being early detection of these impairments of great importance, once it can increase the detection of dementia and other pathologies. Neuropsychological assessment (NPA), and more specifically, brief cognitive screening tests, like the Montreal Cognitive Assessment (MoCA) remain the best method to monitoring the progression of dementia (Strauss et al., 2006; Larner, 2017a). The objective of this psychometric study, that examined the MoCA convergent validity related to external criteria, was to investigate the relationship between the screening instrument scores (total and per domain) and other scores of standardized tests of the NPA consultation of the "Centro de Prestação de Serviços à Comunidade da FPCEUC". Data was collected from the data base of the consultation (N=79) and the Pearson correlation coefficient was used. The comparisons were made with cognitive screening tools, detailed batteries, and a composite z-score of neuropsychological tests that measured similar constructs to the MoCA domains. The MoCA scores demonstrated significant, positive, moderate to high correlations with these measures, as was hypothesized, providing empirical validation of the convergent validity of this screening tool. Therefore, this study proved that MoCA is a short, reliable, and valid measure of cognitive function, that shows good agreement with commonly used neuropsychological tests, being a useful instrument in clinical practice.

Key Words: Montreal Cognitive Assessment; Convergent Validity; Cognitive Screening; Neuropsychological Tests

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Abbreviations

ACE-R- Addenbrooke’s Cognitive Examination- Revised

AD - Alzheimer’s Disease

ADAS-Cog - Alzheimer’s Disease Assessment Scale-cognitive subscale

CPSC - Centro de Prestação de Serviços à Comunidade

FSIQ - Full-Scale IQ

MCI - Mild Cognitive Impairment

MMSE - Mini Mental State Examination

MoCA - Montreal Cognitive Assessment

MRI - Magnetic Resonance Imaging

NPA - Neuropsychological Assessment

NPT - Neuropsychological Tests

PIQ - Performance IQ

PRI - Perceptual Reasoning Index

PSI - Processing Speed Index

SH - Subcortical Hyperintensities

TMT-A and TMT-B - Trial Making Test - part A and B

TP - Toulouse and Piéron cancelation test

VCI - Verbal Comprehension Index

VIQ - Verbal IQ

VPF - Verbal Phonemic Fluency Test

VSF - Verbal Semantic Fluency Test

WAIS-III - Wechsler Adult Intelligence Scale- third edition

WAIS-IV - Wechsler Adult Intelligence Scale- fourth edition

WMI - Working Memory Index

WMS-III - Wechsler Memory Scale- third edition

Introduction

Cognitive impairments are a major public health concern in the current context of aging population and its presence in it will likely grow with the passage of time, because of an increase in average life expectancy. It is agreed that older age is a prominent risk factor for the development of cognitive decline (Larner, 2017a), often associated with the prevalent neurodegenerative pathologies like Alzheimer´s disease (AD).

It is estimated that, worldwide, 50 million people have some form of dementia (World Health Organization [WHO], 2020) and this prevalence can also be seen in Portugal, where the number of patients with AD and Mild Cognitive Impairment (MCI) is increasing (Santana et al., 2015), which helps to establish cognitive decline as very relevant problem in the present health context of the population and in aging.

Early detection of the cognitive impairments is of great importance once it can increase the detection of dementia and other pathologies, being this the first step to improve clinical care of patients and ensure the management of the disease (Borson et al., 2013). This early detection can also help to improve a rehabilitation program and to predict the prognosis or outcomes of different disorders like Traumatic Brain Injury (eg., An et al., 2019; Panwar et al., 2018), Stroke (Pendleburry et al., 2017) and MCI (Julayanont & Nasreddine, 2017). This, in turn, can lead to an earlier intervention that will help prevent the increment of the negative impact of these impairments. Another benefit would be delaying dementia development, which can be done by, for example, reducing the exposure to risk factors and planning future actions, such as following recommended lifestyle changes given by the healthcare professionals (Rasmussen & Langerman, 2019).

Importance of Neuropsychological Assessment

The definition of reliable disease biomarkers isn’t always present, and when it is, the difficult access to these and the procedure’s consequences or invasiveness for the patient, increase the search for different methods of identification of disorders and impairments (Larner, 2017a). Therefore, neuropsychological assessment (NPA) instruments are of great importance because they allow the identification and description of different disorders. Adding to this, it is not yet clear if biomarkers have better diagnostic utility than cognitive screening instruments (Larner, 2017b).

Effectively, NPA continues to be a privileged method to analyze cognitive functioning and has revealed a high efficiency in the distinction between normative aging and pathological conditions. Furthermore, the brief cognitive screening tests, in particular, remain the best method to monitoring the progression of dementia (Strauss et al., 2006; Larner, 2017a).

Neuropsychological assessment is a process of gathering information about a person and his(hers) characteristics and skills (cognitive, emotional, personalistic). It allows to assess the behavioral and functional expression of brain dysfunction by identifying the influence of brain injury or disease (Chang & Davis, 2011), through administration of specific instruments and its interpreted results. This interpretation is achieved by the comparison of the specific scores of the person on each test to average scores of individuals in those same tests, that have, for example, the same age and/or the same level of education and by analyzing the set of different information that was gathered, which includes the person's life history, context of assessment and the measures of different neurocognitive and other psychological functions.

As one of the main objectives of NPA is characterizing people's cognitive abilities and allowing a more profound insight on the person's daily and emotional functioning, it has multiple clinical applications, such as collecting diagnostic information for dementia, helping in establishing a diagnosis by characterizing the impairments, allocating patients to different treatments and patient follow up (once it can, for example, assess the consequences and impact of a treatment). It is the only process that provides data related to skills, motivation, and potential for future outcomes, adding clinical information to neurological and neuroimaging data, facilitating a differential diagnosis (Harvey, 2012; Lezak et al., 2012; Simões et al., 2016).

This process is also necessary for the early detection of the cognitive impairments once it can be used to predict the evolution of the deficits throughout the time and how the consequences of a lesion can affect the day life person's functioning. However, in the clinical practice often isn't feasible to do a very detailed neuropsychological assessment, whether due to time constraints or to patient's fatigue and disease related difficulties, so there is a need for sensitive and shorter instruments.

The role of Cognitive Screening Instruments

Cognitive screening instruments, like the Montreal Cognitive Assessment (MoCA: Nasreddine et al., 2005; Freitas et al., 2013; Simões et al., 2008), are brief and easily administered tools that allow primary detection of the disease with good sensitivity and specificity. These tests are useful in discriminating between normal and pathological situations, being acceptable to the population and economic; both in time and in cost (Larner, 2017a), which gives them great importance in early detection of the cognitive impairments, remaining the best method to monitor the development of dementia (Strauss et al., 2006; Larner, 2017a).

The use of these instruments is very relevant, especially in the situation we are living, once doctors and psychologists try to keep people, especially the ones with an increased age, away from the hospitals, or if a hospital visit is necessary, they try that the visit is made in the shortest possible time, not only because they are considered at risk groups for Covid-19, but also to ease the pressure on the facilities. So, an optimal cognitive screening instrument should take less than 15 minutes to administer, be of ease administration and interpretation to clinicians, without losing validity and reliability (Larner, 2017a). Besides this, it should be able to detect common cognitive disorders and impairments, assessing all major cognitive domains, like attention, executive functions, visual-spatial, language, orientation, and memory (Larner, 2017a).

As the MoCA assesses all of these domains and fulfills all the other criteria for an optimal screening tool, it was originally created for screening MCI (Larner, 2012), however it is now the recommended screening test for several conditions, such as: Parkinson's Disease Dementia, Vascular Cognitive Impairment (Julayanont & Nasreddine, 2017), Stroke (Chan et al., 2017; Pendlebury et al., 2017), rapid eye Movement Sleep Disorder (REMS, Gagnon et al., 2010), Multiple Sclerosis (Freitas et al., 2018), Traumatic Brain Injury (An et al., 2019; Panwar et al., 2019) and others (www.mocatest.org). It also surpasses the Mini Mental State Examination (Folstein et al., 1975; Freitas, et al., 2014) limitations' by analyzing more relevant domains and having greater sensitivity.

Adding to this, some studies were made that relate performance in the MoCA with brain integrity measures. Paul and collaborators (2011) investigated the neuroimaging signatures and cognitive correlates of this instrument using "structural 3 T magnetic resonance imaging (MRI) to define the volumes of total frontal gray matter, total hippocampus, T2-weighted subcortical hyperintensities, and total brain volume" (p.456), and concluded that better performance in Visuo-spatial/Executive and Attention domains was related to a larger total volume of brain and that better performance on the naming task correlated significantly with total hippocampal volume and frontal lobe volume (Paul et al., 2011). In contrast, the total MoCA score did not correlate significantly with these measures, but a strong tendency was observed between this score and the subcortical hyperintensities (SH), where a lower total score on MoCA was associated with greater SH. These results are in partial agreement with the study from Ritter and colleagues (2017), where a smaller hippocampal volume was significantly correlated with lower memory scores on this instrument, suggesting that further assessment of brain atrophy (for example, hippocampal atrophy) should be prompted by worst performance on MoCA domains. However, the relationships between performance in the MoCA and brain integrity measures needs additional investigation.

International Studies of Montreal Cognitive Assessment's convergent validity

MoCA's convergent validity has been proven with several studies, like the one from Lam and colleagues (2013) that tested the relationship of the MoCA total score with the total score of the MMSE and with a composite z-score for different domains calculated from other neuropsychological tests (NPTs). They found a significant moderate correlation between MoCA and MMSE (r=.66, p<.001) and the MoCA's subscores association, with the respective composite scores from the other instruments, varied from moderate to high, being the lowest for the language domain (r=.46, p<.001) and the highest for the memory domain (r=.73, p<.001) in patients with MCI and Alzheimer's disease (Lam et al., 2013). Adding to these, the MoCA's subscores showed fair to good accuracy for impairment in its domains (Lam et al.,2013). These results are in agreement with the study from Vogel and colleagues (2015) where the MoCA scores loaded onto similar factors measured by other NPTs, such as the subtests of Block Design, Digit Span and Similarities from the Wechsler Adult Intelligence Scale - fourth edition (WAIS-IV; Wechsler, 2008). In this study, the overall test battery mean correlated significantly and moderately with the MoCA total score (r=.66, p<.001), showing a relationship between the overall performance on the MoCA and on a larger battery (Vogel et al., 2015). Adding to these, the MoCA subscores showed high factor loadings with the standard neuropsychological measures of similar constructs.

A similar pattern of moderate correlations of the MoCA with a composite z-score of neurocognitive tests was found in the investigation of Srisurapanont and colleagues (2017) where the concurrent/convergent validity of the screening tool was proved in individuals with major depressive disorder. The composite z-score was highly correlated with the MoCA total score (r=.78, p<.01) and all MoCA domains correlated moderately to high with the analogous NPTs (Srisurapanont et al., 2017)

The relationship between WAIS-IV and MoCA also has been studied. The results showed that both the Full-Scale IQ and the index factors are significantly correlated with MoCA's scores, being the total score of the screening tool moderately correlated with the

Full-Scale IQ (FSIQ) of WAIS-IV [r=.64, p<.01 in the study of Sugarman and Axelrod (2013) and p<.001 in the study of Di Nuovo et al., (2018)]. All subtests of the WAIS-IV had significant moderate to high correlations with the MoCA total score (lowest r=.36, p<.01- Symbol Search subtest, highest r=.75, p<.001 — Digit Span subtest), with the exception of the Visual Puzzles and Cancellation subtests (Di Nuovo et al., 2018). As to the factor indexes, all but the Processing Speed Index, correlated moderately with the respective MoCA domains, with the exception of the abstraction, memory and orientation ones, in a sample of individuals with intellectual disability. Another conclusion that is important to mention is the fact that the Verbal Comprehension Index (VCI) was the best predictor of the impairment measured by the MoCA total score, as well as the Working Memory Index (WMI) highest correlation was with the attention domain (Di Nuovo et al., 2018).

Comparing the MoCA with other screening instruments, convergent validity is also proved, being the correlations with the MMSE moderate to high (Lam et al., 2013; Julayanont & Nasreddine, 2017), and a higher correlation between the MoCA and the FSIQ, that is bigger than the one with the MMSE (Sugarman & Axelroad, 2013), was also found. Regarding the relationship between the Addenbrooke's Cognitive Examination-Revised (ACE-R, Mioshi et al., 2006; Firmino et al., 2017) and the MoCA, the study of Pendlebury et al., (2017) found strong correlation between the two (Spearman r^2= .87, p<.01), being both MoCA's and ACE-R's subtests good at discriminating between subjects. Both MoCA and ACE-R show comparable results regarding different conditions (for more information, see Hodges & Larner, 2017) and are proved to be more discriminant than the MMSE (Larner, 2012; Rocha et al., 2014).

Portuguese studies of Montreal Cognitive Assessment's convergent validity

Regarding the Portuguese case, several studies about the MoCA's psychometric proprieties (Freitas et al., 2011; Freitas et al., 2012a; Freitas et al., 2014) and validation for different diseases have been made, being considered a valid instrument for discriminating MCI and AD (Freitas et al., 2013), Frontotemporal Dementia (Freitas et al., 2012b), Vascular Dementia (Freitas et al., 2012c) and Multiple Sclerosis (Freitas et al., 2018).

Furthermore, convergent validity of this screening tool as also been showed in these studies, where the correlation between the MoCA and the MMSE was showed to be moderate to high in different diseases, for example, in the study of Freitas and colleagues (2012c), both the instruments scores were significant and positively correlated in the total sample (r=.741;

p<.001) and in the vascular dementia group (*r*=.782; *p*<.001), being the MoCA's scores per domain also positively correlated with the total score. In agreement with these results, the study of Freitas and colleagues (2013) showed high positive correlations between the two cognitive screening tools (*r*=.849; *p*<.001), being present statistically significant differences in all MoCA domains and in all group comparisons, which confirms a better capacity of the tool to discriminate between normal aging and pathologic cognitive decline (Freitas et al., 2012a). Another study (Duro et al., 2010) found not only a high correlation between the MoCA total score and the MMSE (*r*=.82; *p*<.001) but also a significant and moderate negative correlation (*r*= -.76; p<.001) of the first instrument and the Alzheimer's Disease Assessment Scale-cognitive subscale (ADAS-Cog; Mohs, Rosen, Davis, 1983; Rosen, Mohs, Davis, 1984; Guerreiro et al., 2008) together "with moderate to high correlation values between common cognitive areas assessed by all instruments" (Duro et al., 2010, p.732).

All these studies also showed a superiority of the MoCA in detecting, discriminating and differentiating the different disorders in comparison with the MMSE. In fact, the results showed that both the full and short versions of the MoCA discriminate the healthy versus control groups better than the MMSE (Freitas et al., 2012c) and that "MoCA is sensitive to cognitive decline in a short period of time and may capture profiles of cognitive deterioration along the evolution of the disease" (Freitas et al., 2013, p.42).

For the cognitive screening instruments' (like the MoCA) development and validation, it is important to understand the relationship between cognitive screening and the gold standard of cognitive evaluation, that is a full and detailed NPA (Vogel et al., 2015). Adding to it, studies of this nature are very few in current literature, as far as my knowledge goes, so, this study was developed to investigate the convergent validity of the MoCA, regarding a total sample of a NPA consultation.

Objectives and Hypothesis

The general aim of the present study is to examine the MoCA convergent validity related to external criteria, namely the ACE-R, the MMSE and Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997; 2008a) and other NPTs like the Wechsler Memory Scale-III (WMS-III;Wechsler, 1997; 2008b), the Rey Complex Figure (RFC; Rey, 1964; Bonifácio, 2003; Espírito-Santo et al., 2015), the Toulouse and Piéron cancelation test (TP; Tolouse & Piéron, 1904; Lima et al., 2021), the Trail Making Test - part A and B (TMT-

A and TMT-B; Reitan, 1958; Cavaco et al., 2013a; Cavaco, 2015) and the Verbal Phonemic and Semantic Fluency Tests (VPF and VSF; Cavaco et al., 2013b).

This psychometric study will allow to investigate the relationship between the cognitive screening test and other standardized NPTs, more specifically, the association of the MoCA total score and cognitive domains subscores with the scores obtained in the assessment instruments which compose the NPA protocol administered at level of consultation in the "Centro de Prestação de Serviços à Comunidade Faculdade de Psicologia e Ciências de Educação da Universidade de Coimbra (CPSC)".

Adding more depth to it, the specific objectives of the study are:

- To examine the convergent validity of MoCA scores (total and domains) by comparing it with to the total scores of the other instruments that measure general cognitive function (MMSE, ACE-R, WAIS-III);
- To compare the total MoCA score with the scores of specific neuropsychological tests (Wechsler Memory Scale-III, Rey Complex Figure, Toulouse-Piéron cancelation test, the Trial Trail Making Test - part A and B and Verbal Phonemic and Semantic Fluency Tests) that form a composite z-score;
- To compare the MoCA domain scores with the same composite z-score, divided by domains (memory, attention, language, executive functions and visuospatial) that was created by the other instruments' scores that measure similar constructs[1] and with the total composite z-score.

It is hypothesized that the MoCA total score will correlate moderately to high with the total score of the ACE-R, MMSE and the Full-Scale IQ of WAIS-III. It is also expected that the MoCA domains scores will correlate moderately to high with the scores of the domain of the ACE-R and with the factorial index of WAIS-III that measure similar constructs, such as executive functions (Executive Functions domain on ACE-R and Working Memory Index), visuospatial/constructional skills (Visuospatial Domain of the ACE-R and Perceptual Reasoning Index) and language (Language Domain of the ACE-R and Verbal Comprehension Index), and with the composite z-score per domain that was defined. If the hypothesis is confirmed, it would give evidence of the convergent validity of the MoCA, which would prove the utility of this instrument as a measure of cognitive function that is precise and has robust psychometric properties, therefore, giving additional evidence of it being a good screening tool, essential to clinical practice.

[1] For more detailed information, see Table 2.

Method

Participants

The data will be retrieved from the database of the neuropsychological assessment consultation of the "Centro de Prestação de Serviços à Comunidade da Faculdade de Psicologia e Ciências de Educação da Universidade de Coimbra (CPSC)".

The sample (*N*=79) is composed by 58.2% females. The average age of all the participants is 49.61 years-old (SD= 10.917; range: 19-67 years) and average education is 10.35 years (SD= 5.522; range: 1 to 19 completed years). The MoCA average total score of the subjects is 19.62 (SD=6.115; range: 2-29). Out of these 79 subjects, there is a subgroup of people who had results on the ACE-R and the MMSE (*N*=66).

The referral question was classified in 3 different types: Court-Order or Work Accident (48.1% — 38 cases), Early Retirement (12.7% — 10 cases) and a request for detailed Neuropsychological Assessment (39.2% — 31 cases).

Materials

The instruments that will be analyzed with more detail in the dissertation are: MoCA, ACE-R, MMSE, WAIS-III, WMS-III, the RFC, TP, TMT-A and TMT-B and the VPF and VSF. These were applied by a trained neuropsychologist and are of established practice on the consultation (common procedures) so institutional ethical appraisal will not be mentioned.

The MoCA is brief cognitive screening instrument widely used that measures cognitive impairment. It assesses six cognitive domains (Table 1): Executive Function, Language, Visuospatial Skills, Short-Term Memory, Attention/Concentration/Working Memory and Temporal/Spatial Orientation (Freitas, et al., 2012) being the target population younger and older adults.

It has been validated in several populations and different languages, having good psychometric proprieties, for example, in the Portuguese population, it showed high internal consistency [Cronbacch's alfa between .723 for MCI and .847 for Frontotemporal Dementia, with .775 for controls (Freitas et al., 2011; Freitas et al., 2012; Freitas et al., 2013)]. MoCA also has a considerable number of studies with the Portuguese population, like, for example, the validation for Frontotemporal Dementia (Freitas et al., 2012) or for cognitive dysfunction in Multiple Sclerosis (Freitas et al., 2018).

Table 1

Montreal Cognitive Assessment Subtests and Domains.

Montreal Cognitive Assessment Subtest	Montreal Cognitive Assessment Domain
Trail Making Test- B	Executive Functions
Cube Draw	Visuospatial
Clock Draw	
Animal Naming	Naming (Language)
Word List	Memory[2]
Digit Span Direct	Attention
Digit Span Backwards	
Target Detention Task	
Subtraction Task	
Sentence Repetition	Language
Verbal Phonemic Fluency- letter P	
Similarities Task	Abstraction (Executive Functions)
Recall of word list	Delayed Recall (Memory)
Identify Day	Orientation
Identify Month	
Identify Year	
Identify Weekday	
Identify Place	
Identify City/Village/Town	

Regarding the interpretation of results, the performance of the participant is compared to individuals with the same age and education level, having total scores and scores by domain, to be understood according to the norms and means with standard deviation. One of the advantages of this test is that is of short duration but also very sensitive to impairment, preventing patient fatigue and helping with time constraints, which is very important in the clinical setting, taking more or else 15 minutes to administer, being this one of the criteria for the optimal cognitive screening instrument according to the Research Committee of The American Neuropsychiatric Association (Malloy et al., 1997).

As for examples of disadvantages, the MoCA showed less specificity to detect some disorders, like, for example, Huntington's disease or traumatic intracranial hemorrhage (Julayanont & Nasreddine, 2017) and poor sensitivity for right hemisphere deficits (Chan et al., 2017).

The MoCA will be compared to the other instruments, by its total score, to the total scores of the MMSE, the ACE-R and the WAIS-III FSIQ, VIQ, PIQ and factorial indexes (WMI, PRI, Processing Speed Index – PSI and VCI), as well as to the total composite z-score formed by analogous NPTs. Another level of analysis will be the MoCA domains (visuospatial, executive, language, attention and memory) and its relationship with the ACE-

[2] Not scored.

R domains and the WAIS-III factorial indexes, as well as with a composite z-score per domain (Table 2) formed by the subtests of the other instruments mentioned above.

Other cognitive screening instruments, that will be an external validity criterion, are the ACE-R) and the MMSE. These are sensitive and discriminant of several disorders [for example, to distinguish different types of dementia (Hodges & Larner, 2017)], have good psychometric proprieties and are validated in several populations and different languages. These instruments also have a considerable number of studies with the Portuguese population, like, for example, the use of the ACE-R in the diagnosis of subcortical vascular dementia and AD (Gonçalves et al., 2014) and a study of cut-off-scores of the MMSE (Morgado et al., 2010). As cognitive screening instruments, these have the same advantage of the MoCA test; however, MMSE has ceiling effects and has less specificity and sensitivity than the MoCA and ACE-R (Mitchell, 2017) and the ACE-R's items that were joined to the MMSE, added little information to estimate of cognitive ability (16%) on AD (Law et al., 2012).

The WAIS-III is a neuropsychological assessment battery of general cognitive function and intelligence for older adolescents and adults (Strauss et al, 2006). It is also widely used and known, having some studies in Portugal [for example, a study related to the performance in these battery after primary brain tumor surgery (Gonçalves et al., 2016)] and robust psychometric proprieties (for more information, see Strauss et al., 2006). It allows a more deep and detailed assessment of the cognitive skills of a person, having 7 different composite measures, 3 IQs: Verbal IQ, Performance IQ, Full Scale IQ (M=100; SD=15; range from 45 to 155) and 4 Factor Indices: VCI, PRI, WMI and PSI (M=100; SD=15; range from 50 to 150). The analysis can also be made by comparing the subtests' (Vocabulary, Similarities, Information, Arithmetic, Digit Span, Letter-Number Sequencing, Comprehension, Picture Completion, Block Design, Matrix Reasoning, Digit Symbol Coding, Symbol Search, Picture Arrangement and Object Assembly) scores. Its raw scores are converted to age scaled scores [M=10; SD=13; range from 1 to 19 (Strauss et al., 2006)]) and these are used for the interpretation of the battery.

Table 2

Neuropsychological Tests, that will form the composite z-score, assigned according to Montreal Cognitive Assessment domains.

Domain	MoCA Components	Tests contributing to the composite z-score
Visuospatial	Cube Copy Clock Draw	ACE-R Cube Copy ACE-R (MMSE) Pentagons Copy ACE-R Clock Draw ACE-R Perception Tasks RCF Copy WAIS-III Block Design WAIS-III Matrix Reasoning
Language	Animal Naming Sentence Repetition	ACE-R Naming ACE-R Repetition ACE-R Comprehension ACE-R Reading WAIS-III Vocabulary WAIS-III Comprehension
Attention	Subtraction task Vigilance task Digit Span	ACE-R Subtraction task ACE-R Spelling task TMT-A TP cancelation test WAIS-III Arithmetic WAIS-III Symbol Search WAIS-III Digit Symbol- Coding WAIS-III Digit Span
Executive	TMT VPF task letter P Abstraction task	TMT-B ACE-R Fluency tasks Verbal Phonemic and Semantic Fluency Tests WAIS-III Similarities WAIS-III Letter-Number Sequencing Task WAIS-III Picture Arrangement
Memory	Delayed Recall Orientation Tasks	ACE-R Delayed Recall ACE-R Anterograde Memory ACE-R Retention Task WMS-III Logical Memory I and II WMS-III Word List I and II RCF immediate memory ACE-R Orientation tasks

Note. MoCA: Montreal Cognitive Assessment; MMSE: Mini Mental State Examination; ACE-R: Addenbrooke's Cognitive Examination- Revised; WAIS-III: Wechsler Adult Intelligence Scale- 3rd edition; WMS-III: Wechsler Memory Scale- 3rd edition; RCF: Rey Complex Figure; VPF: Verbal Phonemic Fluency; VSF: Verbal Semantic Fluency; TMT- Trial Making Test; TMT-A: Trial Making Test- part A; TMT-B: Trial Making Test- part B.

Regarding the memory domain, the WMS-III is a battery used to assess different components of memory, which allows a more detailed description of the impairments in this area. It is composed by 11 subtests (6 main subtests and 5 optional ones), having interpretation by principal indexes, such as, Immediate Auditory and Visual Memory, Immediate Memory, Delayed Auditory and Visual Memory, Auditory Recognition, Working Memory and General Memory, and complementary composite indexes.

Also, the RFC, as is divided in two tasks, the second being of immediate recall of the figure, can be used as a measure of visual immediate memory. The first task of this instrument is the copy of the figure, which allows to measure visual constructional abilities.

The TP and the TMT-A are tests that can be used to measure attention, being the first a cancelation task where the examined needs to select between a large group of symbols specific target ones, in 10 minutes, and the TMT-A a task of drawing a line between several numbers in crescent order.

As for the TMT-B, together with the verbal fluency tests (both phonemic and semantic), are measures of executive functions, and more specifically, cognitive flexibility. The first, consists of drawing a line connecting a number, following crescent order, and a letter, following alphabetic order, and the second consists of evocating the maximum number of words with specific constrains/rules (i.e., in the phonemic fluency task, saying the maximum number of words that start with the letter P, M or R and in the semantic fluency task, saying the maximum number of animal names, for example), in one minute.

Procedures

As previously mentioned, the data will be retrieved from the database of the NPA consultation of the "Centro de Prestação de Serviços à Comunidade da Faculdade de Psicologia e Ciências de Educação da Universidade de Coimbra (CPSC)". The participants gave oral consent for the use of their data, that were anonymized. All the neuropsychological instruments were applied by a trained neuropsychologist and are of established practice on the consultation, being common procedures on it, so institutional ethical appraisal will not be mentioned.

Statistical Analysis and Measures

Statistical analysis will be made with the Statistical Package for the Social Sciences (SPSS) Statistics 25 and the measure will be the Pearson correlation coefficient. Its interpretation will be based on the classification scheme of Hopkins (2014), once it is a more detailed scale.

As for more specific measures, a composite z-score of each domain assessed in the cognitive screening instrument (MoCA) together with the domains assessed by the other neuropsychological assessment tests will be analyzed and correlated.

The domains of the composite z-scores will be visuospatial, executive, language, attention and memory. The tests that form each composite z-score are present in Table 2. Each test that forms the composite z-score correlated significantly (*p*<.01) and moderately to high (see appendix B) with the allocated domain z-score (memory domain: *r*=[.532; .846]; attention domain: *r*=[-.445; .835]; language domain: *r*=[.269; .857]; executive functions: *r*=[-.648; .935] and visuospatial: *r*=[.456; .876]).

Regarding the total composite z-score, it was calculated by two different methods. One resulted from the sum of all the neuropsychological tests composite z-score (method 1) and the other was created by the mean result of these (method 2).

Besides this, the total scores and domain scores of some of the mentioned tests will be used (Table 3).

Table 3

Additional measures.

MoCA Score	Other Tests Score
Total	ACE-R (Total) MMSE (Total) WAIS-III (FSIQ) WAIS-III (VIQ) WAIS-III (PIQ) WAIS-III (WMI) WAIS-III (PSI) WAIS-III (VCI) WAIS-III (PRI)
Visuo-Spatial/Executive Domain	ACE-R Visuospatial Domain ACE-R Fluency Domain WAIS-III WMI WAIS-III PRI
Memory	ACE-R Memory Domain
Attention	ACE-R Attention and Orientation Domain WAIS-III WMI WAIS-III PSI
Language	ACE-R Language Domain WAIS-III VCI

Note. MoCA- Montreal Cognitive Assessment; WAIS-III- Wechsler Adult Intelligence Scale- 3rd edition; FSIQ- Full Scale IQ; VIQ- Verbal IQ; PIQ- Performance IQ; WMI- Working Memory Factorial Index; PSI-Processing Speed Factorial Index; VCI- Verbal Comprehension Factorial Index; PRI- Perceptual Reasoning Factorial Index; MMSE- Mini Mental State Examination; ACE-R- Addenbrooke's Cognitive Assessment-Revised

Results

The study sample comprise 79 individuals that attended the NPA consultation of the CPSC. Table 4 shows the sociodemographic characteristics of the sample.

Table 4

Sociodemographic characteristics of the study sample (N=79).

Characteristics	Number
Age in years	49.61 ± 10.917 [19;67]
Years of Education	10.35 ± 5.522 [1;19]
Gender (Female)	46 (58.2%)
Employment Status	Active- 15 (19.0%) Retired- 6 (7.6%) Unemployed- 14 (17.7%) Health Leave- 40 (50.6%) Student- 4 (5.1%)
Marital Status	Single- 18 (22.8%) Married- 41 (51.9%) Divorced- 16 (20.3%) Widowed- 2 (2.5%) Separated- 1 (1.3%) Unknown – 1 (1.3%)
Referral Request	Work Accident or Court Order- 38 (48.1%) Early Retirement- 10 (12.7%) Neuropsychological Assessment- 31 (39.2%)

Note. Age and education: Results are presented as mean ± standard deviation and additionally are provided the range of the results [minimum value; maximum value]. Gender is characterized by female's n and respective percentage (%). Data of other variables are presented as n and respective percentages.

Montreal Cognitive Assessment total score

The average MoCA total score is 19.62 ± 6.12 (range: [2-29]). Appendix A shows the descriptive statistics for every measure analyzed.

The total MoCA score was significantly, positively, and very high correlated with the WAIS-III Full-Scale IQ (r=.850; p<.01), the total score of the MMSE (r=.840; p<.01) and the total score of the ACE-R (r=.908; p<.01), which was expected, supporting convergent validity of the first screening instrument (Table 5).

Adding to this, the total MoCA score also correlated significantly, positively and high with the ACE-R domains (highest: r=.853; p<.01- language and lowest: r=.694; p<.01 – visuospatial) and the WAIS-III IQ's and factorial indexes (highest: r=.845; p<.01- verbal IQ and lowest: r=.744; p<.01 – processing speed factorial index), being the peak correlation with the ACE-R language domain and the bottom one with the ACE-R visuospatial domain (Table 6).

Table 5

Correlations of the MoCA total score and the other total scores of neuropsychological measures.

		MoCA: Total Score	WAIS-III: Full-Scale IQ	MMSE: Total Score	ACE-R: Total Score
MoCA: Total Score	Pearson Correlation	-			
	N	79			
WAIS-III: Full-Scale IQ	Pearson Correlation	.850**	-		
	N	79	79		
MMSE: Total Score	Pearson Correlation	.840**	.772**	-	
	N	69	69	69	
ACE-R: Total Score	Pearson Correlation	.908**	.837**	.909**	-
	N	66	66	66	66

Note. MoCA- Montreal Cognitive Assessment; WAIS-III- Wechsler Adult Intelligence Scale- 3rd edition; MMSE- Mini Mental State Examination; ACE-R- Addenbrooke's Cognitive Assessment-Revised
**. Correlation is significant at the 0.01 level (2-tailed).

Table 6

Pearson's correlation coefficients for the total MoCA Score and the domain scores of the other Neuropsychological tests.

N		MoCA: Total Score
78	**WAIS-III: Verbal IQ**	.845**
78	**WAIS-III: Performance IQ**	.828**
78	**WAIS-III: Working Memory Index**	.778**
79	**WAIS-III: Verbal Comprehension Index**	.809**
79	**WAIS-III: Perceptual Reasoning Index**	.817**
78	**WAIS-III: Processing Speed Index**	.744**
66	**ACE-R: Attention and Orientation Domain**	.802**
66	**ACE-R: Memory Domain**	.781**
66	**ACE-R: Fluency Domain**	.762**
66	**ACE-R: Language Domain**	.853**
66	**ACE-R: Visuospatial Domain**	.694**

Note. MoCA- Montreal Cognitive Assessment; WAIS-III- Wechsler Adult Intelligence Scale- 3rd edition; ACE-R- Addenbrooke's Cognitive Assessment-Revised
**. Correlation is significant at the 0.01 level (2-tailed).

Following the same pattern of results, the total composite z-score, calculated by the two methods, correlated positively and very high with the MoCA total score (r=.898 and r=.896, p<.01, for method 1 and method 2, respectively).

Another analysis correlated the MoCA total score with the composite z-score per domain (Table 7 - column 1), emerging a similar pattern of significant, positive and high correlations (highest: r=.858; p<.01 – memory composite score; lowest: r= .767; p<.01; visuospatial composite score), supporting once again convergent validity.

Table 7

Pearson's correlation coefficients for the total and domain scores of the MoCA and of the z-composite scores.

N		MoCA Total	MoCA: Memory Domain	MoCA: Orientation Domain	MoCA: Visuospatial Domain	MoCA: Executive Functions Domain	MoCA: Attention Domain	MoCA: Language Domain
79	**Visuospatial Composite Score**	.767**	.207	.616**	.657**	.641**	.703**	.678**
79	**Language Composite Score**	.821**	.312**	.712**	.607**	.608**	.735**	.760**
79	**Attention Composite Score**	.797**	.337**	.583**	.610**	.700**	.736**	.650**
79	**Executive Functions Composite Score**	.819**	.379**	.623**	.599**	.784**	.686**	.667**
77	**Memory Composite Score**	.858**	.436**	.716**	.627**	.667**	.733**	.729**

Note. MoCA- Montreal Cognitive Assessment.

**. Correlation is significant at the 0.01 level (2-tailed).

Montreal Cognitive Assessment domains scores

The scores per domain of the MoCA correlated significantly, positively and moderately to high with the domains from the other NPTs (Table 8), being the highest (r=.815; p<.01) between the MoCA Attention Domain score and the WAIS-III verbal IQ. The lowest (r=.277; p<.05) was between the MoCA Memory Domain score and the WAIS-III Working Memory Index.

Regarding the results between the domains that measured similar constructs, each MoCA domain score correlated significantly, positively and moderately to high with the respective domain score as assessed by the other instruments (Table 8), as expected, supporting convergent validity of the MoCA.

Table 8

Pearson's correlation coefficients for the domain scores of the MoCA and of the other Neuropsychological tests.

N		MoCA: Memory Domain	MoCA: Orientation Domain	MoCA: Visuospatial Domain	MoCA: Executive Functions Domain	MoCA: Attention Domain	MoCA: Language Domain
78	**WAIS-III: Verbal IQ**	.317**	.614**	.614**	.716**	.815**	.737**
78	**WAIS-III: Performance IQ**	.383**	.578**	.604**	.729**	.802**	.643**
78	**WAIS-III: Working Memory Index**	.277*	.536**	.562**	.573**	.813**	.658**
79	**WAIS-III: Verbal Comprehension Index**	.337**	.567**	.588**	.732**	.757**	.673**
79	**WAIS-III: Perceptual Reasoning Index**	.378**	.581**	.598**	.673**	.811**	.638**
78	**WAIS-III: Processing Speed Index**	.313**	.513**	.551**	.692**	.697**	.534**
66	**ACE-R: Attention and Orientation Domain**	.307*	.769**	.631**	.593**	.630**	.733**
66	**ACE-R: Memory Domain**	.382**	.600**	.484**	.673**	.731**	.611**
66	**ACE-R: Fluency Domain**	.346**	.542**	.578**	.768**	.602**	.629**
66	**ACE-R: Language Domain**	.308*	.764**	.591**	.665**	.755**	.759**
66	**ACE-R: Visuospatial Domain**	.107	.579**	.699**	.557**	.605**	.637**

Note. MoCA- Montreal Cognitive Assessment; WAIS-III- Wechsler Adult Intelligence Scale- 3rd edition; ACE-R- Addenbrooke's Cognitive Assessment-Revised
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

For instance, the ACE-R Attention and Orientation Domain score and the MoCA orientation domain score correlated highly (r= .769; p<.01), as well as the ACE-R fluency domain score and the MoCA executive functions domain score (r= .768; p<.01). More examples are the high and moderate correlation, respectively, between the WAIS-III Verbal Comprehension factorial Index and the MoCA Language domain score (r=.673; p<.01) as well as the WAIS-III Perceptual Reasoning factorial Index and the MoCA visuospatial domain score (r= .598; p<.01).

As for the results of the comparisons between the MoCA domains scores and their analogous NPTs (Table 7), as seen in the composite z-scores, the same pattern is observed, having the MoCA domains scores correlated significantly, positively and moderately to high the respective domain z-score. The highest value was between the executive functions composite z-score and the MoCA executive functions domain (r=.784; p<.01) and the lowest between the memory composite z-score and the MoCA memory domain (r=.436; p<.01).

Although there was significant cross-correlations between the different MoCA domains and the composite z-scores (Table 7), generally the best correlation was between the respective MoCA score and composite z-score domain (except for the memory and visuospatial composite scores). For example, the Language and Attention composite score correlated highly with the respective MoCA domain (r=.760; p<.01 and r= .736; p<.01, respectively), supporting convergent validity.

Regarding the analysis with the total composite z-score (methods 1 and 2) and the MoCA domains scores, similar positive and moderate to high correlations were observed (method 1- highest: r=.795, p<.01, attention domain; lowest: r=.370, p<.01, memory domain; method 2- highest: r=791, p<.01, attention domain; lowest: r=.374, p<.01, memory domain, Table 9).

Table 9

Pearson's correlation coefficients for the domain and total scores of the MoCA and of the total composite z-score.

N		MoCA: Total	MoCA: Memory Domain	MoCA: Orientation Domain	MoCA: Visuospatial Domain	MoCA: Executive Functions Domain	MoCA: Attention Domain	MoCA: Language Domain
79	**Total composite z-score 1**	.898**	.370**	.720**	.685**	.753**	.795**	.772**
79	**Total composite z-score 2**	.896**	.374**	.715**	.682**	.755**	.791**	.768**

Note. MoCA- Montreal Cognitive Assessment.; Method 1- sum of all the composite z-scores; Method 2- mean of all the composite z-scores.
**. Correlation is significant at the 0.01 level (2-tailed).

Discussion and Conclusions

Cognitive impairments are a major public health concern in the current context of aging population. It is agreed that older age is an increased risk factor for the development of cognitive decline (Larner, 2017a), often associated with the prevalent neurodegenerative pathologies like AD.

Effectively, NPA continues to be a privileged method to analyze cognitive functioning and has revealed a high efficiency in the distinction between normative aging and pathological conditions. Furthermore, brief cognitive screening tests, like the MoCA remain the best method to monitoring the progression of dementia (Strauss et al., 2006; Larner, 2017a).

The objective of this psychometric study, that examined the MoCA convergent validity related to external criteria, was to investigate the relationship between the screening instrument and other standardized NPTs, more specifically, the association of the MoCA total score and cognitive domains subscores with the scores obtained in the assessment instruments which compose the NPA protocol administered at level of consultation in the CPSC.

The individual MoCA scores (total and domain) demonstrated positive, moderate to high correlations with standard neuropsychological measures (other cognitive screening instruments, NPTs, and the formed composite z-scores, being this last one created with other NPTs and divided per domain and two total composite z-scores) declared to measure similar constructs, as was hypothesized, providing empirical validation of the convergent validity of this screening instrument.

As the hypothesis were confirmed, this study gives evidence of the convergent validity of the MoCA, which helps to prove the utility of this instrument has a measure of cognitive function that is short, but precise, giving additional evidence of it being a good screening tool, essential to clinical practice. The MoCA total score was highly correlated with the global cognitive performance as measured by the WAIS-III full-scale IQ (r=.850, p<.01), the MMSE total score (r=.840, p<.01), the ACE-R total score (r=.908, p<.01) and the total composite z-scores (method 1: r=.898, p<.01 and method 2: r=.896, p<.01). A similar pattern of results was observed with the comparison of the MoCA total score and the factorial indexes of WAIS-III (highest: r=.845; p<.01- verbal IQ and lowest: r=.744; p<.01 – processing speed factorial index), ACE-R domains (highest: r=.853; p<.01- language and lowest: r=.694; p<.01 – visuospatial) and the composite z-score per domain (highest: r=.858; p<.01 – memory composite score; lowest: r= .767; p<.01; visuospatial composite score). This elevated values between total or global scores and the MoCA total score are important to mention, being a positive aspect of this study.

Regarding the MoCA domain scores, moderate to high correlations were present with all the defined measures (WAIS-III verbal IQ, performance IQ and factorial indexes, ACE-R domains score, composite z-scores created with analogous NPTs and the total composite z-score, for method 1 and 2).

Concerning the relationship of these scores with the WAIS-III, the highest result (*r*=.815; *p*<.01) was observed between the MoCA Attention Domain score and the WAIS-III verbal IQ. The lowest (*r*=.277; *p*<.05) was observed between the MoCA Memory Domain score and the WAIS-III Working Memory factorial Index. As for the ACE-R domains, the highest correlation (r=.769, p<.01) was between this instrument Attention and Orientation domain score and the MoCA orientation domain score, being the lowest result (*r*=.382, *p*<.01) between the ACE-R and MoCA's memory domains.

The correlations between the composite z-scores per domain with the MoCA domain scores varied from *r*=.436 (*p*<.01), between the memory composite z-score and the MoCA memory domain; and *r*=.784 (*p*<.01), between the executive functions composite z-score and the MoCA executive functions domain. The correlation between the language domains of both the MoCA and the composite z-score was *r*=.760 (*p*<.01), followed by *r*=.736 (*p*<.01) for the attention domains and *r*=.657 (*p*<.01) for the visuospatial ones.

The total composite z-score analysis with the domains of the screening tool showed the following results: for method 1, the highest was *r*=.795, (*p*<.01), on the attention domain and the lowest was *r*=.370, (*p*<.01), for the memory domain and for method 2 the highest was *r*=791, (*p*<.01), for the attention domain and the lowest was *r*=.374 (*p*<.01), for the memory domain.

These results allow to further support the use of the MoCA as a brief screening instrument of cognition that reflects similar constructs as those of other neuropsychological tests, including a more detailed battery, being this relevant not only because it shows the reliability and validity of this widely used instrument, but also because, as stated above, brief cognitive screening tests, remain the best method to monitoring the progression of dementia (Strauss et al., 2006; Larner, 2017a). In fact, early detection of cognitive impairments can prevent the progression to more pronounced cognitive decline, helping the management of the disease (Borson et al., 2013) and to improve a rehabilitation program.

Adding to this, the present context urges health-care professionals to reduce the number of people in the hospitals as well as the permanence time of these in the institution, being of great utility a brief and informative instrument like the MoCA.

Another relevant point of this study is the fact that as far my knowledge goes, there is little information regarding the convergent validity of MoCA in an heterogenous sample (Vogel et al., 2015), so it can allow an advance to the field, once it contributes to the improvement of the quality of NPA instruments, more specifically, screening tools. Because of the high correspondence between MoCA domain scores and the standard neuropsychological measures, the results suggest that this screening tool can provide a good understanding of the performance of a person in different cognitive functions (such as, visuoconstructional skills, executive functions, language, attention and memory), once the score reflects the cognitive performance on that area.

This study findings were similar to the studies of Di Nuovo and colleagues (2018), Lam et al., (2013), Srisurapanont and colleagues (2017) and Vogel et al., (2015), once moderate to high correlations between the MoCA scores and other analogous neuropsychological measures like the WAIS-IV or a composite score created with different tests were shown.

Besides this, memory functions assessed by the MoCA appear to be distinct from those of the WAIS-III working memory, as seen in the study of Di Nuovo and colleagues (2018), having this higher correlation with the MoCA attention domain (r=.813, p<.01).

Regarding the analysis made with other screening instruments, the results were in agreement with both international (Lam et al., 2013; Julayanont & Nasreddine, 2017); Pendleburry et al., 2017) and portuguese studies (Duro et al., 2010; Freitas et al., 2012c; Freitas et al., 2013), where high correlations were found between the MoCA scores and the MMSE or ACE-R scores.

Even though the correlations observed in this study were generally higher than the ones present on the literature[3], the interpretation followed the same pattern as previous studies. For example, in the study of Lam and colleagues (2013) the correlation between MoCA and MMSE was of r=.66 (p<.001), and the one observed in our sample was of r=.840 (p<.01). Like this, the correlation between the same two screening tools in the study of Freitas et al. (2012c) was r=.741 (p<.001) being also smaller than the one observed in this study. The difference in sample size and its constitution (for example, presence or absence of impairments that differed from the previous studies) might explain this difference.

An apparently surprising result was the high correlation between the WAIS-III processing speed index and the MoCA attention and executive functions domain, once this function isn’t purposed to be directly measured by the screening tool. This result suggests that the tasks that form the executive functions and attention domain on MoCA, like for example,

[3] Taking into account both the international and portuguese studies, the portuguese ones showed more similar results to this present study.

the digit span or the TMT, might require both of these skills to function (Vogel et al., 2015), as well as processing speed (see Jacobs et al., 2013 for the documentation of the association between these cognitive functions). Adding to this, both working memory and processing speed are related to executive functions and attention (Lichtenberg & Kaufman, 2009), which may also justify these results.

One major difference that can be mentioned is the fact that in the literature the higher correlations are mainly with the memory domain score (for example, in the study of Lam et al., 2013 and in the study of Vogel et al., 2015), which didn't happen in this analysis, being the correlations with this domain smaller than with the others. Methodology differences, such as the use of different memory tests on the formation of the composite z-score, and non-identical impairments with different degrees could explain the discrepancy on the results.

Like previous convergent validity studies, one important limitation of this investigation might be the difficulty in finding analogous tests that theoretically measure similar functions. For instance, like the human functioning does not rely on only one cognitive skill, being necessary taking into account different information for responding to a challenge or for simply taking action, a neuropsychological test or task needs more than one mechanism to be completed (Srisurapanont et al., 2017). For example, the ability to complete the TMT part A or B and the Digit Span, is correlated with Processing Speed, Working Memory (Sánchez-Cubillo et al., 2009), attention and other functions. Just like these assignments, in order to perform the delayed recall task, attention and language functions are probably needed.

Adding to this, a consensus about the cognitive domains assessed by each instrument isn't universally accepted (Srisurapanont et al., 2017), being also important to note that an instrument that measures only one cognitive domain doesn't exist.

Another limitation could be related to the generalization of these results, once the sample was majorly consisted by females (58.2%) and caucasian people, being only collected on the NPA consultation of the Faculty of Psychology and Education Sciences of the University of Coimbra. Besides this, the small number of participants and the heterogenous characteristics of these could have also influenced the results.

Therefore, future studies should include samples with greater diversity, not only in gender and race/ethnicity but also in education and professional level. Other suggestion could be evaluating the diagnostic sensitivity and specificity of the MoCA domain scores or preform a convergent validity analysis in different groups (presence or absence of cognitive decline [e.g., community, MCI, Stroke] and presence or absence of psychopathology [e.g., community, Depression or Anxiety disorders]).

In conclusion, this study proved the convergent validity of the Montreal Cognitive Assessment in a neuropsychological assessment consultation sample, by using different measures of comparison that included other cognitive screening tools, detailed batteries, and analogous neuropsychological tests. The positive and moderate to high correlations found of the MoCA scores with the other instruments, allows a better understanding of this test's psychometric properties, being a valid and reliable short tool for detecting cognitive impairment, and, therefore, a useful instrument in the clinical practice.

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Annexes

Annexe A- Descriptive Statistics of the measures used.

Table 10

Descriptive statistics of all the measures used.

	N	Min	Max	Mean	SD
MoCA: Total Score	79	2	29	19.62	6.12
MoCA: Memory Domain	79	0	4	1.32	1.30
MoCA: Orientation Domain	79	1	6	5.27	1.20
MoCA: Visuospatial Domain	79	0	4	2.87	.95
MoCA: Executive Functions Domain	79	0	4	2.15	1.32
MoCA: Attention Domain	79	0	6	4.09	1.83
MoCA: Language Domain	79	0	5	3.92	1.37
MMSE Total	69	8	30	24.64	4.58
ACE-R: Total	66	17	97	76.41	17.09
ACE-R: Attention and Orientation Domain	66	5	18	16.15	2.59
ACE-R: Memory Domain	66	1	26	17.42	6.10
ACE-R: Fluency Domain	66	0	12	7.53	3.28
ACE-R: Language Domain	66	5	26	22.00	5.05
ACE-R: Visuospatial Domain	66	5	16	13.30	2.71
ACE-R: Temporal Orientation task	66	1	5	4.50	.92
ACE-R: Spatial Orientation task	66	2	5	4.33	.75
ACE-R: Retention task	66	1	3	2.91	.34
ACE-R: Attention and Concentration task	66	0	5	4.41	1.19
ACE-R: Delayed recall 1 task	66	0	3	1.80	1.04
ACE-R: Anterograde Memory task	66	1	7	5.91	1.42
ACE-R: VPF task	66	0	6	3.45	1.82
ACE-R: VSF task	66	0	7	4.08	1.73
ACE-R: Comprehension 1 task	66	0	1	.82	.39
ACE-R: Comprehension 2 task	66	0	3	2.71	.65
ACE-R: Writing task	66	0	1	.88	.33

ACE-R: Repetition 1 task	66	0	2	1.42	.79
ACE-R: Repetition 2 task	66	0	1	.88	.33
ACE-R: Repetition 3 task	66	0	1	.92	.27
ACE-R: Naming 1 task	66	1	2	1.95	.21
ACE-R: Naming 2 task	66	0	10	8.23	2.56
ACE-R: Comprehension 3 task	66	0	4	3.35	1.22
ACE-R: Reading task	66	0	1	.83	.38
ACE-R: Pentagnos Copy task	66	0	1	.85	.36
ACE-R: Cube Copy task	66	0	2	1.26	.79
ACE-R: Clock Draw task	66	1	5	3.95	1.29
ACE-R: Perception 1 task	66	0	4	3.36	1.17
ACE-R: Perception 2 task	66	2	4	3.88	.37
ACE-R: Delayed Recall 2 task	66	0	7	3.21	2.23
WAIS-III: Full-Scale IQ	79	48	124	92.62	20.64
WAIS-III: Verbal IQ	78	54	133	97.69	19.52
WAIS-III: Performance IQ	78	47	117	87.90	19.50
WAIS-III: Verbal Comprehension Factorial Index	79	59	145	101.08	19.85
WAIS-III: Perceptual Reasoning Factorial Index	79	50	123	91.24	18.70
WAIS-III: Working Memory Factorial Index	78	53	117	90.83	16.49
WAIS-III: Processing Speed Factorial Index	78	54	122	86.94	17.23
WAIS-III: Vocabulary Subtest	76	3	60	34.16	15.24
WAIS-III: Digit-Symbol Coding Subtest	75	5	84	36.25	19.05
WAIS-III: Similarities Subtest	76	1	30	15.39	7.65
WAIS-III: Block Design Subtest	76	0	58	23.11	11.77
WAIS-III: Arithmetic Subtest	76	1	18	9.38	3.81
WAIS-III: Matrix Reasoning Subtest	76	0	25	10.83	6.09
WAIS-III: Digit Span Subtest	76	1	20	10.91	3.84

WAIS-III: Picture Arrangement Subtest	76	0	20	6.05	4.66
WAIS-III: Comprehension Subtest	76	3	32	15.17	7.07
WAIS-III: Symbol Search Subtest	76	0	32	14.03	8.32
WAIS-III: Letter-Number Sequencing Subtest	75	0	13	6.60	2.87
WMS-III: Logical Memory I	74	4	63	27.28	13.11
WMS-III: Logical Memory II	74	0	40	15.77	9.99
WMS-III: Word List I	70	13	38	24.27	6.44
WMS-III: Word List II	70	0	11	4.61	3.06
RCF Copy	71	8.0	36.0	28.67	7.69
RCF Immediate Memory	72	.0	26.5	13.66	7.20
Toulouse-Pieron Cancelation Test Total	73	-10.7	30.7	10.60	7.67
VPF Letter M	72	0	22	7.78	4.53
VPF Letter P	74	0	20	8.84	4.84
VPF Letter R	72	0	21	7.51	4.19
VPF Total	72	0	63	24.00	12.61
VSF Animal Naming	74	3	28	13.70	5.66
TMT-A Total	74	16	515	76.88	76.67
TMT-B Total	69	35	416	154.62	91.20

Note. MoCA: Montreal Cognitive Assessment; MMSE: Mini Mental State Examination; ACE-R: Addenbrooke's Cognitive Examination- Revised; WAIS-III: Wechsler Adult Intelligence Scale- 3rd edition; WMS-III: Wechsler Memory Scale- 3rd edition; RCF: Rey Complex Figure; VPF: Verbal Phonemic Fluency; VSF: Verbal Semantic Fluency; TMT-A: Trial Making Test- part A; TMT-B: Trial Making Test- part B.
All the tests' scores are presented by raw scores, except for WAIS-III Full Scale IQ, WAIS-III Verbal IQ, WAIS-III Performance IQ, WAIS-III Verbal Comprehension Factorial Index, WAIS-III Perceptual Reasoning Factorial Index, WAIS-III Working Memory Factorial Index and WAIS-III Processing Speed Factorial Index, where standard scores are described.

Annex B: Composite scores per domain.

Table 11

Correlations between the tests that form the memory domain composite score.

	Memory_CS Total	Zscore: WMS-III Logical Memory I	Zscore: WMS-III Logical Memory II	Zscore: WMS-III Word List I	Zscore: WMS-III Word List II	Zscore: RFC Immediate Recall	Zscore: ACE-R Temporal Orientation	Zscore: ACE-R Spacial Orientation	Zscore: ACE-R Retention Task
Memory_CS Total	-								
Zscore: WMS-III Logical Memory I	**.846**** (N=74)	- (N=74)							
Zscore: WMS-III Logical Memory II	**.840**** (N=74)	**.909**** (N=74)	- (N=74)						
Zscore: WMS-III Word List I	**.805**** (N=70)	**.747**** (N=69)	**.718**** (N=69)	- (N=70)					
Zscore: WMS-III Word List II	**.782**** (N=70)	**.643**** (N=69)	**.642**** (N=69)	**.674**** (N=70)	- (N=70)				
Zscore: RFC Immediate Recall	**.598**** (N=72)	**.340**** (N=71)	**.373**** (N=71)	**.401**** (N=68)	**.491**** (N=68)	- (N=72)			
Zscore: ACE-R Temporal Orientation	**.677**** (N=66)	**.400**** (N=64)	**.432**** (N=64)	0.244 (N=61)	**.403**** (N=61)	**.365**** (N=62)	- (N=66)		
Zscore: ACE-R Spacial Orientation	**.667**** (N=66)	**.453**** (N=64)	**.488**** (N=64)	**.269*** (N=61)	**.429**** (N=61)	**.267*** (N=62)	**.492**** (N=66)	- (N=66)	
Zscore: ACE-R Retention Task	**.532**** (N=66)	**.311*** (N=64)	**.256*** (N=64)	0.175 (N=61)	-0.045 (N=61)	0.144 (N=62)	**.546**** (N=66)	**.423**** (N=66)	- (N=66)
Zscore: ACE-R Delayed Recall I	**.635**** (N=66)	**.511**** (N=64)	**.499**** (N=64)	**.498**** (N=61)	**.516**** (N=61)	**.272*** (N=62)	**.266*** (N=66)	**.243*** (N=66)	0.167 (N=66)
Zscore: ACE-R Anterograde Memory	**.781**** (N=66)	**.559**** (N=64)	**.495**** (N=64)	**.538**** (N=61)	**.472**** (N=61)	**.306*** (N=62)	**.484**** (N=66)	**.504**** (N=66)	**.430**** (N=66)
Zscore: ACE-R Delayed Recall II	**.718**** (N=66)	**.606**** (N=64)	**.619**** (N=64)	**.498**** (N=61)	**.503**** (N=61)	**.318*** (N=62)	**.369**** (N=66)	**.417**** (N=66)	0.189 (N=66)

Note. CS: composite z-score; WMS-III: Wechsler Memory Scale- 3rd edition; RFC: Rey Complex Figure; ACE-R: Addenbrooke's Cognitive Examination-Revised.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 11

Correlations between the tests that form the memory domain composite score- part 2.

	Zscore: ACE-R Delayed Recall I	Zscore: ACE-R Anterograde Memory	Zscore: ACE-R Delayed Recall II
Zscore: ACE-R Delayed Recall I	- (N=66)		
Zscore: ACE-R Anterograde Memory	**.528**** (N=66)	- (N=66)	
Zscore: ACE-R Delayed Recall II	**.423**** (N=66)	**.642**** (N=66)	- (N=66)

Note. ACE-R: Addenbrooke's Cognitive Examination-Revised.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 12

Correlations between the tests that form the attention domain composite score.

	Attention_ CS Total	Zscore: ACE-R Attention and Concentration	Zscore: WAIS-III Symbol Search	Zscore: WAIS-III Digit Span	Zscore: WAIS-III Arithmetic	Zscore: WAIS-III Digit-Symbol Coding	Zscore: TMT-A Total	Zscore: TP Cancelation Test Total
Attention_CS Total	- (N=79)							
Zscore: ACE-R Attention and Concentration	**.738**** (N=66)	- (N=66)						
Zscore: WAIS-III Symbol Search	**.835**** (N=76)	**.427**** (N=63)	- (N=76)					
Zscore: WAIS-III Digit Span	**.775**** (N=76)	**.439**** (N=63)	**.606**** (N=76)	- (N=76)				
Zscore: WAIS-III Arithmetic	**.790**** (N=76)	**.520**** (N=63)	**.616**** (N=76)	**.626**** (N=76)	- (N=76)			
Zscore: WAIS-III Digit-Symbol Coding	**.835**** (N=75)	**.429**** (N=62)	**.773**** (N=75)	**.535**** (N=75)	**.609**** (N=75)	- (N=75)		
Zscore: TMT-A Total	**-.445**** (N=74)	**-.427**** (N=63)	**-.490**** (N=71=)	**-.444**** (N=71)	**-.536**** (N=71)	**-.530**** (N=71)	- (N=74)	
Zscore: TP Cancelation Test Total	**.773**** (N=73)	**.435**** (N=62)	**.682**** (N=70)	**.463**** (N=70)	**.531**** (N=70)	**.634**** (N=70)	**-.541**** (N=72)	- (N=73)

Note. CS: composite z-score; ACE-R: Addenbrooke's Cognitive Examination-Revised; WAIS-III: Wechsler Adult Intelligence Scale- 3rd edition; TMT-A: Trial Making Test-part A; TP: Toulouse-Pieron.

**. Correlation is significant at the 0.01 level (2-tailed).

Table 13

Correlations between the tests that form the language domain composite score.

	Language_CS Total	Zscore: ACE-R Repetition I	Zscore: ACE-R Repetition II	Zscore: ACE-R Repetition III	Zscore: ACE-R Naming I	Zscore: ACE-R Naming II	Zscore: ACE-R Comprehension III
Language_CS Total	- (N=79)						
Zscore: ACE-R Repetition I	**.722**** (N=66)	- (N=66)					
Zscore: ACE-R Repetetion II	**.429**** (N=66)	0.202 (N=66)	- (N=66)				
Zscore: ACE-R Repetition III	**.347**** (N=66)	0.082 (N=66)	**.245*** (N=66)	- (N=66)			
Zscore: ACE-R Naming I	**.269*** (N=66)	0.025 (N=66)	-0.081 (N=66)	-0.062 (N=66)	- (N=66)		
Zscore: ACE-R Naming II	**.857**** (N=66)	**.602**** (N=66)	**.344**** (N=66)	0.229 (N=66)	**.249*** (N=66)	- (N=66)	
Zscore: ACE-R Comprehension III	**.833**** (N=66)	**.517**** (N=66)	0.222 (N=66)	0.224 (N=66)	**.303*** (N=66)	**.826**** (N=66)	- (N=66)
Zscore: ACE-R Reading	**.652**** (N=66)	**.452**** (N=66)	0.208 (N=66)	0.179 (N=66)	0.098 (N=66)	**.472**** (N=66)	**.531**** (N=66)
Zscore: ACE-R Writing	**.478**** (N=66)	**.440**** (N=66)	**.289*** (N=66)	**.245*** (N=66)	-0.081 (N=66)	**.253*** (N=66)	**.260*** (N=66)
Zscore: ACE-R Comprehension I	**.493**** (N=66)	**.408**** (N=66)	0.066 (N=66)	-0.135 (N=66)	0.086 (N=66)	**.352**** (N=66)	**.395**** (N=66)
Zscore: ACE-R Comprehension II	**.296*** (N=66)	0.032 (N=66)	0.050 (N=66)	0.138 (N=66)	0.015 (N=66)	0.188 (N=66)	0.206 (N=66)
Zscore: WAIS-III Comprehension	**.770**** (N=76)	**.609**** (N=63)	0.158 (N=63)	0.110 (N=63)	0.118 (N=63)	**.678**** (N=63)	**.624**** (N=63)
Zscore: WAIS-III Vocabulary	**.829**** (N=76)	**.623**** (N=63)	**.250*** (N=63)	0.133 (N=63)	0.187 (N=63)	**.739**** (N=63)	**.654**** (N=63)

Note. CS: composite z-score; ACE-R: Addenbrooke's Cognitive Examination-Revised.
**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 13

Correlations between the tests that form the language domain composite score- part 2.

	Zscore: ACE-R Reading	Zscore: ACE-R Writing	Zscore: ACE-R Comprehension I	Zscore: ACE-R Comprehension II	Zscore: WAIS-III Comprehension	Zscore: WAIS-III Vocabulary
Zscore: ACE-R Reading	- (N=66)					
Zscore: ACE-R Writing	**.457**** (N=66)	- (N=66)				
Zscore: ACE-R Comprehension I	**.316**** (N=66)	0.066 (N=66)	- (N=66)			
Zscore: ACE-R Comprehension II	0.052 (N=66)	-0.022 (N=66)	0.155 (N=66)	- (N=66)		
Zscore: WAIS-III Comprehension	**.330**** (N=63)	0.165 (N=63)	**.342**** (N=63)	0.057 (N=63)	- (N=76)	
Zscore: WAIS-III Vocabulary	**.402**** (N=63)	0.225 (N=63)	**.353**** (N=63)	0.177 (N=63)	**.845**** (N=76)	- (N=76)

Note. CS: composite z-score; ACE-R: Addenbrooke's Cognitive Examination-Revised; WAIS-III: Wechsler Adult Intelligence S
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 14

Correlations between the tests that form the executive functions domain composite score.

	Executive Functions_CS Total	Zscore: ACE-R VPF	Zscore: ACE-R VSF	Zscore: WAIS-III Letter-Number Sequencing	Zscore: WAIS-III Picture Arrangement	Zscore: WAIS-III Similarities	Zscore TMT-B Total
Executive Functions_CS Total	- (N=79)						
Zscore: ACE-R VPF	**.895**** (N=66)	- (N=66)					
Zscore: ACE-R VSF	**.837**** (N=66)	**.709**** (N=66)	- (N=66)				
Zscore: WAIS-III Letter-Number Sequencing	**.750**** (N=75)	**.643**** (N=62)	**.505**** (N=62)	- (N=75)			
	.697** (N=76)	**.576**** (N=63)	**.587**** (N=63)	**.576**** (N=75)	- (N=76)		

Zscore: WAIS-III Picture Arrangement							
Zscore: WAIS-III Similarities	.766** (N=76)	.690** (N=63)	.584** (N=63)	.690** (N=75)	.637** (N=76)	- (N=76)	
Zscore TMT-B Total	-.648** (N=69)	-.682** (N=59)	-.523** (N=59)	-.578** (N=66)	-.605** (N=66)	-.687** (N=66)	- (N=69)
Zscore: VPF Letter M	.863** (N=72)	.812** (N=62)	.638** (N=62)	.475** (N=69)	.409** (N=69)	.560** (N=69)	-.498** (N=66)
Zscore: VPF Letter P	.917** (N=74)	.828** (N=64)	.720** (N=64)	.584** (N=71)	.597** (N=71)	.630** (N=71)	-.621** (N=68)
Zscore: VPF Letter R	.836** (N=72)	.749** (N=62)	.513** (N=62)	.553** (N=69)	.340** (N=69)	.516** (N=69)	-.515** (N=66)
Zscore: VPF Total	.935** (N=72)	.868** (N=62)	.679** (N=62)	.572** (N=69)	.479** (N=69)	.609** (N=69)	-.584** (N=66)
Zscore: VSF Animal Naming	.823** (N=74)	.696** (N=64)	.876** (N=64)	.582** (N=71)	.527** (N=71)	.564** (N=71)	-.640** (N=68)

Note. CS: composite z-score; ACE-R: Addenbrooke's Cognitive Examination-Revised; WAIS-III: Wechsler Adult Intelligence Scale- 3rd edition; TMT-B: trial making test- part B; VPF: Verbal Phonemic Fluency; VSF: Verbal Semantic Fluency.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 14

Correlations between the tests that form the executive functions domain composite score-part 2.

	Zscore: VPF Letter M	Zscore: VPF Letter P	Zscore: VPF Letter R	Zscore: VPF Total	Zscore: VSF Animal Naming
Zscore: VPF Letter M	- (N=72)				
Zscore: VPF Letter P	.809** (N=72)	- (N=74)			
Zscore: VPF Letter R	.802** (N=72)	.803** (N=72)	- (N=72)		
Zscore: VPF Total	.933** (N=72)	.938** (N=72)	.926** (N=72)	- (N=72)	
Zscore: VSF Animal Naming	.630** (N=72)	.738** (N=74)	.650** (N=72)	.720** (N=72)	- (N=74)

Note. CS: composite z-score; ACE-R: Addenbrooke's Cognitive Examination-Revised; WAIS-III: Wechsler Adult Intelligence Scale- 3rd edition; TMT-B: trial making test- part B; VPF: Verbal Phonemic Fluency; VSF: Verbal Semantic Fluency.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 15

Correlations between the tests that form the visuospatial domain composite score.

	Visuospatial_CS Total	Zscore: RCF Copy	Zscore: WAIS-III Block Design	Zscore: WAIS-III Matrix Reasoning	Zscore: ACE-R Pentagnos Copy	Zscore: ACE-R Cube Copy	Zscore: ACE-R Clock Draw	Zscore: ACE-R Perception I	Zscore: ACE-R Perception II
Visuospatial_CS Total	- (N=79)								
Zscore: RCF Copy	**.692**** (N=71)	- (N=71)							
Zscore: WAIS-III Block Design	**.876**** (N=76)	**.566**** (N=68)	- (N=76)						
Zscore: WAIS-III Matrix Reasoning	**.809**** (N=76)	**.533**** (N=68)	**.763**** (N=76)	- (N=76)					
Zscore: ACE-R Pentagnos Copy	**.743**** (N=66)	**.454**** (N=61)	**.533**** (N=63)	**.350**** (N=63)	- (N=66)				
Zscore: ACE-R Cube Copy	**.599**** (N=66)	**.348**** (N=61)	**.498**** (N=63)	**.465**** (N=63)	**.408**** (N=66)	- (N=66)			
Zscore: ACE-R Clock Draw	**.576**** (N=66)	**.365**** (N=61)	**.333**** (N=63)	**.299*** (N=63)	**.479**** (N=66)	**.267*** (N=66)	- (N=66)		
Zscore: ACE-R Perception 1	**.715**** (N=66)	**.344**** (N=61)	**.573**** (N=63)	**.440**** (N=63)	**.423**** (N=66)	**.246*** (N=66)	**.285*** (N=66)	- (N=66)	
Zscore: ACE-R Perception 2	**.456**** (N=66)	0.120 (N=61)	**.339**** (N=63)	**.266*** (N=63)	**.318**** (N=66)	-0.049 (N=66)	-0.012 (N=66)	**.490**** (N=66)	- (N=66)

Note. CS: composite z-score; RCF: Rey Complex Figure; WAIS-III: Wechsler Adult Intelligence Scale- 3rd edition;
ACE-R: Addenbrooke's Cognitive Examination-Revised.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).