Universidade de Aveiro Departamento de Educação e Psicologia
Ano 2019

João Pedro Braga Valente

Desempenho cognitivo em idosos com e sem défice cognitivo ligeiro: Efeito da hora do dia e sua relação com o cronótipo

Cognitive performance in the elderly with and without MCI: Effect of time of day and relationship with chronotype

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Psicologia da Saúde e Reabilitação Neuropsicológica, realizada sob a orientação científica da Doutora Isabel Maria Barbas dos Santos, Professora Auxiliar do Departamento de Educação e Psicologia da Universidade de Aveiro

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palavras-chave Hora do dia, cognição, performace cognitiva, cronótipo, ritmo circadiano

resumo

A influência de diferentes horas do dia e estado cognitivo, no desempenho cognitivo encontra-se largamente por estudar. Na literatura têm sido descritos picos de desempenho cognitivo ao longo do dia, para populações idosas. Além disto, parece existir uma relação de envelhecimento com efeitos de hora do dia, no desempenho cognitivo de idosos. Espera-se que esta relação seja evidente em casos de DCL. 34 idosos portugueses caucasianos (um grupo com DCL e um grupo normativo) formando grupos de manhã e de tarde, completaram o Wiscosin card sorting test, o span de dígitos, o choice response time, o Halstead category test e o attentional network task. Não se verificaram efeitos de hora do dia, para nenhuma tarefa. Interações do efeito de hora do dia foram significantes para o span de dígitos inverso e o Choice Response Time. Emergiram alguns padrões interessantes de maior efeito de hora do dia para o grupo DCL, com melhores desempenhos de manhã para tarefas que requeriam capacidade de inibição, aprendizagem do feedback e tarefas temporizadas. No entanto, algumas destas interações não alcançaram significância estatística. O presente estudo sugere que pode existir um efeito de hora do dia maior para população DCL, com melhores desempenhos durante a manhã. Também sugere que para o span de dígitos inverso a população normativa poderá ter maior efeito de hora do dia, com melhores desempenhos durante a tarde. Sugere-se que no futuro se explorem a relação de efeito de hora do dia e declínio cognitivo aprofundadamente na capacidade de inibição, de aprendizagem do feedback, raciocínio abstrato e velocidade de processamento, em amostras de adultos idosos com DCL e estados de declínio cognitivo mais avançado, bem como em jovens adultos.

keywords Time of day, cognition, cognitive performance, chronotype, circadian rythm.

abstract The influence of different times of day and cognitive status, in the cognitive performance is still mostly not investigated. In the literature it has been described peaks of cognitive performance throughout the day, for older adults.Besides, there seems to exist a relationship between aging and time of day effects, in the cognitive performance of older adults. It is expected that this relationship would be evident in MCI groups. 34 Caucasian older adults (one MCI group and a normative group) forming a morning group and an afternoon group completed the Wisconsin card sorting test, the digit span task, the choice response time, the Halstead category test and the attentional network task. There was no time of day effect for the cognitive tasks. There were time of day and cognitive status interaction for choice response time and backwards digit span. It was found some interesting patterns of larger time of day effects for MCI group, with better performance in the morning period in tasks that required inhibitory control, learning from feedback and timed tasks. However, some of these patterns did not reach statistical significance. The present study suggests that there might be a larger time of day effect for MCI population, with better performance in the morning period. Is also suggests that there might be a larger time of day effect for normative population, on the backwards digit span, with better performance in the afternoon. Future research should investigate the relationship of cognitive decline and time of day effects, in some cognitive functions, such as inhibitory control, learning from feedback, abstract reasoning and processing speed, in older adults with MCI and more advanced cognitive decline states and young adults as well.

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Introduction

Chronotype (CT) can be defined as the expression of the individual circadian rhythm. Researchers have been classifying CT in three types: Morning-types (MT), Evening-types (ET), or neither/indifferent (NT) (Adan et al., 2012; Waterhouse, 2010). It is a phenotypical aspect of sleep, representing the preference of sleep time and activity time. It also represents the interindividual variation of sleep (Gabehart & Van Dongen, 2017). Investigation from the last two decades suggests that CT has consequences in our biological and psychological functioning (Adan et al., 2012). For this study's purpose, we will present just the most relevant findings (See Adan et al., 2012 for a comprehensive review).

MTs are described as waking up early before 7:45am, and feeling refreshed, best time of day before 10:00am, bedtime is around 10:15pm, defining themselves as more active in the morning, having a high regularity of sleep schedule in working and leisure days, having a very similar sleep-wake cycle to the light-darkness cycle and more difficulty adapting to shift work and jet-lag. ETs are characterized for waking up later than 9:30am and feeling very tired, best time of day being from 4pm onwards, going to bed later than midnight, defining themselves as clearly more active in the afternoon/evening, showing low regularity of sleep schedule between work days and leisure days, having somewhat different sleep-wake rhythms than the light-darkness cycles and less difficulty adapting to shift work and jet-lag (Adan, 2015).

Our circadian rhythms, our wakefulness and our sleep are modulated by endogenous regulating systems (the biological clock), which also regulate our waking behavior, performance, alertness and determine CT. This biological clock in influenced by some factors, that are called *zeitgebers*, such as time cues and time givers. The most important one is the light-darkness cycle (Waterhouse, 2010; Adan, 2015; Gabehart &Van Dongen, 2017). As there is a close relation between sleep and the circadian rhythms and a correlation between CT and the circadian rhythms, it is expected that interindividual differences in CTs are associated to differences in circadian rhythms (Horne & Östberg, 1976). Evidence suggests that CT is influenced by individual factors, like sex, age and environmental factors, such as the photoperiod at birth, geographical coordinates and light exposure (Adan et al., 2012).

When it comes to age, research shows that morningness tends to increase as age increases, especially after the age of 50 (Kim et al., 2010; Merikanto et., 2012). There seems to be an increase in morningness following the teenager years. (Randler 2008, 2011; Zimmermann, 2011). This is such a significant tendency that Adan et al. (2012) considers it to be a biological marker of the end of adolescence. Research has shown that sex might influence CT, but results have been contradictory. Using the Morningness-Eveningness Questionnaire (MEQ), some studies found a higher predominance of MT in women and a higher predominance of ET in men (Randler, 2011;

Borisenkov, Perminova & Kosova, 2012). Yet other studies show no significant differences (Paine et al., 2006; Zimmermann, 2011), while others report the reverse pattern (Merikanto et al., 2012).

Chronotype, time of day and cognitive functioning.

Research on the relationship between CTs, circadian rhythms and cognitive performance has had heterogeneous results. This is in part due to different methodologies. Some methodologies create artificial conditions in order to remove: i) effects of the kind of task used and the differences between subjects in task performance (masking); ii) the clock-like circadian effect (process C or the fluctuations of sleepiness and tiredness we experience through the day) and iii) homeostatic influences (process S or the drive for sleep, meaning that the longer we lack sleep, the harder it is to avoid it) (Blatter & Cajochen, 2007). However, it is suggested that these influences can be recorded, and cognitive performance can be evaluated in normal day-night conditions without these influences, when CT is considered. This allows for better ecological validity (Adan et al., 2012).

Adan et al. (2012) refer to the relationship between CT and cognitive performance as difficult to summarize, even after decades of study, due to the great number of variables involved. However, ETs appear to be in worse activation condition during the conventional school or conventional work time periods (Adan et al., 2012; Adan, 2015). Studies investigating the role of CTs in cognitive performance have indicated better cognitive performance in ETs, mostly in correlational research (Kyle et al., 2017; Nowack & Meer, 2014; Roberts & Kyllonen, 1999), with a negative correlation between verbal IQ and scores on the MEQ – higher scores on the MEQ indicate higher tendency to be a morning-type (Killgore & Killgore, 2007). So, it seems that CTs alone do not fully explain different cognitive performances. It would be reductionist to link cognitive performance only to underlying regulatory systems. Other mechanisms also might play a role, such as contextual or motivational factors (Adan et al., 2012; Adan, 2015).

Circadian rhythm's effect on performance has a long history of investigation. One of the most well-known models is the arousal model. This model postulates that circadian performance variation would be reflected in a circadian rhythm represented by basal arousal level. Hence, when core body temperature (CBT) is high, neurobehavioral performance levels tend to be high. Following this logic, both extreme CTs would have similar patterns of performance, reaching better performance, and higher CBT in the second half of the day (Adan et al., 2012; Schimdt, Collette, Cajochen & Peigneux, 2007; Valdez, Reilly, Waterhouse, 2008; Waterhouse, 2010).

Opposing to this model's predictions, Horne, Brass and Pettit (1980) found reverse patterns with better performance of MTs in the first half of the day and better performance of ETs

in the second half of the day, on a simple motor task. There seems to be evidence to support differentiated optimal times of day, between CTs (Adan 2015; Schimdt et al., 2007; Valdez & Waterhouse, 2008). Hence, a model that tries to explain the data opposing the arousal model, is the synchrony effect. Following this model, alertness is a key variable to predict cognitive performance. As such, alertness derives from the interaction of body temperature and sleep-wake cycle (referring to the interactions of process S and process C). So, it is postulated that when people are more alert, it is when they will have better performance (Schmidt et al., 2007; Adan et al., 2012).

Supporting the synchrony effect, studies found better performance in the optimal time of day in: young adults forgetting or distractions (Ngo, Biss & Hasher, 2018); inhibitory control in older adults (Anderson et al., 2014; 2017), and young adults (Ngo & Hasher, 2017); visuospatial working memory tasks (Rowe, Hasher & Turcotte, 2009) alerting effect of Attentional Network Task (ANT) for MT participants in the morning (Matchock & Mordkoff, 2009), controlled but not automatic retrieval, with MT older adults (Yang, Hasher & Wilson, 2007) and fluid but not crystalized intelligence scores (Goldstein et al., 2007), for adolescents.

However, the synchrony effect does not seem to explain cognitive performance variations fully. The results are not that simple in more complex tasks, such as problem-solving tasks (Wieth and Zacks, 2011). Other example is shown by Matchock and Mordkoff (2009), where alerting effect showed a synchrony effect, but not orienting and conflicting effects. There is also evidence for NTs immunity for synchrony effect on automatic processes, but not on more complex tasks, such as those requesting executive functions (EF) (May & Hasher, 2017). So, research has been showing contradictory results, with no clear pattern of cognitive performance in relation with CT.

This might suggest that not only arousal and alertness explain cognitive performance, but also the characteristics of the task, such as the cognitive domain needed to complete it and its level of complexity, difficulty, etc. (Schmidt et al., 2007; Adan et al., 2012; Adan, 2015). Even in more ecologically valid contexts, it appears that this interaction is more complex than previously thought. For example, positive correlations were found for MTs and academic achievement, but not cognitive abilities, and the reverse pattern was observed for ETs, in a meta-analysis (Preckel, lipnevich, Schneider and Roberts, 2011). This suggests that MTs show worst correlations with cognitive abilities but might benefit from the conventional schedule of school.

Other way to explain how results vary across the circadian cycle is through peaks of performance related to time of day (time of day effects, when CT is used as a controlled variable). Differences in performance were found on: performance speed on a repetitive task and serial search tasks that peaks in the evening (Schimdt et al., 2007), digit span (forwards and backwards)

scores higher in the morning (Croschere, Dupey, Hilliard, Koehn & Mayra, 2012), short term memory peaks in early to mid-morning (Laird, 1925, *cit in* Schimdt el al., 2007), complex tasks, such as logical reasoning, peak in late morning (Folklard, 1975), memory performance is better in the morning period, and benefits from learning a repetitive task were bigger for older than younger adults, in morning and evening (Hogan et al., 2009), and time of day differences in schizophrenic patients, when compared to healthy controls (both groups performed better in the afternoon, but time of day effect was higher for the patient group) (D'Reaux, Neumann & Rhymer, 2000).

Differences were found in brain network organization, among time of testing in an inhibitory control task. Young and older adults tested in the morning activated different brain regions than older adults tested in the afternoon (Anderson et al., 2014; 2017). May and Hasher (2017) found a small effect, significant differences with time of day in Stroop naming and TMT part B for older (faster in the morning and midday) but not younger adults. No time of day interaction was found in color naming, reading color words for the Stroop task, neither part A of the TMT task, nor a priming task. This seems to suggest that, with cognitive decline, the interaction of cognitive performance with circadian rhythms also changes in more complex tasks. These results suggest an age interaction with time of day effects, where older adults might be affected by time of day in demanding tasks and tasks that involve inhibitory or other executive functions (EF).

As it seems, cognitive decline might play a role in this age and time of day effect interaction. So, we can expect that on a more advanced cognitive decline stage (mild cognitive impairment, MCI) these differences would be evident. Then we might expect that normative older adults might have a weaker time of day effect, relative to MCI participants, who should perform better in the morning period.

Mild cognitive impairment (MCI)

MCI has been investigated for over 30 years, as a concept of an intermediate state between dementia and normal cognition, which has been associated with geriatric medicine (Petersen, 2011; Allan, Behrman, Ebmeier & Valkanova, 2017; Tangalos & Peternsen, 2018). It has gained popularity among the scientific community, being recognized nowadays by DSM-5 and ICD 10.

MCI is recognized in the DSM-5 as a "less severe level of cognitive impairment" (American Psychiatric Association, 2013, p. 591). According to the DSM-5, to be diagnosed with MCI, there is a need to show a modest cognitive decline from a pre-morbid level in various cognitive domains. These cognitive deficits do not interfere with independence in everyday activities, the cognitive deficits do not occur exclusively in the context of a delirium and are not

better explained by another mental disorder. There are specifiers for: Alzheimer's disease, frontotemporal lobar degeneration, Lewy body dementia, vascular disease, traumatic brain injury, substance/medication use, prion disease, HIV infection, Parkinson's disease, Huntington's disease, another medical condition, multiple etiologies and unspecified (APA, 2013).

In the ICD 10, MCI is presented in the category of other mental disorders due to brain damage and dysfunction and to physical disease. As in the DSM-5, here it can also be associated with dementia. MCI is characterized as an "impairment of memory, learning difficulties, and reduced ability to concentrate on a task for more than brief periods." (World Health Organization, 2016).

There have been difficulties differentiating MCI from dementia, especially because its usefulness as a diagnostic entity is extending the detection of dementia to its earlier manifestations. It is suggested that considerable judgement is needed to make a distinction between age decline, and impairments not attributable to age decline and not representing dementia (Allan et al., 2017; Tangalos & Peternsen, 2018). As such, questions about the usefulness of this diagnostic have been raised (Petersen et al., 1999; Tangalos & Peternsen, 2018).

A distinction has been made between two types of MCI, one characterized by a memory impairment (Amnesic MCI), and the other by other domains affected (non-amnesic MCI) (Petersen, 2009, 2011; Allan et al., 2017; Tangalos & Petersen, 2018). Amnesic MCI requires the patient to have a memory complaint, objective memory impairment (normally 1.5 standard deviations or more below age-corrected norms), preserved general cognitive function, intact activities of daily function living and to not be demented. Also, multiple other domains might be slightly impaired (0.5-1.0 SDs below age and education corrected norms). Non-Amnesic MCI is like Amnesic, but without memory impairment and it can be single domain (one domain impaired) or multiple domains (Petersen, 2011; Allan et al., 2017; Tangalos & Petersen, 2018).

There is a solid basis of investigation that suggests that episodic memory tests and other memory tests (e.g. semantic naming) are useful to differentiate individuals that convert from MCI to AD, and other individuals with MCI, with better performance from the latter group for approximately 3 years before AD diagnosis (Albert, Moss, Tanzi & Jones, 2001; Albert et al., 2007; Blackwell et al., 2004; Chen et al., 2001; Dierckx et al., 2009; Grober et al., 2008; Rabin et al., 2009; Sarazin et al., 2007) and some studies state the same tendency for executive functions (Albert et al., 2001; 2007; Chen et al., 2001; Grober et al., 2008; Sarazin et al., 2007).

MCI is nowadays considered a valuable diagnosis, since it affects between 3.2%-24.3% of the population over 60 years old, worldwide (DiCarlo, 2003; Ganguli, Dodge, Shen & DeKosky, 2004; Petersen, 2009). Incidence rates estimated of 9.9/1000 person, in a 1265 older

adult sample (Larrieu et al., 2002; Ganguli et al., 2004; Petersen, 2009). In Portugal, it was reported a prevalence of MCI of 12.3%, following Mini-Mental State Examination (MMSE) and a complete neurological consultation in 1146 participants between 55 and 79 years old (Nunes, Silva, Cruz, Roriz, Pais & Silva, 2010). In other study, Sousa (2013) screened 368 older adults using the MMSE and found a 16.8% prevalence of MCI. Both studies found bigger prevalence in women.

Following Peterson (2009) some predictors of rates of progression to AD are: clinical severity, i.e, the more severe the more rapid progression tends to be, the gene ApoE ε4 carrier status, PET scan pattern of AD, cerebrospinal fluid markers compatible with Alzheimer's disease; and postive amyloid imaging scan.

A complete assessment of MCI should incorporate a full history of cognitive changes over time, mental state, physical and neurological examination, medication review and laboratory testing, to identify reversible forms of MCI due to other conditions. Also, underlying pathological processes that can be discovered should be considered in the differential diagnosis (Allan et al., 2017). Detecting MCI is a difficult task, since there is no functional impact in everyday life yet (Allan et al., 2017; Tangalos & Petersen, 2018).

If performance varies across time of day differently to what it would in a normative person, it would be expected that studying the interaction of MCI with time of day effect would benefit this assessment. On expected cognitive decline with age, older adults showed a time of day effect that was not significant in young adults, especially on more complex tasks (Anderson et al., 2014; 2017; May and Hasher, 2017). Therefore, in a pathological cognitive decline (such as MCI), we might expect this time of day effect to become more apparent. Hence, the aim of this study is to compare the performance of older adults in EF, processing speed, attention, and working memory tasks between morning and afternoon and between MCI and normative older adults, controlling CT. We hypothesized: 1) There will be an overall time of day effect, across cognitive domains, with better performance in the morning period; 2) The difference between morning and afternoon will be higher for MCI participants, compared to normative participants.

Methods

Participants

36 older adults participated in the study. Two people dropped out of the study by which their data was immediately excluded (N=34). Ten people were not able to complete the CRT. The CRT was analyzed without these participants (N= 24). One participant was unable to complete the ANT, so this data was excluded from the final analysis (N= 33).

The mild cognitive impairment (MCI) group consists of 17 Portuguese adults (65 years or older; 36.4% men; 27.3% were MT and 9.1% were ET) from the community or institutionalized, with MCI identified based on the score of the Montreal Cognitive Assessment (MoCA) neuropsychological test (the cutoff score used was from the Portuguese validation) (Freitas et al., 2013). The normative group is composed of 17 Portuguese adults (65 years or older; 26.1% men; 43.5% were MT and 17.4% were ET) from the community or institutionalized, that scored above the MoCA cutoff. Both groups had a mean MEQ score of NT. A summary of the descriptive statistics is presented in Table 1, the complete descriptive statistics are presented in Tables 12 to 16 (Appendix A). In the next section we present the tasks and tests used.

Table 1. Mean age, MEQ scores, years of education, MoCA and HADS scores, with standard deviations.

Group	Age	MEQ	Years of education	MoCA	Anxiety (HADS)	Depression (HADS)
MCI (N = 17)						
Morning (N = 9)	73.56 (7.37)	51.33 (6.04)	5.89 (3.48)	21 (1.32)	7.56 (4.10)	4.11 (2.26)
Afternoon (N = 8)	70.71 (3.09)	53.29 (4.88)	8.29 (3.59)	19.13 (2.17)	5.14 (2.73)	4.57 (3.46)
Normative (N = 17)						
Morning (N = 7)	73.37 (6.61)	52 (5.87)	4.88 (1.81)	24.57 (1.40)	9.25 (5.29)	6.25 (4.40)
Afternoon (N = 10)	74.66 (4.74)	49.33 (8.71)	9.33 (4.00)	25.11 (1.17)	5.78 (2.44)	5.00 (3.71)

Notes: MCI = Mild Cognitive Impairment Group; MEQ = Morningness-Eveningness Questionnaire; MoCA = Montreal Cognitive Assessment Test; HADS = Hospital Anxiety and Depression Scale.

Materials

Computerized tasks.

All computerized tasks were run on an ACER Aspire E5-573 laptop computer, with Intel Pentium 1.70GHz, 8GB RAM, Windows 10 and 64-bits operating system, with 15.6" screen size. Participants were at arm's length of the laptop. All computerized tasks except the Halstead Category Test were run with the computer program Psychology Experiment Building Language (PEBL). PEBL is a "free, open-source software that allows researchers and clinicians to design, run, and share behavioral tests" (p. 1, Mueller & Piper, 2014).

Wisconsin Card Sorting Test (WCST).

WCST is a test that measures abstract reasoning, depending on the executive functions of human beings. It is a test based on problem solving and decision making, use of external cues to guide behavior, self-monitoring and preservation. The traditional version of the WCST is administered using 128 stimulus cards, which should be matched, based on an unsaid principle (shape, color or number of symbols, i.e, the characteristics of the cards). The possible matching characteristics are the four colors (yellow, green, red and blue), the four shapes (circle, star, triangle and cross), and the number of symbols (ranging from 1 to 4) (Fernandes, 2007; Hamdan & Pereira, 2009). The test takes about 10 minutes to administer.

The subject, based on the feedback given by the examiner, adjusts his/her response, to find out the principle. After 10 correct responses, it is admitted that the participant found the principle, and the latter is changed (although this is not made explicit to the participant). Several performance scores can be obtained, but usually the number of categories completed, number of preservative errors and total number of errors are used (Romine et al., 2004; Hamdan & Pereira, 2009). For this study, the PEBL 2.0 version was used (BCST), with the following settings: keyboard responses (1, 2, 3 and 4 top keys), two repetitions of the deck (128 stimulus) and 10 correct responses before switching the rule.

Digit Span.

Digit Span is a task that measures attention, short-term retention capacity and working memory (Lezak, 2012). This task entails two simple tasks. The *direct digit span*, where participants are presented with a series of numbers, and are asked to repeat them back immediately, in the same order. If the participant was successful, he/she is presented with a longer series of numbers. This process continues until the participant can no longer repeat the series back. The longest series is the participant's digit span. The *backwards digit span*, where

participants are presented with a series of numbers and are required to immediately repeat them backwards. The same process as with the forward digit span applies. The longest series successfully repeated is the participant's reverse digit span (Croschere et al., 2012). Its administration takes 5-10 minutes to complete. The PEBL 2.0 version was used. In this version, two trials with the same number of digits are presented, and the test ends when the participant fails two trials with the same number of digits. Digits are visually presented on the screen, and participants are required to type them in the same or reversed order, using the keyboard.

Choice Response Time (CRT).

The CRT task measures processing speed. It consists of a first stimulus (a letter), that is subsequently (after 500 ms) masked, followed by two different stimuli. The participant must choose between both stimuli, indicating which one is equal to the one presented before. The full task takes about 5 minutes to complete. It's a 2-alternative forced choice task. The PEBL 2.0 version was used, including five blocks. Each block consists of five repetitions of the stimulus set, with six different stimuli per set. The total trials were 150 per participant. The ISI was 2000ms, with 1500ms allowed to give a response.

Attention Network Task (ANT).

ANT is an attentional task. Performance on the ANT involves three independent attentional processes: alerting (achieving and maintaining an alert state, associated with frontal and parietal regions of the right hemisphere), orienting (selection of information from sensory input, associated with parietal and frontal areas), and executive function (resolving conflict among responses, associated with anterior cingulate activation). It requires a 30-minute session to apply and it is adequate to patients. This task requires participants to determine the direction of a central arrow (right or left, using the right or left shift keys). ANT uses cued conditions: i) no-cue; i) center cue; iii) double simultaneous cue (above and below the fixation cross); iv) spatial cue, where a cue is presented above the fixation cross followed by a cue presented below the fixation cross. And flanker conditions: i) neutral, with a central arrow pointed in one direction; ii) congruent, with the center arrow pointed in the same direction of the lateral arrows; iii) incongruent, with the center arrow pointed in the opposite directions of the lateral arrows. Efficiency of the attentional networks is calculated by how response time (RT) is influenced by the different conditions. Alerting effect is calculated by subtracting the mean RT of the double simultaneous cue conditions from the mean RT of the no-cue conditions. Orienting effect was calculated by subtracting the mean RT of the spatial cue conditions from the mean RT of the center cue. Conflicting effect was calculated by subtracting the mean RT of all congruent flanker conditions from the mean RT of incongruent flanker conditions. This task has shown test-retest

reliability (Fan et al., 2002). A 4000ms inter-trial interval was used, with two repetitions through four cue conditions x two target locations x two target directions x three flanker conditions.

Halstead Category test (HCT).

The HCT is part of the Halstead-Reitan neuropsychological assessment battery. The HCT is a relatively complex concept formation test that requires: the ability to note similarities and differences between presented stimuli; hypothesis formulation; hypothesis testing, learning from prior feedback; and hypothesis adaptation, based on that feedback, which indicates whether the answer to the previous stimulus was correct or incorrect. The goal of the HCT is to determine if the subject is capable of learning from negative and/or positive past experiences, altering his or her performance accordingly. It can be considered the best measure of abstraction, reasoning and logical analysis abilities used in organized planning, from the Halstead-Reitan battery (Grant & Adams, 2009). The test has seven sub-tests, with various figures and forms for which the participant must attribute a number, from 1 to 4, according to an underlying abstract principle. The participant should test hypothesis of implicit rules, to get the correct answer.

A computerized version of the test was used, programmed with the software E-prime 2.0 (Psychology Software Tools, Pittsburgh, PA). Its administration requires approximately 20 minutes and the participant uses the keys 1, 2, 3 and 4 to answer. Usually, the only score considered from this test is the total number of errors. In the present study, we considered the total number of errors and the mean response time for the correct answers for the whole test.

Paper tests and questionnaires.

Montreal Cognitive Assessment Test (MoCA).

The MoCA is a neuropsychological screening test, designed to detect cognitive impairment. This test assesses executive function, visuospatial ability, memory, attention, concentration, working memory, language and spatial and temporal orientation. Its administration time is 10 to 15 minutes and it scores to a maximum of 30 points (Freitas, Simões, Santana, Martins & Nasreddine, 2013).

This test is adapted and validated for the Portuguese population (Freitas, Simões, Martins, Vilar and Santana, 2010; Simões et al., 2008), with good psychometric characteristics: high internal consistency (Cronbach α= .903), high test-retest (.877 for 18 months) and high interrater reliability (.988) (Freitas et al., 2013). Also, in a systematic review, Lonie, Tierney & Ebmeier (2009) found that it is a measure with adequate specificity and sensitivity to screen MCI. In the present study this test was used to select the participants that would integrate the MCI

group. The version used was the one from Simões et al., 2008. A cutoff score between 17 and 22 was used to identify MCI participants (Freitas et al., 2013).

HADS.

The Hospital Anxiety and Depression Scale (HADS) is a 14-item questionnaire, organized in two subscales, one to assess anxiety and one to assess depression. Its aim is to help clinicians to better identify the emotional components of physical disease. It takes 2-5 minutes to administer. It is validated to the Portuguese population, with good internal consistency and reasonable test-retest validity (Pais-Ribeiro, 2007). HADS manual presents a score of 0-7 as normal, 8-10 as mild, 11-14 as moderate and 15-21 as severe. With good internal consistency for anxiety (Cronbach α= .76) and for depression (Cronbach α= .81), test-retest (pearson correlation of .75 for anxiety and .75 for depression, with 1-week interval) and good factorial validity for depression but lower for anxiety (Pais-Ribeiro et al., 2007). Reliability analysis, on the present study showed reasonable values for depression (α= .71) and the anxiety (α= .74).

Morningness-Eveningness Questionnaire (MEQ).

Chronotype (CT) is usually measured through self-report questionnaires (Adan, 2015; Adan et al., 2012). CT questionnaires ask about preferred periods for certain activities, energy and mood at certain periods of the day, for example. The most used is the Morningness-Eveningness Questionnaire (MEQ) (Horne & Östberg, 1976). The MEQ is validated for the Portuguese population (Silva et al., 2012).

The Portuguese version is composed of 16 items, and its administration takes about 15 minutes. Some items are multiple choice, while others are presented on a temporal scale (participants must choose the hour of day that better applies to the situation, in the temporal scale). Based on the total score, respondents will be classified in one of four possible types: “definitely morning”, “moderately morning”, “moderately evening” and “definitely evening”. The result allows to classify respondents as morning-type (MT), evening-type (ET) or neither-type/indifferent (NT) (Silva et al., 2002; Horne & Ostberg, 1976). In the present study reliability analysis showed a low value (α= .57).

Procedures

The testing took place in two sessions lasting around 60 minutes each, to avoid fatigue effects. In the first session, participants responded to the: MEQ, MoCA, sociodemographic questionnaire, HADS and HCT. In the second session, the tasks CRT, Digit Span, ANT, and BCST were administered. The Morningness-Eveningness-Stability-Scale improved (MESSi), (Randler, Diaz-Morales, Rahafar & Vollmer, 2016), a composite scale to measure circadian

preference and stability, was also part of the study protocol, although it was not analyzed in the present study, and therefore will not be further mentioned.

Several institutions were contacted, to recruit the geriatric sample. Contacts were made with *Centro Paroquial e Social da Vera Cruz- Clube Véritas (Aveiro), Junta de Freguesia de* Samora Correia, *Santa Casa da Misericórdia de* Vila Franca de Xira, *Lar* Padre Tobias (Samora Correia) and *Sociedade Filarmónica de União Samorense (SFUS) (Samora Correia).* Additional contacts were made with the community and part of the sample was obtained via participants from the institutions. The testing sessions occurred in a space provided by each institution, since it would be difficult to bring every participant to the same setting. Community participants where tested in a private setting provided by *SFUS* (Samora Correia). The testing occurred in the most neutral, calm and quiet setting, possible.

Recruitment of participants started in April, through institutions such as daycare or senior universities, and community activities (such as musical groups) for geriatric population. Participant recruitment and data collection took place from April to August 2019.

This study used a 2x2 experimental design, with two between-subjects variables: time of day (morning: 9:00-13:00 and afternoon/evening: 14:00-19:00) and cognitive status (MCI and non-MCI/normative). The two 60-minute sessions for each participant took place in the same day period (morning or afternoon/evening). Random distribution of participants by the two time of day groups was not performed for logistic reasons. Participants were allocated according to their availability and remained in the same time of day on the first and second sessions.

Cognitive status' identification was not disclosed to the participants at any point. The two sessions were scheduled with minimal intervals, to avoid variability. In some cases, participants were unable to use the keyboard, and so the investigator registered the participants' answer himself. These participants data was included in the final analysis, to maintain sample size.

Data analysis.

Statistical analysis was performed in SPSS 24.0 (IBM corp, 2016)**.** All variables were tested for normality and homogeneity of variance. Some variables violated the principle of normality according to the Shapiro-Wilk test. However, according to Kline (1998, cited in Marôco, 2014), symmetry values below 3 and kurtosis values below 7 are not considered problematic and general linear models can still be used. Some scores on subtest level for HCT task, years of education, errors and accuracy in ANT task violated normality and homogeneity of variance. These variables were excluded from further analysis, including non-parametric, because

CT was not controllable in these types of analysis. In the case of HCT, total scores were analyzed, instead of subtest scores.

T-tests were performed to ensure groups did not differ in any relevant variable. No significant differences were found between times of day for scores on the MoCA, t(29.5)=.119, *p*=.906; anxiety, t(31)= -.654, *p*=.518; depression, t(31)= -1.067, p=.294; years of education t(32)= -.312, *p*=.757; age t(32)= -.716, *p*=.479 and MEQ scores t(32)= .914, *p*=.368. No differences were found between cognitive status groups for depression, t(31)= .001, *p*= .972; anxiety, t(31)= .159, *p*= .693; MEQ scores, t(32)= .074, *p*= .787; time of testing for session 1, t(32)= .227, *p*= .637, nor session 2, t(32)= .042, *p*= .838; there was, however, a significant difference in years of education, t(32)= 10.797, *p*= .002. No significant differences were found in the normative group for years of education, MEQ scores, anxiety or depression, nor in the MCI group for years of education, MEQ scores, anxiety or depression.

Results

Two-way analysis of covariance (ANCOVAs) were performed with time of day (morning vs afternoon/evening) and cognitive status (MCI vs normative) as between-subjects variables for the dependent variables of the various cognitive tasks, using CT as a covariable.

Table 2 presents the results for the ANCOVA that was carried out to analyse the effects of time of day and cognitive status, on the various parameters that can be extracted from the WCST. The descriptive statistics in each condition for each of the dependent variables can be found in Appendix A (table 12). Various types of errors given by PEBL were inserted in this ANCOVA, such as number of errors, number of preservative answers, number of preservative errors, number of non-preservative errors, unique errors trials to complete the first category, failures to maintain set and conceptual responses. There a statistically significant time of day and cognitive status for unique errors, with a larger time of day effect for the MCI group and higher score of unique errors in the afternoon. Although not achieving statistically significance, an interesting pattern was found in total number of errors and preservative errors with larger time of day effect for the MCI group, that committed more errors in the afternoon. The reverse pattern was found in the trials to complete the first category and non-preservative errors parameter, with the normative group needing more trials to complete the first category in the afternoon and committing more non-preservative errors in the morning. The figures 7 to 11 show these comparisons (Appendix B).

Table 2. Time of day and cognitive effects for WCST.

WCST	F	Df	Sig	η^2p
total number of errors				
ToD	.222	1, 29	.641	.008
Cog Status	1.707	1, 29	.202	.056
ToD x Cog Status	.126	1, 29	.079	2.481
MEQ	.178	1, 29	.676	.006
number of preservative answers				
ToD	1.489	1, 29	.232	.049
Cog Status	.033	1, 29	.857	.001
ToD x Cog Status	.177	1, 29	.677	.006
MEQ	.601	1, 29	.445	.020
number of preservative errors				
ToD	1.758	1, 29	.195	.057
Cog Status	.177	1, 29	.677	.006
ToD x Cog Status	.460	1, 29	.503	.016
MEQ	.393	1, 29	.536	.013
number of non-preservative errors				
ToD	.446	1, 29	.509	.015
Cog Status	.210	1, 29	.650	.015
ToD x Cog Status	.186	1, 29	.669	.006
MEQ	.476	1, 29	.496	.016
number of unique errors				
ToD	1.203	1, 29	.282	.040
Cog Status	.276	1, 29	.603	.009
ToD x Cog Status	4.371	1, 29	.045	.131
MEQ	.007	1, 29	.936	.000
Trials to complete the first category				
ToD	.238	1, 29	.629	.008

Cog Status	.276	1, 29	.603	.009
ToD x Cog Status	1.436	1, 29	.240	.047
MEQ	2.622	1, 29	.116	.083
Failure to maintain set				
ToD	1.734	1, 29	.198	.056
Cog Status	.122	1, 29	.730	.004
ToD x Cog Status	2.590	1, 29	.118	.082
MEQ	.041	1, 29	.840	.001
Conceptual responses				
ToD	.060	1, 29	.808	.002
Cog Status	.828	1, 29	.370	.028
ToD x Cog Status	2.585	1, 29	.119	.082
MEQ	.042	1, 29	.839	.001

Note: ToD= time of day effects. Cog Status= cognitive status' effect. ToD x Cog Status= interaction between time of day and cognitive status. MEQ= Morningness-Eveningness Questionnaire.

Table 3 presents the results for the ANCOVA that was carried out to analyse the effects of time of day and cognitive status, on the forward and backwards span scores from the digit span task. The descriptive statistics in each condition for each of the dependent variables can be found in Appendix A (table 12). There were statistically significant cognitive status effects for forwards and backwards digit span, with the normative group scoring higher in both versions. There was also statistically significant time of day and cognitive status interaction for the backwards version. Time of day effect was larger for the normative group, with higher performances in the afternoon period (figure 1).

Table 3. Time of day and cognitive effects for Digit Span

Digit Span	F	Df	Sig	η²p
Forward				
ToD	.193	1, 29	.664	.007
Cog Status	6.947	1, 29	.013	.193
ToD x Cog Status	.621	1, 29	.437	.021
MEQ	.000	1, 29	.997	.000
Backwards				
ToD	.336	1, 29	.566	.011
Cog Status	17.701	1, 29	.000	.379
ToD x Cog Status	7.333	1, 29	.011	.202
MEQ	.053	1, 29	.819	.002

Note: ToD= time of day effects. Cog Status= cognitive status' effect. ToD x Cog Status= interaction between time of day and cognitive status. MEQ= Morningness-Eveningness Questionnaire.

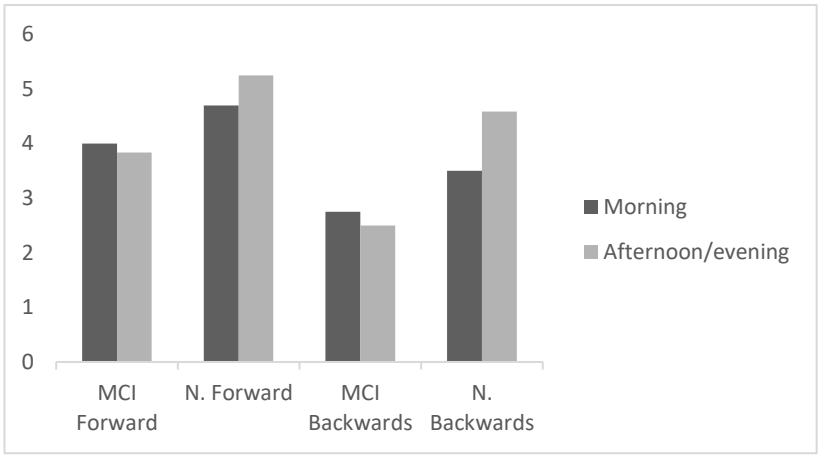

Figure 1. Means on the Digit Span task. Notes: N.= normative. MCI= Mild cognitive impairment.

Table 4 presents the results for the ANCOVA that was carried out to analyse the effects of time of day and cognitive status, on the response time for the CRT. The descriptive statistics in each condition for each of the dependent variables can be found in Appendix A (table 12).

There was a statistically significant time of day and cognitive status effect for response time, with larger time of day effect for the MCI group, and lower mean response time in the morning period (figure 2).

Table 4. Time of day and cognitive effects for CRT.

CRT	F	Df	Sig	η^2p
Response time				
ToD	1.824	1, 19	.193	.088
Cog Status	1.132	1, 19	.301	.056
ToD x Cog Status	5.376	1, 19	.032	.221
MEQ	.469	1, 19	.502	.024

Note: ToD= time of day effects. Cog Status= cognitive status' effect. ToD x Cog Status= interaction between time of day and cognitive status. MEQ= Morningness-Eveningness Questionnaire.

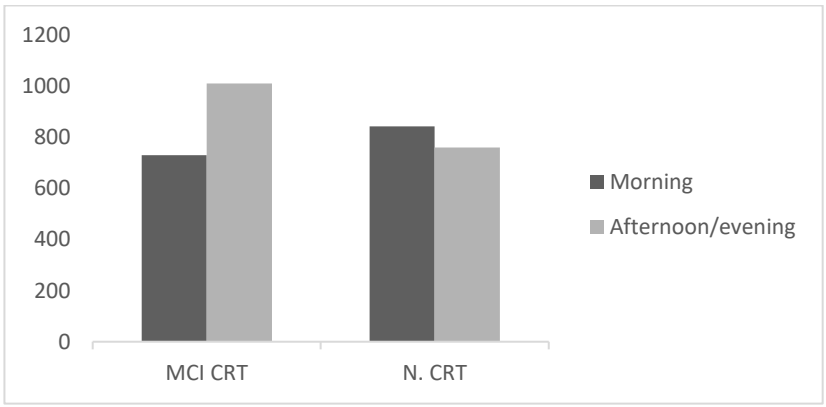

Figure 2. Means on the Choice Response Time task. Notes: N= normative. MCI= mild cognitive impairment.

Table 5 presents the results for the ANCOVA that was carried out to analyse the effects of time of day and cognitive status, on the extracted parameters of the ANT. Only correct trials were analysed to avoid confounding factors. The descriptive statistics in each condition for each of the dependent variables can be found in Appendix A (table 12). There were statistically

significant cognitive status effects for conflicting effect, orienting effect and mean response time, with higher orienting, conflicting scores and lower mean response time for the normative group.

Table 5. Time of day and cognitive effects for ANT.

ANT	F	Df	Sig	η^2p
Alerting effect for correct answers				
ToD	.006	1, 28	.937	.000
Cog Status	3.108	1, 28	.089	.100
ToD x Cog Status	2.001	1, 28	.168	.067
MEQ	.877	1, 28	.357	.030
Orienting effect for correct answers				
ToD	.006	1, 28	.937	.000
Cog Status	5.351	1, 28	.028	.160
ToD x Cog Status	.620	1, 28	.438	.022
MEQ	1.487	1, 28	.233	.050
Conflicting effect for correct answers				
ToD	2.323	1, 28	.139	.077
Cog Status	6.973	1, 28	.013	.199
ToD x Cog Status	.714	1, 28	.405	.025
MEQ	.154	1, 28	.698	.008
Mean response time for all trials				
ToD	3.610	1, 28	.068	.114
Cog Status	18.723	1, 28	.000	.401
ToD x Cog Status	3.716	1, 28	.064	.117
MEQ	.216	1, 28	.645	.008

Note: ToD= time of day effects. Cog Status= cognitive status' effect. ToD x Cog Status= interaction between time of day and cognitive status. MEQ= Morningness-Eveningness Questionnaire.

Table 6 presents the results for the ANCOVA that was carried out to analyse the effects of time of day and cognitive status, on the extracted parameters of the HCT. Only scores for the whole task were analysed, as some subtests scores violated the normality assumption. The descriptive statistics in each condition for each of the dependent variables can be found in Appendix A (table 13). None of the effects reached statistical significance.

Table 6. Time of day and cognitive effects for HCT.

HCT	F	Df	Sig	η^2p
Total number of errors				
ToD	.270	1, 28	.607	.010
Cog Status	1.873	1, 28	.182	.063
ToD x Cog Status	.041	1, 28	.842	.001
MEQ	2.425	1, 28	.131	.080
Mean response time				
ToD	.001	1, 28	.971	.000
Cog Status	.186	1, 28	.669	.007
ToD x Cog Status	.353	1, 28	.557	.012
MEQ	.988	1, 28	.329	.034

Note: ToD= time of day effects. Cog Status= cognitive status' effect. ToD x Cog Status= interaction between time of day and cognitive status. MEQ= Morningness-Eveningness Questionnaire.

Discussion

The aim of the present study was to compare the performance of older adults in EF, processing speed, attention, and working memory tasks between morning and afternoon and between MCI and normative older adults, controlling CT. Significant time of day differences were expected, with older adults having better performance in the morning. Also, significant interactions between time of day and cognitive status were expected, with a larger time of day effect on the MCI group and better performances in the morning period.

In general, the present results reject the first hypothesis. No time of day effect was found, meaning that no differences between the group tested in the morning and in the afternoon were statistically significant. The second hypothesis is also rejected. Although the MCI group had a significantly larger time of day effect for CRT, and the MCI group performed better in the morning period (i.e., lower response time), the same was not verified for the other tasks. A significant time of day and cognitive status interaction was present, but unexpectedly, the normative group presented larger time of day effect (i.e., larger difference between the morning and afternoon performances).

One explanation for the discordant results on the first hypothesis may be that only older adults were tested, as most of the studies mentioned compared the older adults' group with a younger adults' one. This allowed to draw interactions with age. Other methodological limitations might explain these results. Our sample is considerably small, resulting in some lack of statistical power. Also, the tasks were not performed in a laboratory setting and some context factors might have influenced performance. Additionally, it was not possible to make more stratified groups (only a morning group and an afternoon group were used, compared to other studies that used two to three groups for different morning hours and the same for the afternoon), which made the time of day manipulation considerably loose. Finally, the number of hours of sleep was not controlled.

Also, differences in tasks might explain the different results. Studies in the literature that found time of day effects did not include the same processes that were involved in our tasks, such as learning from feedback and hypothesis testing. As aforementioned, the characteristics of the task also play a part in cognitive performance variations across the circadian rhythm (Schmidt et al., 2007; Adan et al., 2012; Adan, 2015).

As for the results related to the interaction between time of day and cognitive status, the same methodological issues apply that could explain these results. The literature consulted had mostly used normative or healthy participants. This study suggests that time of day and cognitive status interactions can be found in some cognitive tasks, but not all. Although not reaching significance, some interesting patterns emerged, with larger time of day differences for the MCI group and better performance in the morning period for the total number of errors in the HCT, total number of errors, preservative errors and unique errors in the BCST (only the latter reached statistical significance). The same pattern emerged in the conflicting effect in the ANT task. These are parameters that rely heavily on inhibiting responses, in order to choose the right option and learning from positive/negative experiences. Contrary to this, there was a significant interaction between time of day and cognitive status, with larger time of day effect for the normative group in the backwards digit span (which is an attention task and requires working memory and mental tracking to complete successfully). Also, a larger time of day effect pattern for the normative

group (not statistically significant) emerged in other parameters of the BCST task (conceptual response, and trials to complete the first category). These parameters have in common the ability to form abstract concepts, through abstract thinking.

The MCI group had a larger time of day effect with better performance in the morning period for the CRT task (lower response time), this pattern was found in other temporized tasks, such as alerting and orienting effects (with correct trials) in the ANT task, although not reaching statistical significance. In relation to the time to complete the tasks, the same pattern emerged in the ANT and HCT tasks. All these parameters require processing speed, to give a correct answer in time, or to score lower response times. Processing speed loss or "behavioral slowing is a common characteristic of both aging and brain damage" (p. 101, Lezak et al., 2012). So, these results might reflect a time of day effect on processing speed, directly related to a cognitive decline specific effect.

Some evidence suggests that aging and the associated cognitive decline may play a role in the time of day effect (Anderson et al., 2014; 2017; May and Hasher, 2017; Hogan et al., 2009; Rowe, Hasher & Turcotte, 2009), but, to the best of our knowledge, no study had yet been carried out exploring this effect on cognitive performance of both MCI and normative older adults, in a Portuguese sample. The present study might reflect that a pathological decline (represented by a decline above the expected for age and sociodemographic characteristics) and normative decline might relate differently to time of day effects. Some psychiatric conditions seem to interact with time of day effects, such as schizophrenia (D'Reaux, Neumann & Rhymer, 2000). Hence, we expected to find a straightforward time of day and cognitive status interaction, but our results suggest this interaction either might not exist or are specific to certain aspects of cognition. Processing speed, response inhibition and learning from feedback seem to be more affected in the afternoon that in the morning in MCI comparatively to normative older adults. A larger time of day effect seems to be present on normative decline than MCI for mental tracking/working memory and abstract thinking. However, there are also other variables that may account for these differences, such as the cognitive strategies used or the idiosyncrasy of the cognitive declining process, for example.

Our results provide minimal evidence that MCI and normative geriatric population might differ in time of day effects, in processing speed, response inhibition, learning from feedback, mental tracking and abstract thinking. We cannot draw definitive conclusions from the present study. In future research, differences between these groups and older adults with a more advanced pathological decline should be tested. Moreover, the present results should be replicated with a bigger sample and other methodologies (a longitudinal design or stratified randomized groups by various periods of the day) should be used to investigate time of day effects and compare MCI

and normative older adults. Future research should also attend more specifically to some cognitive domains (such as EF, for example working memory or abstract thinking). As aforementioned some interesting patterns emerged with these aspects of cognition, it would be interesting investigating further on them. This is a key issue for practice, since time of day and cognitive decline interactions can be a confounder in neuropsychological assessment, if not studied and explicitly described.

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Appendix

Appendix A. Full descriptive statistics (tables 7, 8, 9, 10, 11and 12).

Table 7. Sociodemographic frequencies by group and time of testing.

Group	Sex (females)	Civil status (single)	Civil status (married)	Civil status (divorced)	Diagnosis*	Taking medication	Previously seen by a MHP
MCI	63.4	0	36.4	18.2	45.5	90.9	40
Normative	73.9	17.4	34.8	26.1	21.7	69.6	21.7
Morning	62.5	12.5	56.3	25	75	87.5	31.3
Afternoon	77.8	11.1	16.7	22.2	77.8	94.4	23.5
Total	70.6	8	35.5	23.5	76.2	91.2	27.3

Notes: All results are presented in percentage. MHP= mental health professional. Civil status could be single, married, divorced or widowed. *Diagnosis refers to participants that have identified at least one diagnosis given by a health professional.

Table 8. Complete descriptive statistics for morning group. Skewness and kurtosis presented with standard errors.

	Mean	Standard deviation	Variance	Skewness (standard error)	Kurtosis (standard error)	Minimum	Maximum
Age (N= 16)	72.31	5.91	34.90	2.30 (.56)	6.57 (1.09)	67	91
Years of education (N= 16)	6.94	3.62	13.13	.62 (.56)	-1.67 (1.09)	4	12
MEQ (N= 16)	52.19	5.48	30.03	-.41 (.56)	.34 (1.09)	40	62
Depression (N= 16)	4.31	2.75	7.56	.18 (.56)	-1.24 (1.09)	0	9
Anxiety (N= 16)	6.5	3.67	13.47	1.19 (.56)	1.50 (1.09)	2	16
MoCA (N= 16)	22.56	2.25	5.06	.027 (.56)	-.12 (1.09)	18	26

Table 9. Complete descriptive statistics for afternoon group. Skewness and kurtosis presented with standard errors.

	Mean	Standard deviation	Variance	Skewness (standard error)	Kurtosis (standard error)	Minimum	Maximum
Age *(N=18)*	73.7	5.57	31.04	.44 (.54)	-.20 (1.04)	65	86
Years of education *(N=18)*	7.33	3.74	14	.36 (.54)	-1.91 (1.04)	4	12
MEQ *(N=18)*	50.11	7.47	55.87	-.48 (.54)	.54 (1.04)	35	61
Depression *(N=17)*	5.59	3.97	15.76	-.03 (.55)	-1.26 (1.06)	0	11
Anxiety *(N=17)*	7.41	4.29	18.38	1.06 (.55)	.66 (1.06)	2	17
MoCA *(N=18)*	22.44	3.45	11.91	-.53 (.54)	-1.21 (1.04)	17	27

Table 10. Complete descriptive statistics for MCI group. Skewness and kurtosis presented with standard errors.

Group	Mean	Standard deviation	Variance	Skewness´ (standard error)	Kurtosis (standard error)	Minimum	Maximum
Age (*N=17)*	73.27	5.98	35.81	.83 (.66)	.614 (1.28)	65	86
Years of education (*N=17)*	4.55	1.51	2.273	3.10 (.66)	9.84 (1.28)	4	9
MEQ (*N=17)*	50.64	5.39	29.06	-.24 (.66)	.28 (1.28)	40	59
Depression (*N=17)*	5	3.52	12.40	.034 (.66)	-.671 (1.28)	0	11

Anxiety (*N=17)*	7.36	3.75	14.06	1.21 (.66)	1.64 (1.28)	3	16
MoCA (*N=17)*	19.09	1.70	2.89	-.17 (.66)	-1.93 (1.28)	17	21

Table 11 Complete descriptive statistics for normative group. Skewness and kurtosis presented with standard errors.

Group	Mean	Standard deviation	Variance	Skewness (standard error)	Kurtosis (standard error)	Minimum	Maximum
Age *(N=17)*	72.96	5.68	32.23	1.57 (.48)	3.44 (.94)	66	91
Years of education *(N=17)*	8.39	3.71	13.79	-.21 (.48)	-1.96 (.94)	2	12
MEQ *(N=17)*	51.30	7.21	51.95	-.70 (.48)	-.31 (.94)	35	62
Depression *(N=16)*	4.95	3.48	12.14	.31 (.49)	-1.02 (.95)	0	11
Anxiety *(N=16)*	6.77	4.14	17.14	1.17 (.49)	.98 (.95)	2	17
MoCA *(N=17)*	24.13	1.66	2.755	-.30 (.48)	-1.41 (.94)	22	27

Table 12 Complete descriptive statistics for normative group. Skewness and kurtosis presented with standard errors.

	Morning		Afternoon	
	MCI	Normative	MCI	Normative
ANT *(N=33)*				
Response time (msec)	926.78 (68.92)	790.17 (36.79)	1115.11 (87.82)	771.29 (32.23)
Alerting (all trials)	45.74 (20.56)	39.99 (16.33)	30.52 (14.37)	53. 08 (7.75)
Orienting (all trials)	36.82 (15.18)	23.98 (13.85)	17.88 (12.92)	36.54 (7.69)
Conflicting (all trials)	167.63 (26.90)	84.53 (12.50)	131.13 (50.23)	77.85 (16.23)
Alerting (correct trials)	30.93 (23.28)	36.03 (12.59)	11.11 (18.51)	49.67 (5.22)
Orienting (correct trials)	25.76 (16.24)	41.03 (9.06)	13.89 (4.36)	40.67 (7.99)
Conflicting (correct trials)	197.38 (58.50)	92.47 (11.90)	125.00 (36. 97)	79.65 (17.21)
Digit span *(N=34)*				
Forward	4 (.41)	4.7 (.21)	3.83 (.70)	5.25 (.33)
Backwards	2.75 (.48)	3.5 (.17)	2.5 (.22)	4.58 (.23)
CRT *(N=24)*				
RT (msec)	729.04 (54.09)	842.45 (93.76)	1009.12 (63.78)	759.05 (50.66)
WCST *(N=34)*				
Total number of errors	59 (4.60)	70.2 (6.21)	82 (4.97)	60.67 (5.81)
Preservative answers	37.80 (17.61)	37.60 (8.96)	53.83 (17. 82)	49.34 (7.02)
Preservative errors	24.20 (11. 39)	25.20 (6.18)	39.34 (13.26)	31.42 (5.26)
Non-preservative errors	42 (16.01)	45 (10.75)	42.67 (16.22)	29.25 (6.99)

Unique errors	.75 (.75)	6.2 (2.65)	15.17 (9.05)	3.08 (2.28)
Trials to complete first category	21.75 (13.49)	19.7 (6.88)	15.83 (6.59)	31.5 (7.38)
Failure to maintain set	2.8 (.97)	1.6 (.58)	1 (.37)	1.84 (.37)
Conceptual answers	44.75 (2.14)	27.80 (7.46)	22.33 (6.68)	45.68 (7.76)
HCT *(N=34)*				
Response time (msec)	5229.15 (1039.69)	5079.84 (744.38)	5441.17 (1087.56)	4764.39 (644.06)
Total number of errors	96.75 (16.81)	104.4 (7.44)	79.33 (6.23)	107 (14.34)

Notes: ANT= attentional network task. CRT= choice response time. WCST= Wisconsin card sorting test. HCT= Halstead category test. RT= response time. MSEC= milliseconds.

Appendix B. Figures 3, 4, 5, 6, 7, 8, 9, 10 e 11.

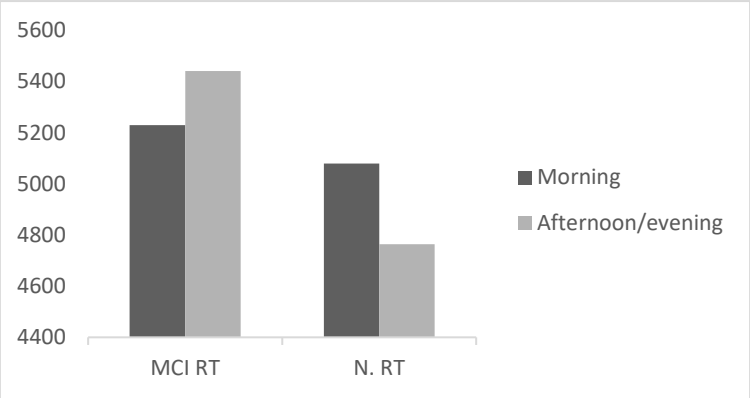

Figure 3. Means on the HCT response time (RT), in msec. Notes: N.= normative. MCI= Mild cognitive impairment.

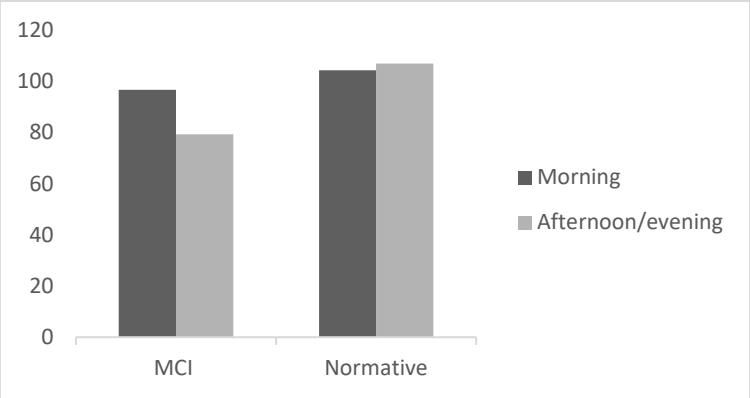

Figure 4. Means on the HCT errors. N.= normative. MCI= Mild cognitive impairment.

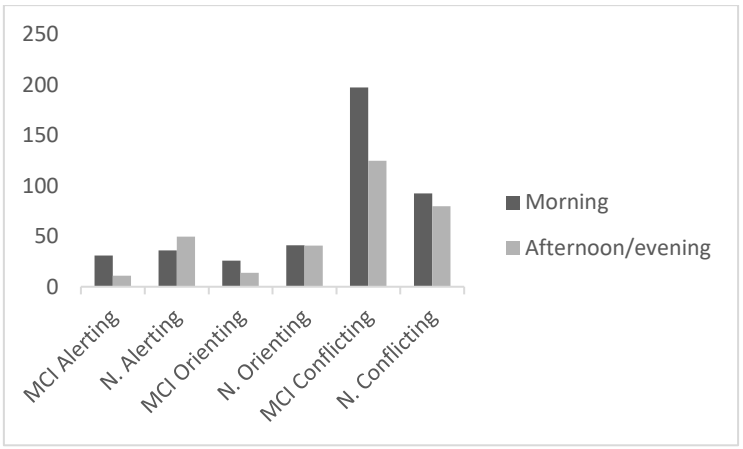

Figure 5. Means on the ANT task. Notes: N.= normative. MCI= Mild cognitive impairment

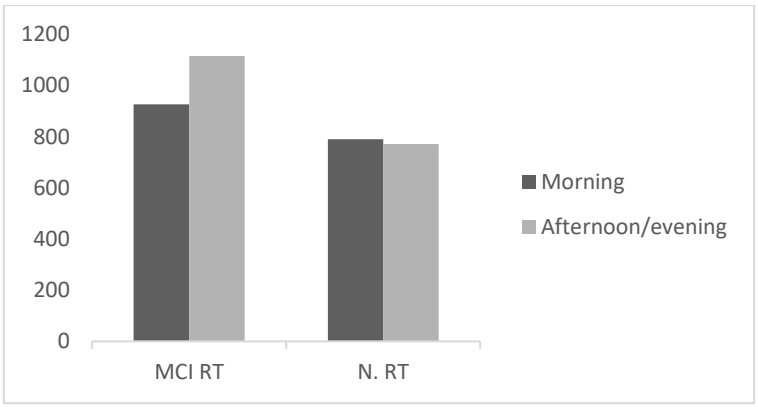

Figure 6. Response time (RT) means in msec, on the ANT task. N.= normative. MCI= Mild cognitive impairment.

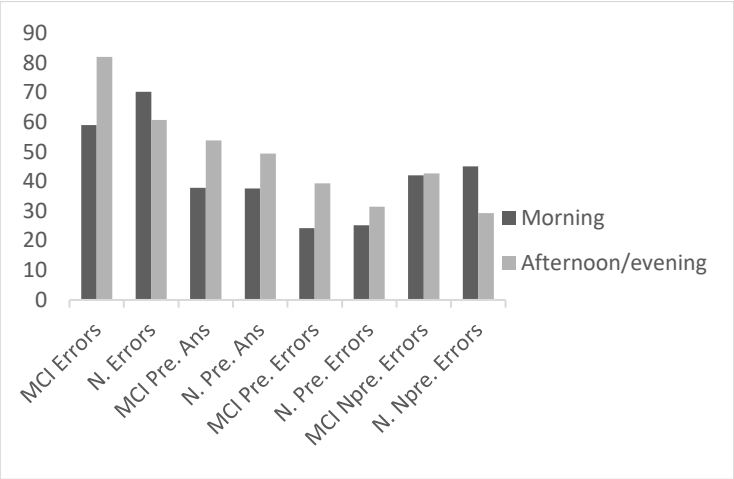

Figure 7. Error and type of errors means for the WCST. Notes: N.= normative. MCI= Mild cognitive impairment. Pre. Ans= preservative answers. Pre. Errors= preservative errors. Npre. Errors= non-preservative errors.

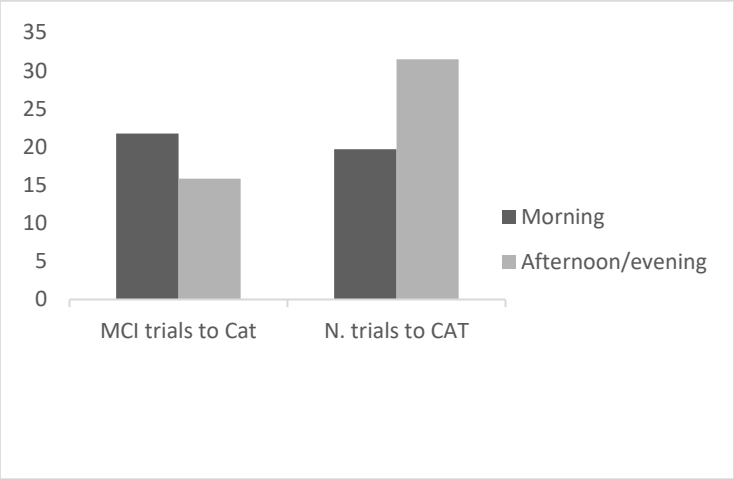

Figure 8. Means of trials to CAT from the WCST. Notes: N.= normative. MCI= mild cognitive impairment.

Figure 9. Means of unique errors from the WCST. Notes: N= normative. MCI= mild cognitive impairment

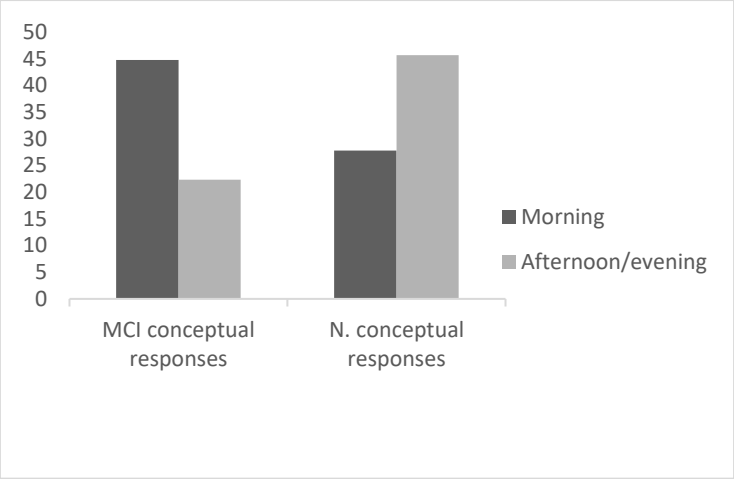

Figure 10. Means of conceptual responses from the WCST. Notes: N= normative. MCI= mild cognitive impairment

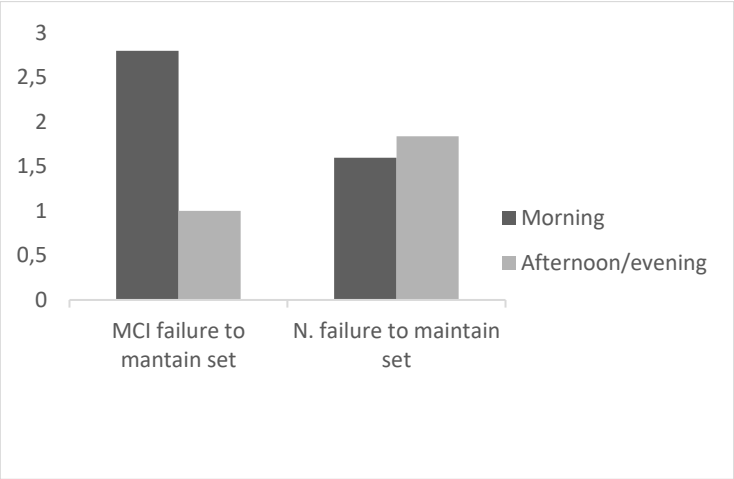

Figure 11. Means of failure to maintain set from the WCST. Notes: N= normative. MCI= mild cognitive impairment