An Exploration of Prospective Memory Components and Subtasks of the Memory for Intentions Test (MIST)

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**Abstract**

Introduction:

Prospective Memory (PM), the ability to execute future intentions, decreases with age and memory-related disorders and may be an early predictor of dementia. The Memory for Intentions Test (MIST) allows the assessment of multiple aspects of PM using a range of subtasks. The current study evaluated and explored a Portuguese version of the MIST and its subtasks.

Method

Forty-one patients with Mild Cognitive Impairment (MCI) and forty healthy participants performed the MIST, neuropsychological tests and questionnaires. Analyses were performed testing relationships between MCI and PM components of the MIST, and differences between subtasks of the test were explored.

Results:

Reliability of the PM component was acceptable within the patient group, but not within the control group. PM components were significantly lower in the MCI patients, but this effect was dependent on subtasks. Groups differed most strongly at shorter intervals. PM scores predicted MCI status. Correlations were found between PM components and cognitive functioning scales.

Conclusions:

The Portuguese version of the MIST seems suitable for use in clinical practice and research. MCI is differentially related to different PM components and subtasks of the MIST.

**Keywords:** Prospective Memory; MIST; Mild Cognitive Impairment; MCI; Portuguese.

It is estimated that in 2050 there will be 131.5 million cases of dementia worldwide (Prince et al., 2015). Identifying early markers of this disease is essential for optimal management and treatment outcomes (Mariani, Monastero, & Mecocci, 2007). Prospective memory (PM) may play a role as such an early marker (Dermody, Hornberger, Piguet, Hodges, & Irish, 2015; Duchek, Balota, & Cortese, 2006; Huppert, Johnson, & Nickson, 2000; Jones, Livner, & Bäckman, 2006; Marcone et al., 2017; Tse et al., 2014). PM refers to the ability to retrieve and execute intended actions at the appropriate moment in the future (Meacham & Leiman, 1982), which is essential for independent living and quality of life (Beaver & Schmitter-Edgecombe, 2017; Lanzi, Wallace, & Bourgeois, 2019; Pirogovsky, Woods, Vincent Filoteo, & Gilbert, 2012; Schmitter-Edgecombe, Woo, & Greeley, 2009; Woods et al., 2015; Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012). PM difficulties have been found to be closely associated with cognitive decline (Crawford, Smith, Maylor, Della Sala, & Logie, 2003; Hsu, Huang, Tu, & Hua, 2014; Smith, Del Sala, Logie, & Maylor, 2000; Woods et al., 2007), in particular Mild Cognitive Impairment, MCI (Costa, Caltagirone, & Carlesimo, 2011; Costa et al., 2015; Jones et al., 2006; Kinsella, Pike, Cavuoto, & Lee, 2018; Lee et al., 2016; Niedźwieńska & Barzykowski, 2012; Pereira et al., 2015; Tam & Schmitter-Edgecombe, 2013; Thompson, Henry, Rendell, Withall, & Brodaty, 2010; van den Berg, Kant, & Postma, 2012). As MCI frequently precedes dementia, its association with PM may be of significant interest for early detection (Mariani et al., 2007; Mauri, Sinforiani, Zucchella, Cuzzoni, & Bono, 2012; Petersen et al., 1999). It is therefore essential to have validated instruments to adequately assess PM (Raskin, 2018; Schmitter-Edgecombe et al., 2009; Zhou et al., 2012).

One such test is the Memory for Intentions Screening Test, MIST (Raskin, 2004). The MIST has good psychometric properties, with findings of a test-retest reliability of .89 (Raskin, Buckheit, & Sherrod, 2010) and split-half reliability of .70 (Woods et al., 2008a). The MIST has shown a correlation of .80 with a behavioural memory test and associations with various pathologies, including MCI (Karantzoulis, Troyer, & Rich, 2009) and Parkinson’s Disease (Raskin et al., 2011). MIST scores are also associated with everyday functioning (Woods et al., 2008b). The MIST provides separate measures for the retrospective and prospective components of PM. These refer, respectively, to the encoding and storage of the intention versus the retrieval and execution of the intention at the correct time. An example of a prospective item is: “When I hand you a

request for records form, please write your doctors’ names on it”. An example of a retrospective item is: “At any point during this test, were you supposed to: (1) Ask me

when the session ends, (2) Ask me what time the office closes, (3) Ask for your medical records?” Further, the MIST contains multiple types of task. There are time- versus event-based tasks, i.e., whether the task has to be performed after a given duration, or on the occurrence of a given event; tasks with short and long durations between setting the task and the time of its execution; and tasks involving a verbal response versus an action. Such task characteristics may affect relationships between PM assessment and cognitive decline (Karantzoulis et al., 2009; Lee et al., 2016; Niedźwieńska, Kvavilashvili, Ashaye, & Neckar, 2017; Troyer & Murphy, 2007). The MIST thus provides a way to assess effects of potentially important task factors that would be difficult to assess using self-report. The question could nevertheless be raised whether a task-based assessment such as the MIST is needed in addition to existing self-report measures, which may well be more efficient to use. Importantly, task-based assessments may tap into different processes than, e.g., self-report measures (Uttl & Kibreab, 2011). It thus remans important to evaluate assessment tasks such as the MIST.

However, there is currently no validated Portuguese translation of the MIST. The current study therefore aims to validate a new Portuguese translation of the MIST. First, the reliability of global PM scores will be evaluated. Second, differences between MCI patients and healthy controls will be tested: It is expected that patients will have lower scores than controls. Further, the influence of task factors (e.g., event-based versus time-based) on these differences will be tested exploratively. Third, the ability of the MIST scores to predict MCI- versus control-group participants will be determined. Finally, correlations will be tested between MIST scores and mental health questionnaires and neuropsychological tests.

# Method

## Participants

 A sample of 81 participants (41 MCI patients and 40 healthy controls) was recruited at a public hospital outpatient dementia unit and a memory clinic in Lisbon (MCI patients), and in a senior university in Porto (control participants). The study was approved by the ethics committee of the Faculty of Medicine - Santa Maria Hospital in Lisbon. Participants were informed of the experimental protocol and gave their written consent.

MCI patients were selected according to criteria adapted from Petersen and colleagues (1999): 1) memory complaints in the last year, reported by the patient or the caregiver; 2) abnormal memory function, based on immediate recall on the Logical Memory test of the Wechsler Memory Scale (story A). Memory was considered impaired when the subjects scored on immediate free recall of story A of the test at least 1 SD below the respective mean education and age values for the Portuguese population, based on the Battery of Lisbon for the Evaluation of Dementia, BLAD (Garcia, 1984); 3) general cognitive function assessed using the Mini Mental State Examination, MMSE (Folstein, Folstein, & McHugh, 1975) within normal values for Portuguese population; normative cut-off values for the Portuguese population adjusted to education (Guerreiro, Silva, & Botelho, 1994) were used as follows: score above 22 for participants with ≤11 years of education, or above 27 for participants with >11 years of education; 4) no or minimal impairment in activities of daily living determined by the Instrumental Activities of Daily Living Scale, IADL (Lawton & Brody, 1969): no more than one item from the IADL scale was scored as non-independent. Inclusion criteria for the Control group were: 1) Absence of memory complaints; 2) Normal memory function (values of immediate recall on the Logical Memory test of the Wechsler Memory Scale (story A) normal for the Portuguese population); 3) No impairment on Mini Mental State Examination (MMSE) (normal values for the Portuguese population, as above); 4) normal IADL scale (no item from the IADL scale was scored as non-independent). Thus, groups were expected to differ primarily on memory complaints and memory function, although there could remain relatively subtle differences on cognitive scales within the normal range. Descriptive statistics for each group and tests of differences between the groups are presented in the Results. Exclusion criteria for both groups were: 1) Presence of clinical history of alcohol or psychotropic substance abuse; 2) Presence of neurological, psychiatric, systemic or chronic endocrine disorders that can induce cognitive decline; 3) Presence of dementia criteria by de Diagnostic and Statistical Manual of Mental Disorders-IV-TR (American Psychiatric Association, 2000).

## Materials

### MIST

The MIST (Raskin, 2009) requires about 30 minutes to apply and assesses three components of PM: an immediate prospective component (PM-i), a retrospective component (PM-r), and a delayed prospective component (PM-d).

To assess PM-i the examiner gives eight PM tasks that participants are required to fulfill while performing an ongoing task (a word-search puzzle). The tasks are defined by three factors: type of cue (time vs event), type of response (action vs verbal) and length of the delay period (2 vs 15 minutes). There are eight tasks, presented in the order below, with the following task levels (note that the tasks do not involve all combinations of levels as in a factorial design):

1. Time – 2 min– Verbal
2. Event – 2 min – Action
3. Event – 2 min – Verbal
4. Time – 15 min – Verbal
5. Event – 15 min – Action
6. Event – 15 min – Action
7. Time - 2 min – Verbal
8. Time - 15 Min – Action

Examples of PM-i tasks are the participant being asked to tell the examiner that in 15 minutes it is time to take a break (time-based, 15 min, verbal task) and the examiner asking the participant to sign his name on the word search puzzle paper when given a red pen by the examiner, which the examiner does after 2 min (event-based, 2 min, motor task). For time monitoring purposes, a clock is visible to both the examiner and the participant.

Scoring for each task of the PM-i assessment is based on five types of errors that can occur for the response to a task. The types of errors, and the score given for responses involving the respective error, are as follows:

1. PM errors, when participants do not perform any type of response: score = 0.
2. Random errors, when both the response and its timing are incorrect: score = 0.
3. Task substitution errors, when participants provide a response associated with a different task: score = 1.
4. Loss of content errors, when participants reveal that they know it is time to provide a response at the appropriate moment but either cannot recall the nature of the response or recalls an incorrect one: score = 1
5. Loss of time errors, when the participant recalls and executes the appropriate task at an incorrect time: score = 1.
6. No error: score = 2.

The PM-i score is the sum of the scores over the eight tasks.

PM-r is assessed by testing whether the participant can recall each of the PM tasks at the end of the test, via multiple choice. For example, in one of the items, the examiner asks the participant: “When I gave you a red pen, you were supposed to: *i)* sign your name; *ii)* write down your birthday; *iii)* take the pen back home with you”. The total score for PM-r is the number of correct answers.

The PM-d task consists of a phone call from the participant to the examiner 24 hours after the assessment, informing the examiner about the number of hours that the participant slept that night. The score is 0 if the participant does not call the examiner at all; if despite calling the examiner, the participant does not recall the correct intention; or the participant calls the examiner more than two hours before or after the appropriate time. The score is 1 if the participant calls the examiner at the correct time giving the appropriate information.

### Mini-Mental State Examination

The Mini Mental State Examination (MMSE) is a screening test widely used in dementia assessment (Folstein et al., 1975), comprising measures of orientation, memory, attention and calculus, language and constructive praxis. The version utilized for the present study was a validated Portuguese translation (Guerreiro et al., 1994).

### Cancellation task

Letter cancellation tasks are used to assess focused attention, visual scanning abilities and psychomotor speed (Crawford, Parker, & McKinlay, 1992). The task used in the current study required the participant to identify and cancel as fast as possible 16 target-stimuli embedded in a set of 100 letters. The total score depends on the number of target stimuli correctly identified and the amount of time spent to perform the task. The letter cancellation task used for the present investigation is part of the Battery of Lisbon for the Evaluation of Dementia, BLAD (Garcia, 1984; Guerreiro, 1998).

### Logical Memory – story A (Wechsler Memory Scale-III)

The Logical Memory, LM, subtest from the Wechsler Memory Scale - III (Wechsler, 1945) is one of the most commonly used measures of verbal episodic memory and includes both an immediate and a delayed component. The Portuguese version used for the present investigation is part of the BLAD.

### Trail Making Test

The Trail Making Test, TMT (Reitan, 1955) is a cognitive task mostly used to assess attention, mental flexibility, visual search abilities and psychomotor speed (Lezak, Loring, & Howieson, 2004) and includes two parts (A and B). Part A requires the participant to link in ascending order numbered circles scattered on a paper sheet, as fast as possible. Part B presents not only numbered circles but also circles with letters and it is intended that the participant links alternately the numbers and circles, respecting both the numbers ascending order and the alphabet. The time to complete the task is used as the score.

### Prospective and Retrospective Memory Questionnaire

The Prospective and Retrospective Memory Questionnaire, PRMQ (Smith et al., 2000) is a 16-item self-report questionnaire developed to assess prospective (PRMQ-p) and retrospective (PRMQ-r) memory complaints in healthy and cognitively impaired individuals. Answers to each item consist on a 5-point scale, rating how often each type of memory failure occurs to the participants. The present investigation used the PRMQ Portuguese translation by Da Câmara (2011).

### Subjective Memory Complaints

The Subjective Memory Complaints scale, SMC (Schmand, Jonker, Hooijer, & Lindeboom, 1996) is a 10-item self-report multiple-choice questionnaire assessing daily living memory complaints. Scores reflect the severity of the participant’s memory complaints in a maximum of 21 points (corresponding to severe memory complaints) and a minimum of 0 points (no significant memory complaints).

### Geriatric Depression Scale - 30

The Geriatric Depression Scale, GDS – 30 (Yesavage et al., 1982), is a widely used 30-item self-report questionnaire assessing depressive symptoms in the elderly. Items require a yes/no answer concerning depressive symptoms in the week right before the assessment. Each answer suggesting depressive symptomatology is scored with 1 point and answers indicating absence of depressive complaints are scored with 0 points. Therefore, the minimum total score in the GDS-30 is 0 points (absence of depressive symptoms) and the maximum total score is 30 points (severe depressive symptomatology). To assess the participants’ depressive symptomatology, the Portuguese version of the GDS-30 was used (Pocinho, Farate, Dias, Lee, & Yesavage, 2009).

## Process of translation of the MIST

To achieve a conceptually equivalent Portuguese version of the MIST a forward-translation to Portuguese of the completed instrument was performed by a specialist in the field of memory and cognitive decline. This was followed by a back-translation to English performed by a bilingual (English/Portuguese) translator with expertise in this field, who was not associated with this project and had no prior knowledge of this instrument. Discrepancies were discussed with the research team and the independent translators until a satisfactory version was reached (Beaton, Bombardier, Guillemin, & Ferraz, 2000).

## Procedure

Participants provided informed consent on arrival and were subsequently administered the tests and self-report scales. Participants also provided demographic information including age, gender, and education level. There were three levels of education, 1-4 total years of education, 5 – 9 total years, or more than 9 total years.

## Data analysis

Statistical analysis was performed using the IBM Statistical Package for the Social Sciences (IBM SPSS Statistics Version 20.0, SPSS Inc: Chicago, IL), R (R Core Team, 2014) and JASP (JASP Team, 2018). Additional packages used in R were psych (Revelle, 2018) and apaTables (Stanley, 2018).

Reliability of the PM-i and PM-r scores was assessed using Cronbach’s alpha over the eight different tasks.

Independent-samples t-tests were used to test group differences on PM-i, PM-d, and PM-d. Effects of the specific tasks were tested for PM-i and PM-r using a mixed design ANOVA, in which the between-subject variable was group (MCI versus control) and the within-subject factor was task (task 1 through 8). Note that due to the structure of the MIST it is not possible to run a single full factorial analysis for the factors of time versus event, 2 versus 15 min duration, and verbal versus action response. Further, there may be task-order effects to consider. We therefore studied patterns of pairwise post-hoc tests after a significant within-subject effect over all eight tasks. Interactions between task and group were further studied with independent-samples t-tests comparing group differences per task.

The predictive ability of MIST scores was tested using hierarchical binomial logistic regressions. Group was the dependent variable and predictors were PM-i, PM-d, and PM-r. Any significant results were followed up by post-hoc tests to evaluate the individual contributions of predictors. Sensitivity and specificity were evaluated, i.e., respectively, the proportion of MCI patients that were correctly identified and the proportion of controls that were correctly identified.

Finally, correlations between MIST scores (PM-i, PM-r, and PM-d) and the neuropsychological tests and self-report questionnaires were tested within the MCI group and, for completeness, within the control group.

# Results

Descriptive statistics for the two groups and tests of group differences are shown in Table 1. Groups did not differ significantly on age, gender, or education level. MCI patients had significantly worse scores than controls on all tests except the Cancellation task.

<Table 1 around here>

The reliability of PM-i scores was .68 over both groups, .43 in the control group, and .76 in the patient group. The reliability of PM-r scores was .45 over both groups, .35 in the control group, and .50 in the patient group.

Table 2 shows the MIST scores. The MCI group had significantly lower scores than the control group on PM-i and PM-d, while the difference in scores for PM-r did not reach significance.

<Table 2 around here>

The mixed design ANOVAs for PM-i showed the following effects involving tasks (Figure 1). First, there was a within-subject effect of task, *F*(7, 553) = 27.6, *p* < .001, ηp2 = 0.26. Post-hoc tests with Bonferroni correction showed two patterns of significant differences. First, tasks 1, 2, 3, 5, 6, and 7 had higher scores than tasks 4 and 8. Notably, tasks 4 and 8 were long-duration tasks that were not preceded by a different long-duration task that could provide a reminder or induce an increase in effort to recall. Second, tasks 3 and 7 had higher scores than tasks 1, 5, and 6. The lower scores on task 1 seem likely to reflect unfamiliarity with the MIST, and tasks 5 and 6 had a 15 min duration as opposed to the 2 min duration of tasks 3 and 7. Second, there was a task by group interaction, *F*(7, 553) = 3.47, *p* = .001, ηp2 = .042. Independent t-tests per task showed group differences on the tasks 1, 2, 3, 4, and 7 (all *p*’s < .023) , with lower scores for the MCI group; i.e., with the exception of task 4, which was the first 15 min task, group differences were found on the 2 min duration tasks.

<Figure 1 around here>

The mixed design ANOVAs for PM-r showed the following effects involving task (Figure 2). First, there was a within-subject effect of task, *F*(7, 553) = 5.9, *p* < .001, ηp2 = .069. Post-hoc tests with Bonferroni correction showed that this was due to higher scores for task 8 than tasks 1, 2, 5 and 6. Task 1 further had lower scores than tasks 4 and 7. As above, lower scores for task 1 appear to likely be caused by a lack of task familiarity. Relatively high scores for task 8 are likely due to recency, and tasks 2, 5 and 6 notably all had action responses. Second, there was a task by group interaction, *F*(7, 553) = 2.5, *p* = .017, ηp2 = .030. Independent t-tests per task showed a group difference only on task 2, *t*(79) = -2.59, *p* = .011, with lower scores for the MCI group.

<Figure 2 around here>

The binomial logistic regression model significantly predicted MCI status, Chi2(77) = 28, *p* < .001. The coefficients for PM-i (*b* = 0.21, *z* = 2.29, *p* = .022) and PM-d (*b* = 2.07, *z* = 3.70, *p* < .001) were significant within the model, but not the coefficient for PM-r (*b* = -0.23, *z* = -0.84, *p* = .40). Sensitivity was 80% and specificity was 76%. When using each predictor alone, PM-i provided 65% sensitivity and 64% specificity; PM-r provided 78% sensitivity and 46% specificity; and PM-d provided 80% sensitivity and 71% specificity. Together, PM-i and PM-r (i.e., the scores available immediately after testing) provided 68% sensitivity and 63% specificity.

In exploratory analyses, the regression was performed with PM-i and PM-r scores calculated based only on the first three tasks, and the PM-d. Reliability based on the first three PM-i scores was .66 over both groups, .41 in the control group, and .68 in the patient group. Reliability based on the first three PM-r scores was .27 over both groups, .13 in the control group, and .22 in the patient group. Performance of the model was similar to that of the full task, with sensitivity 78% and specificity 78%. The shorter PM-i alone provided 78% sensitivity and 51% specificity; the shorter PM-r alone provided 70% sensitivity and 59% specificity. Together, the shorter PM-i and PM-r provided 65% sensitivity and 61% specificity.

Table 3 shows correlations between MIST scores and the neuropsychological tests and self-report questionnaires within each group. Within the patient group, PM-i was associated positively with MMSE and Cancellation, and negatively with GDS, TMTA and TMTB (note that lower scores on the TMT reflect faster completion); PM-r was associated positively with Cancellation and negatively with TMTA; and PM-d was associated positively with PRMQ-p. Within the control group, PM-i was associated positively with MMSE and Cancellation, and negatively with TMTA and TMTB; PM-r had no significant correlations; and PM-d was associated positively with MMSE and negatively with SMC and GDS.

<Table 3 around here>

# Discussion

The aim of the current study was to evaluate a Portuguese translation of the MIST. Reliability, relationships with MCI, effects of task factors, and correlations with individual differences were evaluated and explored. Reliability was reasonable overall for PM-i scores, but lower for PM-r scores. The groups differed on all three MIST scores, PM-i, PM-r, and PM-d, and MCI status could be reasonably well predicted by MIST scores. Together, these results suggest sufficient psychometric properties of the Portuguese translation of the MIST. More exploratively, it was found that groups differed most strongly on the 2 min rather than 15 min tasks of the MIST. Finally, MIST scores correlated with a range of neuropsychological test scores and self-report questionnaires.

Reliability was clearly highest within the patient group and over both groups; within the control group, it seems likely that there was less meaningful variability and hence lower reliability. PM-r scores had a relatively low reliability of around 0.5 overall and in the patient group. Possibly related to this low reliability, PM-r scores tended to show weaker results than PM-i scores over all analyses. It could thus be considered whether PM-r scores are useful in their current form, although there is a clear theoretical rationale for assessing the retrospective component of PM.

Group differences in the expected direction were found for all MIST scores, providing a first indication of validity of the MIST. Analyses of the separate tasks indicated a dependence of this effect on task duration: MCI patients showed significantly worse performance than the control participants for the tasks with a 2 min interval but not for most of the tasks with a 15 min interval. It seems that control participants had as much difficulty with these tasks as the patients, to the extent they did not show significantly higher scores as was the case for the 2 min tasks. The only exception to this pattern was the first occurrence of a task with 15 min interval, when patients did show lower performance, possibly due to having more difficulty with the novelty of the new kind of task. Exploratory analyses inspired by these findings suggested that the first three tasks of the MIST provided roughly similar predictive ability as the full eight tasks, although this clearly requires replication in a separate data set. These results may be interesting in terms of further development of the MIST. If relationships to cognitive decline are primarily carried by the short-duration tasks, and the additional long-duration tasks do not differentiate controls from patients, it would seem that a significantly shorter version of the MIST would be feasible for some purposes.

Specificity and sensitivity were reasonable when predicting MCI from MIST scores, in the 75-80% range, further supporting validity and potential use of the MIST. The ability to predict group membership was roughly as good using only the first three tasks of the MIST, which may be of interest in future work aimed at reducing the length of the task. A shorter task with similar predictive ability would, of course, be desirable in practice. Further, interestingly the best single predictor was the simple PM-d score for whether the “call back tomorrow” task had been performed correctly; adding PM-i and PM-r did not strongly improve prediction accuracy, in particular not for sensitivity. This superior predictive ability may involve an additional task factor involved in the PM-d, namely the change in context of task memorization versus execution (Tulving & Thomson, 1973). The ability to recall the intended action at home on the following day could require particularly important processes that are externally supported within the assessment setting, in which there is a constant contextual reminder cue of the general tasks and testing situation. Simply adding the PM-d task would appear to be a potentially highly efficient way of including a performance-based PM measure. It could also be interesting to test variations of the PM-i and PM-r measures in which a context change is included in the procedure.

The pattern of correlations within the patient group suggests, as expected from the literature, a broad relationship between PM and various cognitive and mental health-related measures. In particular PM-i was associated with other measures of cognitive performance, likely reflecting common cognitive demands of complex tests (Hernandez Cardenache, Burguera, Acevedo, Curiel, & Loewenstein, 2014; Kamat et al., 2014; Salthouse, Berish, & Siedlecki, 2004). While expected, this does indicate that MIST scores may not represent pure PM ability, and in this sense divergent validity is limited. Future work could focus on acquiring PM-specific measures, relative to other executive functions. Conspicuously, there was no relationship between PM-i or PM-r with a self-report measure of prospective and retrospective memory within the patient group. This is in accordance with work suggesting that self-report measures of PM may not be strongly related to actual PM performance (Uttl & Kibreab, 2011). However, PM-d was specifically correlated with the self-report measure of prospective memory. While clearly more work is needed on this issue, the current results would seem to suggest that the measures with strongest mutual support for a specific assessment of PM could be the PRMQ-p and PM-d.

A limitation of the current study is its cross-sectional design. Evaluating the ability of the MIST to predict future decline would be an important next step. A limitation of the current version of the MIST is that its tasks are not organized in a factorial way, i.e., with one task for every combination of levels of task factors such as duration or response type. This may be useful in future developments, although time-on-task effects and possible effects of sequence would appear to require caution in interpreting effects of task factors. The lack of a gold standard for PM is a limitation for establishing validity. A possible solution in future research could be to use additional PM measures, covering task performance, self-report measures, and observations. The lack of divergent validity must be noted: various cognitive deficits other than strictly PM deficits could result in low performance on the MIST, e.g., lack of sustained attention, reduced working memory, distractibility or impulsivity. Alternatively, such processes could be considered to be components of PM as a complex, compound function. These theoretical issues remain to be resolved and may have implications for assessment: is it desirable to have a measure for specific neurocognitive functions, or could complex functions actually be more relevant? The order of assessments was not randomized, which could have led to systematic effects influencing certain questionnaires due to order or time-on-task. Finally, the control group differed from the patient group on more factors than purely PM. Future research using a non-MCI patient group with more similar, e.g., MMSE scores would be of interest in more strictly testing the discriminative ability of the MIST.

Overall the results thus support the current Portuguese translation of the MIST as a similarly valid measure of PM as the English version. The scores were sensitive to differences between healthy older adults and individuals with MCI. Further, the current findings suggest various directions for future research and development of the MIST itself. Such research will hopefully ultimately help to better predict, treat and understand cognitive decline.

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# Declaration of interest (disclosure) statement

There were no conflicts of interest, but we disclose that one of the authors (Dr. Sarah Raskin) is the developer of the MIST, the test evaluated and explored in the current study.

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*Figure 1*. PM-i scores per task. White and black bars represent the scores in the MCI and control group, respectively.



*Figure 2*. PM-r scores per task. White and black bars represent the scores in the MCI and control group, respectively.



Table 1. Descriptive statistics

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | MCI group | Control group | Test |
| Age | 69.2 (9.2) | 66.3 (7.3) | *t*(79) = 1.58, *p* = .12, *d* = -0.35 |
| Gender | 26 female15 male | 23 female17 male | Chi2(1)= 0.10, *p* = .75 |
| Education | 1-4 years: 105–9 years: 6> 9 years: 25 | 1-4 years: 195–9 years: 6> 9 years: 15 | Chi2(2)= 5.28, *p* = .071 |
| MMSE | .94 (.06) | .97 (.03) | *t*(79) = -3.34, *p* = .0015, *d* = -0.75 \* |
| Cancellation | 5.39 (1.80) | 5.81 (1.48) | *t*(79) = -1.27, *p* = .21, *d* = -0.28 |
| LM-imm | .46 (.15) | .57 (.15) | *t*(79) = -3.47, *p* < .001, *d* = -0.78 \* |
| LM-del | .48 (.21) | .58 (.13) | *t*(79) = -2.70, *p* = .0087, *d* = -0.60 \* |
| TMTA | 61(30.49) | 53 (16) | *t*(79) = 2.21, *p* = .031, *d* = 0.50 \* |
| TMTB | 166 (82) | 131 (45) | *t*(79) = 2.27, *p* = .027, *d* = 0.54 \* |
| PRMQ-p | 11.32 (2.04) | 21.80 (5.13) | *t*(79) = -12.12, *p* < .001, *d* = -2.70 \* |
| PRMQ-r | 11.43 (2.93) | 20.22 (5.12) | *t*(79) = -9.52, *p* < .001, *d* = -2.13 \* |
| SMC | .52 (.16) | .11 (.07) | *t*(79) = 14.57, *p* < .001, *d* = 3.30 \* |
| GDS | .32 (.17) | .15 (.11) | *t*(79) = 5.84, *p* < .001, *d* = 1.32 \* |

*Note*. The Table shows means with standard deviations in parentheses, and test results for group comparisons between the MCI and control groups. The questionnaire abbreviations are the Mini Mental State Examination (MMSE), the Cancellation task of the Battery of Lisbon for the Evaluation of Dementia, the immediate (LM-imm) and delayed (LM-del) components of the Logical Memory test, the Trail Making Test A (TMTA) and B (TMTB), the prospective (PRMQ-p) and retrospective (PRMQ-r) scores of the Prospective and Retrospective Memory Questionnaire, the Subjective Memory Complaints scale (SMC) and the Geriatric Depression Scale (GDS).

Table 2. MIST performance

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | MCI group | Control group | Test |
| PM-i | 6.51 (4.25) | 9.48 (2.76) | *t*(79) = -3.73, *p* < .001, *d* = 0.83 \* |
| PM-r | 6.56 (1.47) | 7.08 (1.02) | *t*(79) = -1.83, *p* = .071, *d* = 0.41 |
| PM-d | 0.29 (0.46) | 0.80 (0.41) | *t*(79) = -5.27, *p* < .001, *d* = 1.18 \* |

*Note*. The Table shows means with standard deviations in parentheses, and test results for group comparisons between the MCI and control groups. The scores are the immediate prospective component (PM-i), retrospective component (PM-r), and delayed prospective component (PM-d) of the MIST assessment of PM.

Table 3. Correlations between MIST scores and questionnaires

3A. MCI group

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. PM\_i |   |   |   |   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 2. PM\_d | .14 |   |   |   |   |   |   |   |   |   |   |   |
|   | [-.18, .43] |   |   |   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 3. PM\_r | .59\*\* | .31 |   |   |   |   |   |   |   |   |   |   |
|   | [.35, .76] | [-.00, .56] |   |   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 4. LM\_imm | .35\* | .28 | .13 |   |   |   |   |   |   |   |   |   |
|   | [.04, .59] | [-.03, .54] | [-.18, .42] |   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 5. LM\_del | .23 | .15 | .11 | .72\*\* |   |   |   |   |   |   |   |   |
|   | [-.08, .50] | [-.17, .43] | [-.21, .40] | [.53, .84] |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 6. PRMQ\_p | .01 | -.31\* | -.02 | .13 | .08 |   |   |   |   |   |   |   |
|   | [-.30, .32] | [-.57, -.01] | [-.32, .29] | [-.19, .42] | [-.23, .38] |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 7. PRMQ\_r | -.06 | -.19 | -.19 | -.08 | -.14 | .62\*\* |   |   |   |   |   |   |
|   | [-.36, .25] | [-.47, .13] | [-.47, .12] | [-.37, .24] | [-.43, .18] | [.39, .78] |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 8. Cancellation | .72\*\* | .18 | .45\*\* | .29 | .30 | .04 | -.09 |   |   |   |   |   |
|   | [.53, .84] | [-.14, .46] | [.16, .66] | [-.02, .55] | [-.01, .56] | [-.27, .34] | [-.38, .23] |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 9. GDS | -.33\* | -.20 | -.30 | -.16 | -.21 | .25 | .38\* | -.33\* |   |   |   |   |
|   | [-.58, -.02] | [-.48, .12] | [-.56, .01] | [-.45, .15] | [-.49, .11] | [-.06, .52] | [.08, .62] | [-.58, -.02] |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 10. SMC | -.04 | .01 | .03 | .05 | -.08 | .58\*\* | .62\*\* | -.17 | .30 |   |   |   |
|   | [-.35, .27] | [-.30, .32] | [-.29, .33] | [-.27, .36] | [-.38, .24] | [.33, .76] | [.39, .78] | [-.46, .15] | [-.02, .56] |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 11. MMSE | .32\* | .15 | .07 | .53\*\* | .54\*\* | .09 | .03 | .21 | -.21 | .13 |   |   |
|   | [.02, .57] | [-.17, .43] | [-.24, .37] | [.26, .72] | [.27, .72] | [-.23, .38] | [-.28, .33] | [-.11, .48] | [-.49, .11] | [-.19, .42] |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 12. TMTA | -.44\*\* | -.05 | -.34\* | .00 | -.11 | -.09 | -.03 | -.53\*\* | .12 | -.03 | -.35\* |   |
|   | [-.66, -.15] | [-.35, .27] | [-.59, -.03] | [-.31, .31] | [-.40, .21] | [-.39, .23] | [-.34, .29] | [-.72, -.26] | [-.20, .42] | [-.34, .29] | [-.59, -.04] |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 13. TMTB | -.39\* | -.04 | -.09 | -.08 | -.22 | -.03 | -.03 | -.43\*\* | -.12 | -.02 | -.35\* | .79\*\* |
|   | [-.63, -.08] | [-.36, .29] | [-.40, .24] | [-.40, .25] | [-.51, .11] | [-.35, .29] | [-.35, .30] | [-.66, -.13] | [-.43, .21] | [-.35, .31] | [-.61, -.03] | [.63, .89] |
|   |   |   |   |   |   |   |   |   |   |   |   |   |

3B. Control group

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. PM\_i |   |   |   |   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 2. PM\_d | .29 |   |   |   |   |   |   |   |   |   |   |   |
|   | [-.02, .55] |   |   |   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 3. PM\_r | .56\*\* | .10 |   |   |   |   |   |   |   |   |   |   |
|   | [.30, .74] | [-.22, .40] |   |   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 4. LM\_imm | .20 | .10 | .16 |   |   |   |   |   |   |   |   |   |
|   | [-.12, .48] | [-.22, .40] | [-.16, .45] |   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 5. LM\_del | .25 | .12 | .14 | .78\*\* |   |   |   |   |   |   |   |   |
|   | [-.06, .52] | [-.20, .42] | [-.18, .43] | [.62, .88] |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 6. PRMQ\_p | -.08 | -.29 | .07 | -.15 | -.22 |   |   |   |   |   |   |   |
|   | [-.38, .24] | [-.55, .02] | [-.24, .38] | [-.44, .17] | [-.49, .10] |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 7. PRMQ\_r | .05 | -.25 | .07 | -.15 | -.05 | .43\*\* |   |   |   |   |   |   |
|   | [-.27, .36] | [-.52, .07] | [-.25, .37] | [-.44, .17] | [-.36, .26] | [.13, .65] |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 8. Cancellation | .42\*\* | .03 | -.03 | .17 | .04 | -.23 | -.19 |   |   |   |   |   |
|   | [.12, .64] | [-.29, .34] | [-.34, .29] | [-.15, .46] | [-.27, .35] | [-.51, .08] | [-.47, .13] |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 9. GDS | -.07 | -.42\*\* | .08 | -.36\* | -.28 | .07 | .39\* | -.16 |   |   |   |   |
|   | [-.37, .25] | [-.64, -.12] | [-.24, .38] | [-.60, -.05] | [-.54, .04] | [-.25, .37] | [.09, .62] | [-.45, .16] |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 10. SMC | .05 | -.31\* | .05 | -.35\* | -.12 | .44\*\* | .48\*\* | -.08 | .45\*\* |   |   |   |
|   | [-.26, .36] | [-.57, -.00] | [-.26, .36] | [-.59, -.04] | [-.41, .20] | [.15, .66] | [.19, .69] | [-.38, .24] | [.16, .67] |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 11. MMSE | .49\*\* | .51\*\* | .04 | .22 | .22 | -.24 | -.27 | .38\* | -.51\*\* | -.29 |   |   |
|   | [.21, .69] | [.23, .71] | [-.27, .35] | [-.10, .50] | [-.10, .49] | [-.51, .08] | [-.54, .04] | [.08, .62] | [-.71, -.23] | [-.55, .03] |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 12. TMTA | -.52\*\* | -.18 | -.24 | -.30 | -.18 | .21 | -.01 | -.49\*\* | .02 | -.04 | -.19 |   |
|   | [-.72, -.25] | [-.47, .14] | [-.51, .08] | [-.56, .01] | [-.46, .14] | [-.11, .49] | [-.32, .31] | [-.70, -.22] | [-.29, .33] | [-.35, .27] | [-.47, .13] |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |
| 13. TMTB | -.51\*\* | -.20 | -.16 | -.40\*\* | -.35\* | .25 | .12 | -.66\*\* | .19 | .13 | -.45\*\* | .63\*\* |
|   | [-.71, -.24] | [-.48, .12] | [-.45, .15] | [-.64, -.11] | [-.59, -.04] | [-.07, .52] | [-.20, .42] | [-.81, -.44] | [-.13, .48] | [-.19, .42] | [-.67, -.16] | [.39, .78] |
|   |   |   |   |   |   |   |   |   |   |   |   |   |

*Note*. The Tables shows correlations between MIST scores and questionnaires. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). \* indicates *p* < .05. \*\* indicates *p* < .01. The questionnaire abbreviations are the Mini Mental State Examination (MMSE), the Cancellation task of the Battery of Lisbon for the Evaluation of Dementia, the immediate (LM-imm) and delayed (LM-del) components of the Logical Memory test, the Trail Making Test A (TMTA) and B (TMTB), the prospective (PRMQ-p) and retrospective (PRMQ-r) scores of the Prospective and Retrospective Memory Questionnaire, the Subjective Memory Complaints scale (SMC) and the Geriatric Depression Scale (GDS).