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Characterization of Everyday Functioning in Mild Cognitive Impairment: A Direct Assessment Approach

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Key Words
Mild cognitive impairment · Activities of daily living · Naturalistic action · Alzheimer's disease

Abstract
Aims: To evaluate the degree and pattern of functional difficulties in mild cognitive impairment (MCI) via direct observation of everyday task performance. ***Methods:*** MCI (n = 25), mild Alzheimer's disease (AD; n = 25), and control (n = 18) participants performed three everyday tasks of increasing complexity. ***Results:*** Although caregivers reported no functional difficulties in MCI, direct observation measures of overall impairment and total errors showed MCI participants performed worse than controls, but better than AD participants, even on simple tasks. MCI and control participants exhibited significantly more difficulty performing steps accurately (i.e. commission errors) than completing task steps (i.e. omission errors), but AD participants showed an even distribution of commissions and omissions. ***Conclusions:*** Diagnostic criteria for MCI should specify mild functional deficits due to the inefficient and imprecise execution of task steps. Functional deficits characterized by omission of major task segments may indicate a diagnosis of dementia.

Introduction

The diagnostic criteria for mild cognitive impairment (MCI) have been controversial, particularly regarding whether functional difficulties should be considered a core feature of the syndrome. However, a consensus is gradually emerging on this topic, as most recent studies have concluded that mild difficulties on complex everyday tasks are common in MCI [1–3]. With the exception of one study [4], recent investigations have used self-/informant-reporting instruments to assess everyday functioning in MCI [5–10]. Ratings may be biased by informant characteristics [11–15], patients' specific pattern of action difficulties [16] and variability in individuals' daily routines. Moreover, most ratings simply denote the presence/absence of problems [17, 18]. Thus, direct observation of everyday task performance is necessary to confirm functional difficulties and to characterize the nature of these deficits, if present.

Griffith et al. [4] have reported the only study to directly examine everyday functioning in MCI using a standardized measure of financial abilities. Their findings revealed that (1) specific domains of performance were more impaired than others (e.g. checkbook management vs. transactions), (2) MCI and control participants

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differed on only the more complex financial tasks, and (3) MCI participants did not differ from controls in their financial *knowledge* but were not always capable of *applying* this knowledge to the task. The present study builds upon the work of Griffith et al. [4] by evaluating performance on everyday tasks (e.g. preparing toast and coffee) in people with MCI using the Naturalistic Action Test (NAT) [19, 20], a direct-observation measure that includes three tasks of increasing complexity and a comprehensive scoring method for quantifying and classifying errors.

Three hypotheses were tested: (1) MCI participants will demonstrate an intermediate level of impairment on everyday tasks relative to healthy controls and mild AD participants; (2) MCI participants' general performance pattern will suggest difficulties in efficiently applying preserved task knowledge to the smooth execution of everyday tasks, and (3) MCI participants will show functional difficulties relative to controls on only complex everyday tasks.

Methods

Participants

Twenty-five MCI and 25 mild AD participants were recruited from a memory assessment program that included a multidisciplinary clinical evaluation. Patient diagnoses were made at an interdisciplinary team conference based on established criteria [1, 2, 21] and clinical data. All MCI and AD participants underwent the same evaluation procedures, including a comprehensive neuropsychological assessment of language (Boston Naming Test [22] and Animal Fluency [23]), executive functioning (Mental Control [24] and Phonemic Fluency [25]) and episodic memory (Philadelphia Verbal Learning Test-Discriminability Index [26, 27]).

Individuals diagnosed with MCI reported a decline in cognitive functioning, obtained MMSE scores in the normal range ($\geq$25) [28], reported preserved activities of daily living (confirmed via informant report) [29], were not depressed (Geriatric Depression Scale $\leq$10) [30], demonstrated impairment in one or more domains of cognitive functioning (i.e. $\pm$1.5 SD from age/education matched normative M on aforementioned neuropsychological tests[1]) and did not meet criteria for dementia [21, 31].

Individuals diagnosed with AD exhibited mild dementia (MMSE = 18–27) and met the criteria for probable AD [21], including impairment in memory [26, 27] and one or more additional domains of cognitive functioning [22–25], progressive worsening of memory and other cognitive functions, and impaired activities of daily living [29].

[1] A cut score of $\pm$1.5 SD was arbitrarily selected for this study. The currently accepted criteria for MCI [1, 2] do not specify cut scores for determining 'impairment' on neuropsychological tests. The guidelines state only that $\pm$1.5 SD cut scores have been used frequently by investigators [1].

Eighteen healthy controls were recruited from the community. The controls did not undergo a formal clinical evaluation and were not administered neuropsychological tests. They were screened for dementia and other exclusion criteria via extensive clinical interview. All controls denied cognitive and functional difficulties and were living independently. Exclusion criteria for all participants included evidence of cortical stroke on neuroimaging/neurologic exam/medical record, insufficient attention to tolerate testing, and/or history of neurological illness (other than dementia for AD and MCI participants), long-standing psychiatric illness, or medical/systemic diseases that affect cognitive functioning.

Procedures

This project was approved by the IRB overseeing the outpatient program. All participants gave informed consent to be videotaped while they performed the NAT in the laboratory.

Naturalistic Action Test (NAT)

The NAT includes 3 items: (1) prepare toast with butter and jelly and prepare coffee with cream and sugar; (2) wrap a gift while salient distractor objects (e.g. garden shears, electric tape) are included on the tabletop, and (3) pack a lunchbox with a sandwich, snack, and a drink and pack a schoolbag with supplies for school while several necessary objects (e.g. thermos lids) are stored out of view in a drawer containing potentially distracting objects (spatula, thread, etc.). Item 3 has been shown to be more difficult than both items 1 and 2 for older adults and other populations [19, 20, 32]. The NAT has good psychometric properties [19, 20], even for adults over age 60 [17, 18, 32–36]. Studies have shown that NAT variables are not affected by education, gender, or motor difficulties [19, 20, 34, 35, 37, 38].

For this study, the following variables were collected from videotape of each participant's NAT performance:

NAT Score. Overall level of performance/impairment. This score combines the percentage of task steps completed with the sum of a subset of key errors that reliably distinguish neurological patients from healthy controls. A score ranging from 0 (accomplishment score $<$50% and 0 or more errors) to 6 (accomplishment score = 100% and $<$2 errors) is assigned to each NAT item and summed to equal the NAT score (range = 0–18). A cut score of 13 has been shown to reliably discriminate patients with mild dementia from controls [32]. If MCI participants show an intermediate level of everyday action impairment relative to controls and mild AD participants (hypothesis 1), then we predicted that NAT scores for MCI participants should be significantly lower than controls and significantly higher than AD participants.

Comprehensive Error Score. The total number of errors made on the NAT, including omissions and commissions (table 1). The total number of all errors was compared across groups. Additionally, commission errors were combined and analyzed as a separate error category from omissions and action additions, as prior studies have shown that these error types reflect dissociable constructs, with omission errors best predicted by general dementia severity and episodic memory impairment and commission errors predicted by executive dysfunction [16]. To evaluate the distribution of error types independent of error rate across groups, the proportion of each error category was calculated from the total number of errors (e.g. proportion omission = total omissions/total comprehensive error score). If MCI participants experience

Table 1. NAT comprehensive error score categories [19, 20]

	Error category	Definitions	Examples from toast and coffee (item 1) and present (item 2) tasks
	Omission	a step or subtask is not performed	does not add sugar to coffee
Commission*	Substitution	semantically related or perceptually similar alternate object used in place of target object	spreads butter on toast with spoon instead of knife
	Anticipation-omission	anticipation of a step which entails a subsequent omission (anticipation-omission), steps or subtasks are performed in reverse order (reversal)	applies butter on bread, without first toasting bread; applies jelly on bread, then applies butter
	Perseveration	a step or subtask is performed more than once; an action is performed repetitively or for an excessive amount of time	toasts multiple slices of bread
	Quality	task performance is grossly inadequate	pours too much cream into coffee so that the cup overflows
	Gesture substitution	correct object is used, but with an inappropriate gesture	grasps knife incorrectly
	Spatial misorientation	object is misoriented relative to the hand/body or another object	misorients wrapping paper with respect to the gift
	Spatial misestimation	the spatial relationship between objects is incorrect	cuts too small a piece of wrapping paper
	Tool omission	action is performed without a tool/implement	rips wrapping paper (i.e. does not use scissors)
	Action-addition	performance of an action not readily interpreted as a task step	eats toast; puts tape on garden shears

* Commission errors entail task steps that are performed inaccurately. However, in the case of commissions, the steps are easily identified as relevant to the task and necessary to achieve the task objective.

difficulties efficiently applying preserved task knowledge to the smooth execution of everyday tasks (hypothesis 2), then we predicted a Group × Error Type interaction, with MCI participants, unlike mild AD participants, showing a higher proportion of commissions than omissions. This error pattern would suggest that MCI participants possessed sufficient task knowledge to achieve the major task objectives, but failed to apply this knowledge in a direct and efficient manner. By contrast, we expected that mild AD patients would show both degraded task knowledge and inefficient task execution (i.e. a comparable distribution of omissions and commissions).

Finally, to compare error rates across NAT items, Standardized Error Scores were calculated based on the maximum number of errors possible on each item as enumerated in the test manual [19, 20]. If MCI participants experience difficulties on only complex tasks (hypothesis 3), then we predicted a Group × NAT item interaction, with MCI participants showing significantly higher error rates than controls on only item 3.

Data Analyses

The required statistical assumptions of analysis of variance (ANOVA) were not met, because the raw dependent variables were not normally distributed and were not easily transformed. Therefore, ANOVAs were performed using ranked data [39]. Post-hoc analyses of between-subject effects were performed using Bonferroni tests with the ranked data. Both M raw and M rank scores were reported below. Effect sizes were calculated for all post-hoc analyses. For small samples, the power efficiency of nonparametric analyses is nearly 95 percent of the t test [40]; therefore, effect sizes were estimated using Cohen's d calculations (0.2 = small; 0.5 = medium; 0.8 = large) [41].

Demographic and Neuropsychological Variables

As shown in table 2, the groups did not differ in age or gender distribution. MCI participants did not differ from the other groups on education. Controls had significantly more years of education than AD participants. However, numerous prior studies have shown that the NAT scores are unrelated to education level [19, 20, 34, 35, 37, 38]. Moreover, significant group differences between AD and controls have been documented [32, 34, 42] and are not the focus of this paper. Therefore, the 1- to 2-year difference in education between AD and controls was considered inconsequential for subsequent analyses. As expected, MCI participants did not differ from controls on MMSE, but both MCI and control participants obtained higher MMSE scores than AD participants.

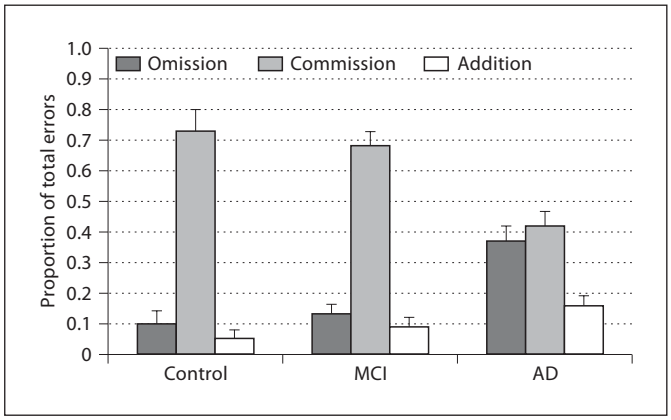

Fig. 1. Mean proportion of each error category from total errors for control, MCI, and AD groups. Error bars reflect +1 SEM. For each participant, proportion scores are calculated by dividing the number of errors from a specific category by the total number of errors across all categories. Note that group differences in mean total errors (i.e. comprehensive error score) showed controls < MCI < mild AD (table 2).

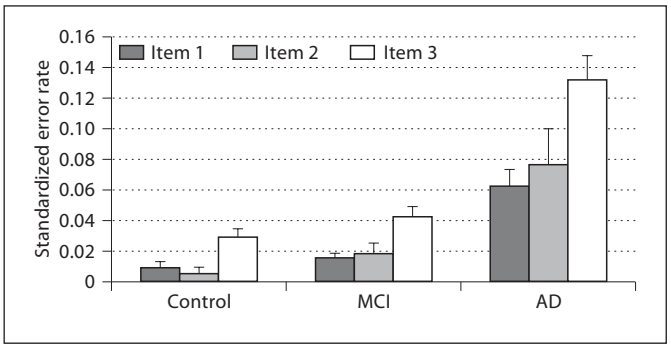

Fig. 2. Standardized error rates for each group (control, MCI, AD) and NAT item are shown. Error bars reflect +1 SEM. For each participant, the standardized error rate is calculated by dividing the total number of errors made on each item by the number of possible errors for each item.

Table 2. Demographic characteristics of the groups and means, standard deviations, and between-group analyses for NAT variables

	Control (n = 18)		MCI (n = 25)		AD (n = 25)		ANOVA		Group differences
	mean	SD	mean	SD	mean	SD	F	d.f.	
Demographic variables									
Age	73.1	3.2	72.2	6.7	73.6	3.8	0.51	2, 65	n.s.
Education	13.7	3.2	12.4	1.4	12.0	1.4	4.1*	2, 65	control > AD
MMSE	28.5	1	27.6	1.4	22.4	2.8	45.7**	2, 65	(MCI = control) > AD
Sex (% women)	72		64		80		$\chi^2 = 1.7$		n.s.
NAT variables									
NAT Score	17.5	0.7	15.6	2.3	10.4	4.5	37.5**	2, 65	AD < MCI < controls
Comprehensive error score	2.7	2.2	4.5	2.6	15.1	8	53.6**	2, 65	AD < MCI < controls

n.s. = Nonsignificant; * $p < 0.05$; ** $p < 0.01$.

Hypothesis 1: Overall Impairment

Consistent with our prediction, the NAT Score, which reflects overall impairment, differed significantly across the three groups (M ranks: control = 52.5; MCI = 38.7; AD = 17.3; table 2). Post-hoc analyses showed that the controls performed significantly better than the MCI ($p < 0.01$, $d = 1.2$) and AD ($p < 0.01$, $d = 2.7$) groups; the MCI group performed significantly better than the AD group ($p < 0.01$, $d = 1.5$). None of the controls, 24% of the MCI group, and 76% of the AD group fell within the impaired range according to cut scores established for healthy older adults [32].

Table 2 also shows that controls committed significantly fewer total errors than the MCI ($p = 0.01$, $d = 0.70$) and AD ($p < 0.01$, $d = 2.4$) groups. MCI participants made significantly fewer errors than AD participants ($p < 0.01$, $d = 2.0$; comprehensive error score M ranks: control = 16.9; MCI = 27.7; AD = 53.9).

Hypothesis 2: Error Patterns

A Group (control, MCI, AD) × Error Type (omission, addition, commission) mixed ANOVA showed significant main effects of Group [$F(2, 64) = 10.82$, $p < 0.01$] and Error Type [$F(2, 64) = 96.47$, $p < 0.01$], as well as a significant Group × Error Type interaction [$F(4, 130) = 6.75$, $p < 0.01$]. As shown in figure 1, error type proportions were quite similar between controls and MCI participants, whereas AD participants demonstrated a very different distribution of errors. As predicted, follow-up within group analyses showed MCI participants obtained a significantly higher proportion commission than proportion omission ($p < 0.01$; $d = 2.77$); this difference also was observed for controls ($p < 0.01$, $d = 2.63$), but not for AD participants ($p = 0.79$). For controls and MCI participants, proportion commissions was higher than proportion additions ($p < 0.01$, $d > 3.10$ for both), but there was no

difference between proportion omissions and proportion additions ($p > 0.29$ for both). By contrast, for AD participants both proportion commissions and proportion omissions were significantly higher than proportion additions ($p < 0.01$, $d > 1.05$ for both).

Follow-up between group analyses were performed using one-way ANOVAs. Results showed significant group effects for the 3 major error types [proportion omissions M ranks: control = 25.2, MCI = 28.7, AD = 47.1; $F(2, 65) = 12.0$, $p < 0.001$; proportion commissions M ranks: controls = 44.3, MCI = 40.6, AD = 21.3; $F(2, 65) = 12.1$, $p < 0.001$; proportion additions M ranks: controls = 25.4, MCI = 32.2, AD = 43.3; $F(2, 65) = 6.4$, $p < 0.001$]. As shown in figure 1, post-hoc analyses showed no significant differences in error types between controls and MCI participants ($p > 0.58$, $d < 0.28$ for all). MCI and control participants obtained a significantly higher proportion commissions and significantly lower proportion omissions than AD participants ($p < 0.01$, $d > 1.2$ for all). Controls showed significantly higher proportion additions than AD participants ($p < 0.01$, $d = 0.79$), but the difference between MCI and AD participants just missed significance ($p = 0.06$, $d = 0.47$).

Hypothesis 3: Differences across NAT Items

Mean standardized error scores across group and NAT item are shown in figure 2. The Item × Group ANOVA revealed significant main effects of group [$F(2, 65) = 33.0$, $p < 0.01$] and Item [$F(2, 64) = 32.1$, $p < 0.01$]; however, the Item × Group interaction was not statistically significant [$F(4, 130) = 0.21$, $p = 0.93$]. The between group differences are shown in table 2. Consistent with past studies [19, 20, 32], within-group analyses (including all groups combined; M ranks: item 1 = 90.3, item 2 = 82.5, item 3 = 134.7) showed error rates were significantly higher for item 3 than both item 1 and item 2 ($z > 5.3$, $p < 0.01$ for both). Items 1 and 2 did not differ ($z = 1.12$, $p = 0.26$).

Discussion

Performance on a series of everyday tasks was compared across MCI, mild AD, and control groups, and three hypotheses were evaluated. First, as predicted, MCI participants demonstrated an intermediate level of overall impairment and total errors relative to controls and mild AD participants. Second, as predicted, MCI participants demonstrated a pattern of errors suggestive of preserved task knowledge with difficulties applying task knowledge to the efficient execution of everyday tasks [4]. More specifically, MCI participants and controls demonstrated a significantly higher proportion of commissions than omissions, whereas AD participants showed an even distribution of commission and omission errors. Third, contrary to prediction, MCI participants did not differ from controls on only the most complex everyday tasks; rather, MCI participants obtained more errors than controls on all NAT tasks, even relatively simple and common activities.

In contrast to studies that have relied on caregiver reports, our findings suggest that participants with MCI may show mild functional difficulties, even on relatively simple tasks. This has implications for the diagnostic criteria of MCI [1–3, 43]; specifically, mild difficulties on simple everyday tasks should not rule out a diagnosis of MCI. However, this conclusion must be qualified based on our detailed error analysis. That is, mild functional deficits in MCI should be characterized by inefficient task execution, poorly sequenced task steps, and inaccurate object selection (i.e. commissions). Functional difficulties in MCI generally do not preclude accomplishment of the primary task goals (i.e. omissions). Thus, reports or observations of omission of major everyday task segments might exclude a diagnosis of MCI.

Prior work from our laboratory has shown that among individuals with dementia, informant reports of functional abilities were significantly related to omission errors but not commission errors [16]. This suggests that caregivers may be unaware of or minimize commission errors; alternatively, informant ratings may be insensitive to commission errors in everyday functioning. Direct observation of everyday task performance is ideal to assess error patterns, but often it is not feasible. Thus, in lieu of direct observation, we suggest that clinicians query caregivers on the quality of patients' everyday action performance using direct and specific questions regarding omission and commission errors [8].

In addition to informing diagnoses, knowledge of functional performance patterns may be useful in educating patients and their family members so that informed intervention strategies may be implemented in the home. For example, the commission error pattern observed in MCI suggests that these patients may benefit from extra time to complete tasks, a clutter-free workspace, and so on [33]. In fact, the functional deficits observed in MCI were similar to those that are often targeted in cognitive training programs, such as goal management therapy [44, 45], a program designed to increase cognitive control over everyday action performance. Levine et al. [45] have shown that this type of training improves performance of complex everyday tasks in healthy older adults. Future studies should explore the efficacy of goal management therapy and related interventions for improving everyday functioning and preventing further functional decline in MCI.

Our results also have implications regarding the neurocognitive substrates of everyday action performance. Based on our prior research [16, 46], we speculate that the high proportion of commission errors in MCI may be

secondary to mild executive deficits consequent to prefrontal cortical disruption [47] or subcortical white matter alterations [48]. Among mild AD participants, the high proportion of omission errors may be caused by episodic and semantic memory deficits associated with the medial temporal, hippocampal, and posterior cortical atrophy characteristic of this disease [49]. Such declarative memory deficits may degrade everyday task knowledge; without sufficient representation of the task objects, steps, and goals, critical task components may be omitted. Alternatively, others have suggested that task omissions, as observed in AD, are best explained by moderate to severe limitations of general cognitive resources associated with any form of brain damage/disease [37, 38]. On this account, resource limitations preclude patients from resolving competition among multiple possible actions such that no action ever achieves threshold activation for execution [37]. However, these conclusions remain speculative; further study is needed before definitive links may be made between specific functional deficits and their neurological substrates.

We acknowledge that our sample size was small; the power to detect small effects between the MCI and control groups was markedly lower than the suggested 0.80. Therefore, we may have missed significant, but small, group differences. Another limitation of this study is that all MCI participants expressed subjective complaints of memory abilities and were recruited from a clinic sample. Therefore, the results may not generalize to MCI participants without subjective memory complaints or MCI participants recruited from community samples. Additionally, controls were screened only via interview; without a formal evaluation, we cannot absolutely rule out subtle cognitive changes/difficulties. Finally, this study included a heterogeneous group of MCI participants, with 40% of the sample (n = 10) diagnosed with amnestic MCI (16% single domain; 24% multiple domain) and 60% of the sample (n = 15) diagnosed with nonamnestic MCI (28% single domain; 32% multiple domain [1, 2]). Our relatively small sample made it unfeasible to reliably examine differences between MCI subtypes, but future studies should explore differences in everyday action between these subtypes and between stable/improving versus progressive MCI subgroups.

These limitations notwithstanding, our results add to the accumulating evidence for everyday action difficulties in MCI. Our findings expand the existing literature by suggesting that everyday action difficulties in MCI differ in both degree and kind from the functional difficulties in dementia. Further study is needed to replicate these findings and determine whether interventions and recommendations based on these conclusions are effective for stalling the debilitating functional deficits associated with AD and other dementias.

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