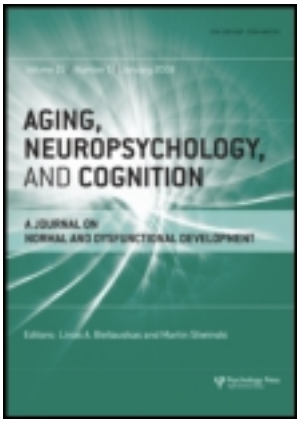

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Executive Functioning in Older Adults with Mild Cognitive Impairment: MCI Has Effects on Planning, But Not on Inhibition

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Executive Functioning in Older Adults with Mild Cognitive Impairment: MCI Has Effects on Planning, But Not on Inhibition

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ABSTRACT

In this study, we compared executive functioning in 32 mild cognitive impairment (MCI) individuals with that of normally aging controls. Cognitive planning tests (Trail Making, Porteus Maze Test, verbal fluency tests) show a group difference favoring the normal controls, but tests for inhibition of prepotent responses (no-go accuracy, two measures of the Stroop effect, and negative priming) failed to uncover a significant group difference. The results indicate that there is no general executive control function impairment in MCI; rather, the deficits found are compatible with the hypothesis that MCI is an accelerated form of normal aging.

Mild cognitive impairment (MCI) refers to a clinical condition in which persons experience a memory loss greater than expected on the basis of their chronological age, yet not severe enough to meet currently accepted criteria for clinically probable Alzheimer's disease (AD; Petersen et al., 2001). Mild cognitive impairment may literally be a transitional state between normal aging and AD; that is, when people with MCI are observed longitudinally, they progress to clinically probable AD at a considerably accelerated rate compared with healthy age-matched individuals. In one 4-year longitudinal study, the conversion rate from MCI to AD was 12% per year, compared to a conversion rate of only 1–2% from normal functioning to either MCI or AD

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(Petersen et al., 1999). Hence, MCI is believed to be a high-risk condition for the development of clinically probable AD.

The generally accepted diagnostic criteria of MCI, as defined by Petersen et al. (1999), are as follows:

1. memory complaint,
2. normal activities of daily living,
3. normal general cognitive function,
4. abnormal memory performance compared to for age,
5. no dementia.

Although a specific syndrome of memory loss coupled with relative preservation of other cognitive functions, some recent studies have demonstrated that MCI individuals also show relative weaknesses in other areas of cognition. Some of these studies suggest that MCI individuals might have deficits in executive functioning in addition to the expected episodic memory deficit (e.g., Chen et al., 2000; Crowell et al., 2002; Daly et al., 2000; Griffith et al., 2003; Perry et al., 2000; Ready et al., 2003; Wang et al., 2002, 2003; Xiao et al., 2002). Even more importantly, executive functioning might be a potential marker of conversion to AD, as indicated in two longitudinal studies using the Trail Making Test B (Chen et al., 2000; Daly et al., 2000).

A question that is still open is whether all aspects of executive control are equally vulnerable to MCI. Executive control obviously has many guises; we concentrate here on two key aspects, namely, planning and inhibition of prepotent responses. Planning is the foundation of goal-directed behavior. Planning ability is usually seen as a required and even essential feature of intelligent systems (Wezel & Jorna, 2002). Likewise, inhibition of prepotent responses (e.g., Friedman & Miyake, 2004), the ability to deliberately override dominant or automatic responses in favor of the task at hand, is a necessary precondition for goal-oriented behavior. Apart from their obvious importance in attentional control, an additional reason to investigate precisely these two domains of executive control, is that they appear to be differentially sensitive to age. A series of meta-analyses have shown that tests purporting to measure inhibition, such as negative priming and the Stroop color-word test are not sensitive to aging if age-related slowing in the baseline conditions is taken into account (Verhaeghen & De Meersman, 1998a, 1998b), whereas tests purporting to measure planning, such as the Wisconsin Card Sorting Test (Rhodes, 2004), appear to show a marked age-related decline; verbal fluency appears to decline with age as well (e.g., Salthouse, 1993; Singer et al., 2003).

Our study, then, was set up to investigate differential MCI effects on measures of planning (Trail Making, the Porteus Maze test, and Verbal Fluency) and inhibition of prepotent responses (a Go/No-Go test, the Stroop

color-word test, and a Stroop version of negative priming). A number of outcomes are possible. First, if the MCI state is indeed well described by explicit episodic memory deficits only, we might expect that MCI individuals and normally aging controls would not differ with regard to their performance on the two types of executive control. Given the studies cited above, this outcome is unlikely. Second, if the MCI state is, as is sometimes claimed, simply an indicator of an accelerated but otherwise normal aging process, we would expect that MCI individuals would score lower than normally aging controls on tests of planning, but at equivalent levels on tests of inhibition of prepotent responses. Third, any other pattern of MCI-related deficits would suggest that MCI is a particular state that is quite distinct from normal or accelerated aging. To our knowledge, this question of differential effects of MCI on distinct domains of executive functioning has not been answered before.

METHODS

Participants

Participants were recruited from a nursing home, a social welfare institute, and residential communities in Beijing. Memory functioning of potential participants was screened by means of the Clinical Memory Scale (CMS, Xu & Wu, 1986). Potential participants who fit the criteria to be included in either the normally aging control (NC) group or mild cognitive impairment (MCI) group received a comprehensive evaluation, including a neuropsychological and psychiatric examination; this process continued until 32 participants were identified for either group. All participants were native speakers and writers of Mandarin.

The diagnosis of MCI was based on Petersen's (1999) criteria. Petersen defined the cut-off for memory scores generally at 1.5 SD below the norm for age and education-matched control subjects. We decided to use a more liberal criterion of 1 SD below the norm, following the suggestion by Crowell et al. (2002) that the traditional 1.5 SD cutoff would limit the likelihood of detecting the early stages of memory impairment. We operationalized these criteria as follows:

a. self-reported or other reported memory decline;

b. ADL < 26 (21 items version) (Zhang et al., 1991);

c. MMSE ≥ 24 (Zhang et al., 1991);

d. a score on the Directed Memory and Free Recall for Pictures subtests of the Clinical Memory Scale of 1 SD or more below the age- and education-appropriate norm;

e. no self-reported diagnosis of dementia or neurological pathology, no history of head surgery, no depression, no anti-depression, or other psychopharmacological medication.

TABLE 1. Means and Standard Deviations of Selected Characteristics for MCI Individuals and Normal Controls, Along with Results of a T-Test for Group Differences

	NC Group			MCI Group			
	n	*M*	*SD*	*n*	*M*	*SD*	*t*
Age	32	73.5	8.5	32	73.7	8.2	–0.06
Year of education	32	12.1	3.5	32	10.7	2.9	1.66
MMSE	32	28.7	1.8	32	27.4	2.0	2.72*
ADL	24	20.5	1.0	24	20.9	1.5	–1.16
GDS	24	2.1	0.9	24	2.9	0.4	–3.93*
Directed memory	24	24.2	4.3	24	15.5	4.4	6.90*
Free recall of picture	24	26.1	3.4	24	14.5	6.2	8.12*

MCI = mild cognitive impairment; NC = normal controls.
*$p < 0.05$.

Selected participant characteristics are reported in Table 1. Due to a clerical error, some of the data of 16 of our participants (8 in each group) were misplaced and subsequently lost, more specifically the data concerning ADL, the Geriatric Depression Scale, directed memory, and free recall. There were no significant differences between the two groups with regard to age, years of education, or ADL scores. There was a significant difference in Geriatric Depression Scale scores (NC participants were less dysphoric). There was also a significant difference in MMSE scores, with MCI participants scoring lower. The effect for MMSE was smaller (mean standardized difference, *MSD* = 0.65) than the effects of the two subscales of the Clinical Memory Scale (*MSD* = 1.93 for Directed Memory and *MSD* = 2.37 for Free Recall of Pictures).

Measures

Clinical Memory Scale

We used the clinical memory scale (CMS) (Clinical Memory Scale Cooperative, 1984) to asses MCI status. The CMS was designed by a group of researchers from the Institute of Psychology at the Chinese Academy of Science, in collaboration with 35 other institutes throughout the People's Republic of China. The norm group consisted of a literate sample of 2,161 subjects and an illiterate sample of 1,149 subjects, with an age range from 20 to 89. The CMS has two parallel forms—A and B; the correlation between the two is .85, indicating excellent reliability. The CMS consists of five subtests: directed memory, paired-association learning, free recall of pictures, recognition of meaningless figures, and associative recall; for time reasons, we only included directed memory and free recall of pictures from Form A in our assessment. These two tests are considered to be most sensitive to MCI.

In the *directed memory* subtest, the participant listens to a recording of two lists of 24 words presented at a pace of 1 s/word with a 2-s unfilled interval between words. The list of 24 words contains a set of 12 words of the same category (fruits for the first list, animals for the second), randomly interspersed with 12 distractor words. The subjects were asked to recall the 12 words in the same category in each group. Recall followed immediately after each list.

For the *free recall of pictures* test, two sets of 15 pictures are shown. Each picture in each set denotes a common object (e.g., bike, knife). Pictures were shown one at a time, at a rate of 4 s/picture with a 2-s unfilled interval between pictures. An immediate recall test with verbal responses followed presentation of each list.

Measures of Executive Control

Measures of executive control included three tests of planning (Trail Making, Porteus Maze test, and Verbal Fluency), and three tests of inhibition of prepotent responses (Go/No-Go test, the Stroop color-word test, and a Stroop version of negative priming) (see Lezak et al. (2004) and Friedman and Miyake (2004) for precedents in categorizing these tests).

We included a Chinese adaptation of the *Trail Making Test*. The Trail Making Test consists of two parts—A and B. In Trail Making Test A, participants are given a sheet of paper containing 25 circles, each containing a different Arabic numeral between 1 and 25 in random order. The participant is required to link the circles according to their numerical sequence. In Trail Making Test B, each of the 25 circles now contains either one of the first 13 Arabic numerals or one of the first 12 Chinese numerals. Participants are required to again link the circles in numerical sequence, interspersing Arabic numerals with Chinese numerals (i.e., 1,·一, ·2,·二, etc.); the last link is from the 十二 (Chinese numeral twelve) to the 13. The experimenter recorded the time for each version using a stop-watch. A planning score is typically derived by subtracting the time needed for Trail Making A from the time needed for Trail Making B.

In the *Porteus Maze Test* (Porteus, 1965), the participant works her way through a series of 10 mazes, each printed on a separate piece of paper. The mazes are ordered in a sequence of increasing difficulty. The participants are required to draw a consistent line from the entrance of the maze to its exit; the pencil should not leave the paper during the test. If a mistake is made on the first attempt, participants are given a second attempt. The test score reflects accuracy, and takes the number of attempts for each maze into account.

We included two versions of a *verbal fluency test*. In the first test, participants were required to name as many fruits as they could in 1 minute. In

the second, participants named as many animals as they could in 1 minute, with the restriction that the animals could not have two legs. The score was the total number of correct responses for each version.

In our version of the *Go/No-Go* test, participants were presented with 108 one-character color words, one at a time, on a computer screen. The words denoted the colors red and green, and they were presented in either red, green, or blue. The participant was required to name the color the word was presented in, except when this color was blue, in which case the participant was asked to remain silent. The 108 words were arranged randomly and separated into three blocks. Participants were allowed to take a short break between blocks. There were three conditions: a baseline condition in which the color of the word matched its meaning; a no-go condition, in which some of the words were presented in blue; and a Stroop interference condition, in which the word and its color did not match. We derived two scores from this test, both reflecting inhibition: a *go/no-go* score, that is, the number of errors on the no-go trials, and a *Stroop interference* score, that is, the RT difference between the Stroop interference condition and the baseline condition.

In our version of the *word-color naming task* (Jin et al., 2002), participants were shown one-character color words denoting the colors yellow, green, red, or blue, presented in either yellow, green, red, or blue on a computer screen, one at a time. There were four blocked conditions, each containing 18 trials: (a) a baseline condition in which the color of the word matched its meaning; (b) a Stroop interference condition, in which the word and its color did not match; (c) a repeated-distractor condition, in which the same color word was repeated throughout (data from this condition were not analyzed in the present study); and (d) a negative priming condition identical to the Stroop condition, except that the presentation color of the current trial matched the color word presented at the previous trial, or, in other words, distractors became targets on the subsequent trial. Order of presentation of conditions was balanced using a Latin-square design. We derived two scores from this test, both reflecting inhibition: a *Stroop interference* score, that is, the RT difference between the Stroop interference condition and the baseline condition, and a *negative priming* score, that is, the difference between the negative priming condition and the Stroop condition. It should be noted that smaller negative priming scores denote lower levels of inhibition, that is, participants who are more able to suppress activation for the distractors will be slowed down more than participants who do not suppress activation of the distractors well.

Procedure

Memory functioning was evaluated individually by trained research assistants from the Institute of Psychology at the Chinese Academy of

Science. The Trail Making Test, the Porteus Maze Test, and the verbal fluency test were administered in a paper and pencil format. The go/no-go and word-color naming tests were administered on a Pentium-PC. Reaction times were recorded by the E-prime serial response box. Stimuli disappeared immediately after each response; response-stimulus intervals were 200 ms. If no response was given within 3000 ms, the trial was considered void, and the next stimulus was presented. Participants were tested individually in a quiet testing room. Participants were allowed to individually optimize their viewing distance from the screen. As a consequence, visual angle of the stimuli differed across participants. All characters were projected at the center of a black screen; the width and the height of each character was 6 cm. The order of the tests was not fixed with the exception that the word-color naming task was always administered before the go/no-go test. The whole experiment lasted about 40 min.

Statistical Testing

Because our hypotheses are directional (i.e., the scores of the MCI group are always expected to be lower than those of the NC group), all tests were one-tailed. Alpha level for statistical significance was set at .05.

RESULTS

Group Differences in Executive Control at the Level of Individual Tests

Table 2 presents descriptive statistics on each of the individual executive control measures for each of the two groups as well as results from *t*-tests for group differences . The *t*-tests revealed that all cognitive planning tests (Trail Making, Porteus Maze Test, verbal fluency tests) show group differences favoring the normal controls, and all inhibition tests (no-go accuracy, the two measures of the Stroop effect, and negative priming) fail to uncover a significant group difference. (A ceiling effect in the no-go accuracy might have limited our ability to detect group differences in that measure.)

One potential problem with the results is that we used the standard procedure of deriving difference scores for Trail Making, the two Stroop measures, and negative priming, that is, a simple difference score. Simple difference scores for timed measures may not be the most appropriate measure when investigating group differences (e.g., Cerella, 1990; Faust et al., 1999; Verhaeghen & De Meersman, 1998a, 1998b). We therefore resorted to a different technique, advocated by Cronbach and Furby (1970) and Embretson (1987), namely, to regress the critical condition on the baseline condition, and use the residuals as markers for executive control. These residual scores then indicate to what extent an individual's score on Trail Making B, the Stroop interference condition, or the negative priming condition is larger or

TABLE 2. Means and Standard Deviations of the Executive Control Tests, Along with Results of a T-Test for Group Differences

	NC Group			MCI Group				
Measure	*n*	*M*	*SD*	*n*	*M*	*SD*	*t*	*t* for Residuals
Planning								
Trail Making (B- A) (*s*)	29	43.8	39.3	29	67.5	46.1	−2.11*	−1.83*
Porteus Maze test	30	15.1	2.2	30	11.8	2.5	5.32*	
Verbal fluency (fruits)	30	14.4	2.2	30	11.6	2.3	4.92*	
Verbal fluency (animals)	30	15.3	2.6	30	12.5	3.3	3.62*	
Inhibition								
Go/no-go								
Accuracy (%)	30	98.3	3.9	30	97.7	5.1	0.97	
Stroop effect (*ms*)	30	185	137	30	178	89	0.24	0.59
Word-color naming								
Stroop effect (*ms*)	30	254	125	30	272	130	−0.55	−0.54
Negative priming (*ms*)	30	8	117	30	11	116	−0.10	−0.49

MCI = mild cognitive impairment; NC = normal controls.
*$p < 0.05$.

smaller than predicted from the individual's baseline scores on these tests. Figure 1 shows the scatterplots. The results of the *t*-test for the group difference using residuals for the four tests are reported in the last column of Table 2. As can be seen, the pattern of results remains the same: a significant group difference in the Trail Making planning score and no group difference in any of the three inhibition scores (the two Stroop measures and negative inhibition).

Confirmatory Factor Analysis

To test whether our set of measures for executive control indeed contained two separable factors, we conducted a confirmatory factor analysis on the variance-covariance matrix using LISREL 8.0. In this analysis (see Figure 2), we constructed two latent factors. Because the results from the residual scores and the difference scores are quasi-identical, we used difference scores rather than residual scores where applicable. The first latent factor represented planning, and consisted of the difference score for Trail Making B-A, the overall score for the Porteus Maze test, and the two verbal fluency tests. The second latent factor represented inhibition, and consisted of the two Stroop interference scores (i.e., the difference between RT on the interference condition and the baseline condition in both go/no-go test and the word-color naming test), the negative priming score (i.e., the difference between RT on the interference condition and the negative priming condition), and the accuracy on the no-go trails of the go/no-go test. In accordance with principles outlined in Schmiedek and Li (2004), MCI status was

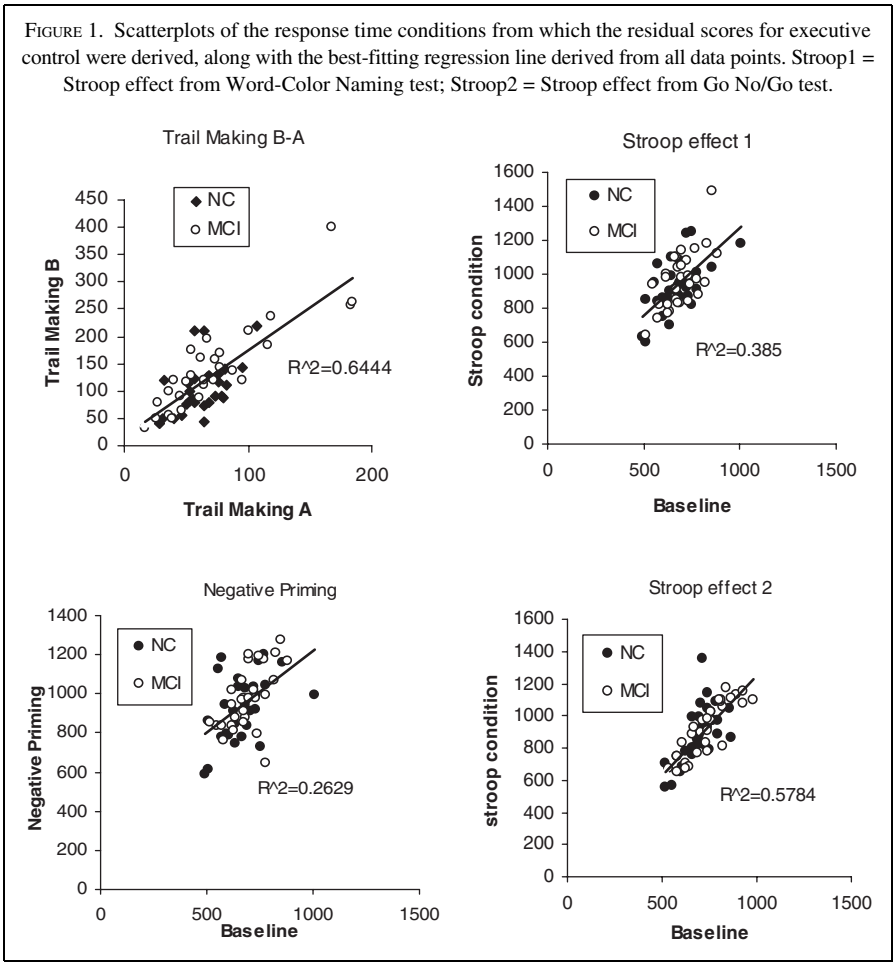
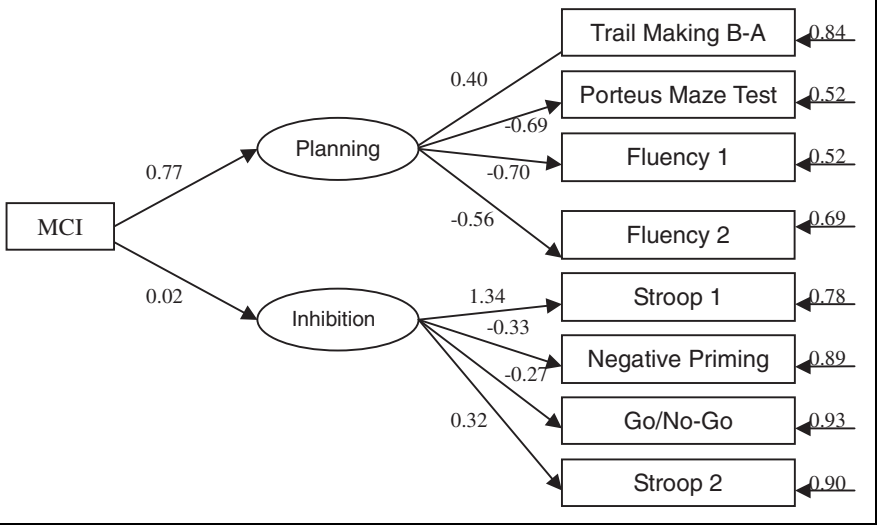


FIGURE 1. Scatterplots of the response time conditions from which the residual scores for executive control were derived, along with the best-fitting regression line derived from all data points. Stroop1 = Stroop effect from Word-Color Naming test; Stroop2 = Stroop effect from Go No/Go test.

included in the model to explicitly remove its effects on the intercorrelations of the latent and observed variables. This model fit the data well, chi-square ($N = 54$, $df = 26$) = 29.24, $p = .30$, $RMSEA = 0.049$, $GFI = .89$, and $AGFI = .81$. In the model, MCI had a significant effect on planning (a point-biserial correlation of .77), but not on inhibition (a point-biserial correlation of .02). The two-factor model fit significantly better than a one-factor model (Δ chi-square ($N = 54$, $df = 1$) = 29.58). Note that because the two factors are correlated, the loadings are regression coefficients and not correlations, and hence can be larger than 1 or smaller than −1.

Modification indices for the final model indicated that none of the tests showed any significant cross-loadings on the other factor. A model with a separate third factor for fluency was also tested, but this did not result in increased fit (Δ chi-square ($N = 54$, $df = 1$) = 2.56).

FIGURE 2. Results of a confirmatory factor analysis of the executive control tasks. Fluency 1 = Verbal Fluency Test (Fruits), Fluency 2 = Verbal Fluency Test (Animals), Stroop1 = Stroop effect from Word-Color Naming test, Go/No-Go = accuracy of the No/Go trails, Stroop2 = Stroop effect from Go No/Go test. Model fit is good: chi-square (N = 54, df = 26) = 29.24, p = .30, $RMSEA$ = 0.049, GFI = .89, $AGFI$ = .81.



DISCUSSION

Our study was set up to answer the question whether the deficits in executive control claimed to exist in MCI are general or domain-specific. In particular, we examined whether planning and inhibition exhibit the same degree of impairment.

The results are clear. Factor analysis indicated that two factors could be distinguished in our tests: planning (Trail Making, Porteus Maze Test, verbal fluency) and inhibition (no/no-go accuracy, the two measures of the Stroop effect, and negative priming). The results showed a significant difference between age-matched controls and individuals suffering from MCI on planning, but not on inhibition. This was true whether we looked at the level of individual tests or at the level of the latent factors.

This result has implications for our interpretation of MCI status. The pattern of results obtained here echoes data on the effects of normal aging on executive control (for an overview, see, e.g., Verhaeghen et al., 2005), that is, tasks involving planning, such as the Wisconsin Card Sort Test, verbal fluency, dual-task performance, and global task-switching, are age-sensitive, whereas tasks that measure inhibition, such as negative priming and Stroop, are not age-sensitive. Our results then suggest that MCI (a) is not a state of normal aging described by explicit episodic memory deficits only; and (b) is

not a state that is radically different from normal aging, for instance, in that it would show across-the-board deficits in executive control. Rather, the present set of results suggests that the MCI state may well be an indicator of an accelerated but otherwise normal aging process.

Are the results compatible with the idea that MCI represents a transitional state between normal cognitive aging and AD? First, the finding of a planning deficit is consistent with previous studies. Daly et al. (2000) found that AD patients developed from questionable AD have significantly worse planning abilities, as measured by Trail Making Test B, a self-ordering test and judgment and problem-solving tasks, and a survey of hobbies and activities performed in the home. Four-year longitudinal results from the Berlin Aging study (BASE) provide additional evidence (Rapp & Reischies, 2005). The authors examined the predictive value of attention and executive function in the preclinical phase of AD. They found that tests of attention and executive function (Digit Letter Test, Trail Making Part B Test, Digit Symbol Substitution Test, and Identical Pictures Test), together with tests of learning and recall, discriminated best between nonconverters and incident AD cases. DeCarli et al. (2004) reported that baseline memory and executive performance significantly predicted the likelihood that MCI individuals develop dementia. Their executive function scale included four tests: the backwards digit-span and backwards visual memory span from the Wechsler Memory Scale–Revised, FAS letter fluency, and the initiation–perseveration subtest of DRS—the latter two being tests of planning.

Second, our finding of preserved inhibition is at odds with the literature on inhibition deficits in minimal AD, mild AD, or AD. In a meta-analysis, Amieva et al. (2004) found that Alzheimer's disease has a strong effect on tasks requiring controlled inhibition processes, such as the Stroop task and negative priming. However, the presence of the disease appears to have relatively little effect on tasks requiring more automatic inhibition, such as the inhibition of return task, suggesting that inhibitory deficits in Alzheimer's disease may not be the result of a general inhibitory breakdown. Obviously, the tasks measuring inhibition in the present study require controlled inhibition processes. Replication of the present results is obviously necessary, but the discrepancy between the present findings and the results from AD studies suggests one diagnostic criterion for distinguishing MCI from the early stages of AD: compared to normally aging controls, MCI spares inhibition, AD does not. This finding is useful because most of the previous work in the field has focused on memory and planning or more global measures of executive control (Albert et al., 2001; Daly et al., 2000; Decarli et al., 2004; Rapp & Reischies, 2005).

Some limitations must be acknowledged. First, our sample is relatively small. Second, these results should be replicated with a group of AD patients. Third, using the cut-off for MCI at 1 *SD* below the mean as suggested by Crowell et al. (2002) rather than at the more usual 1.5 *SD* might

have influenced the findings—perhaps inhibition deficits would become apparent in a more memory-deficient group. Fourth, while our findings are compatible with the notion that MCI presents advanced aging, we acknowledge that it is still possible that it represents a very specific syndrome, separate from normal aging on the one hand and AD on the other. More research, casting a wider net of measures designed specifically to dissociate MCI from normal aging, is obviously needed before we can confidently conclude that MCI does not represent a pathological state. Fifth, although one would expect the factor structure of executive control to be independent of language and culture, a cross-cultural replication might be in order.

We do believe the field would benefit from including a wider range of both traditional and nontraditional executive measures and examining the results at the level of latent factors rather than individual tests.

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