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Embedded online questionnaire measures are sensitive to identifying mild cognitive impairment

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Abstract

Background/Aims—Early changes in cognitively demanding daily activities occur between normal cognition and the development of MCI. These real world functional changes as early signals of cognitive change form a prime target for meaningful early detection of dementia. We examined whether passive aspects of responding to a remotely monitored weekly online questionnaire discriminated between older adults with and without MCI.

Methods—Participants were 83 independent, community dwelling older adults enrolled in a longitudinal study of in-home monitoring technologies, which included completion of a short weekly online questionnaire of health and life events.

Results—In longitudinal analyses, time to complete the online questionnaire decreased over one year in both MCI and cognitively intact participants ($p < 0.01$). MCI and intact participants did not differ in the time of day they submitted their questionnaires initially; however, over the course of one year MCI participants began to submit their questionnaires progressively later in the day and they needed greater assistance from staff as compared to intact participants ($p < 0.05$). The online questionnaire performance measures were significantly correlated to conventional cognitive test scores ($p < 0.05$) across the spectrum of normal cognition to MCI.

Conclusion—Ambiently assessed, passive performance measures embedded within an online questionnaire are able to discriminate between normal cognition and MCI. Remote monitoring of cognitively demanding routine daily activities is a promising approach for ecologically valid real world cognitive assessment.

Keywords

everyday functioning; cognitive assessment; everyday technology; aging; real world settings; computer use; early detection; cognitive impairment; remote monitoring

Introduction

Mild cognitive impairment (MCI) is often considered the prodromal stage for a variety of dementing neurodegenerative disorders, including AD. Although MCI can stem from various etiologies, it is characterized by mild cognitive deficits and subtle changes in high level daily tasks not severe enough to warrant a diagnosis of dementia.¹ MCI has been classified into four subtypes; amnesic or nonamnesic and single or multi-domain. These subtypes are thought to reflect different, although not mutually exclusive, underlying etiologies and trajectories. For example, amnesic MCI may be a more common precursor to Alzheimer's dementia, whereas nonamnesic MCI may be a precursor to other types of dementia (e.g., vascular) or result from a myriad of medical conditions that can impact cognition (e.g., traumatic brain injury, chronic systemic medical illness, psychiatric illness)². Amnesic and nonamnesic MCI subtypes are supported by cluster and discriminant function analyses of multiple MCI classification methods³.

Viewed on a continuum in terms of symptom severity, single-domain MCI might occur in the earliest stage at the interface between normal aging and MCI, with more cognitive domains becoming affected as the disease progresses. Executive functioning, memory, and global cognitive functioning have been shown to be most predictive of everyday activity performance in MCI⁴. In the progression from healthy aging to MCI, everyday task difficulties may evolve from subtle inefficiencies to more overt omission errors, which then lead to inaccuracies in task completion⁵. Single and multi-domain MCI have both been associated with subtle difficulties in complex everyday task completion, although individuals with multi-domain MCI experience more difficulty⁶. Given the heterogeneity of the MCI construct, multiple diagnostic criteria³, and different sample characteristics (e.g., age, community or clinic based) across studies, prevalence rates of MCI in adult populations have ranged from 3–42% with transition rates to dementia ranging from 2–31%.⁷ In general, individuals with MCI are at an increased risk of developing dementia.

The development of reliable methods to advance the early identification of older adults at-risk for cognitive decline is of paramount significance, especially since early treatment may be critical. Ultimately, a modest delay in the onset or progression of MCI and dementia would significantly reduce the number of people affected, costs, and caregiver burden. An important goal is to find the most ecologically valid and sensitive measures of early, subtle cognitive changes that are signals of future decline. Early changes in cognitively demanding daily activities (e.g., computer use, following a medication regimen) occur at the interface between normal cognition and the development of MCI.⁸⁶ These real world functional changes as early signals of cognitive change form a prime target for meaningful early detection of dementia. By contrast, conventional interval-based cognitive assessment methods have limited ecological validity and do not lend themselves to tracking subtle change or variability within individuals over time. Conventional cognitive assessments can also be anxiety provoking, taxing, and time consuming for older adults.

Unobtrusive continuous “*in the background*” monitoring of routine daily activities that occur in one's home environment that requires little to no extra effort is a novel alternate approach to conventional episodic cognitive tests. Frequent observation of individuals within their

own everyday environment will make it possible to obtain larger samples of real world data that may facilitate the detection of subtle yet meaningful change in behavior associated with cognitive decline earlier than conventional methods.⁹ For example, passive sensors embedded within everyday devices and activities (e.g., computer use) can remotely track daily functioning in real time.⁹

Adoption of everyday technology by older adults has increased in recent years. This trend will continue with the aging baby boomer generation. Over 50% of older adults in the US report using the Internet¹⁰ and over 60% report some type of computer use.¹¹ Of 7,000 adults over the age of 65, 47% reported using e-mail, text messaging, or the Internet within the past month; 40% for communication purposes and 42% for reasons other than email.¹² Given that the fastest growing segment of the population adopting mobile and computer technology are those over age 65, it is now feasible and highly relevant to monitor daily functioning of older adults through the channel of computer use.⁹ Previous work at the Oregon Center for Aging and Technology (ORCATECH) has demonstrated everyday activities such as home computer use¹³, medication taking,^{14, 15} and telephone use¹⁶ can be remotely monitored and are sensitive to MCI.

Through ORCATECH, routine use of a weekly, short online questionnaire that queries health and life event status has been used for up to seven years in 265 older adult participants with greater than 80% adherence. In the present study, we examined online questionnaire responding over a one-year period in cognitively intact and MCI participants to establish whether engagement in this type of remotely monitored everyday activity is sensitive to mild cognitive impairment. The online questionnaire was distributed weekly over the Internet and completed by participants on their home computers. The present study is part of a larger, longitudinal cohort study: Intelligent Systems for Assessing Aging Change (ISSAC).⁹

In the present study we were interested in learning whether ambiently assessed, passive aspects of responding to the weekly online questionnaire would discriminate between older adults with and without MCI. Given previous research showing that people with MCI take longer to complete high level everyday activities than cognitively intact older adults¹⁷, we hypothesized that in the current study, the MCI group would take longer to complete the questionnaire as compared to the cognitively intact group. Over time, we hypothesized that the MCI group would show a reduced or 'flat' learning curve compared to the cognitively intact group, showing less improvement (e.g., becoming less quick) in time to complete the questionnaire. Due to their mild cognitive deficits and relative difficulty with complex tasks including computer use¹³, we hypothesized that older adults with MCI would require more assistance from staff than cognitively intact older adults in completing their online questionnaires. Given that individuals with MCI are less efficient, less accurate, and take longer to complete complex everyday tasks than cognitively intact older adults, it is possible that some tasks might be deferred to later and later in the day. To examine this possibility, we explored the time of day that the MCI group submitted their online questionnaires compared to the cognitively intact group over the course of one year. We hypothesized that the MCI group would submit their questionnaires later in the day than the cognitively intact group. Since amnesic and non-amnesic MCI are thought to have different etiologies and

trajectories, we conducted post-hoc subgroup comparisons to better understand how cognitive deficits might manifest differently in terms of performance on the online questionnaire measures. Finally, we examined relationships between the online questionnaire measures and traditional cognitive assessment measures in the total sample, regardless of diagnosis, to provide preliminary evidence of convergent validity of these new measures across the spectrum from normal cognition to MCI.

Methods

Participants

All participants provided written informed consent and were already enrolled in one of two ongoing studies of in-home monitoring: the ORCATECH Living Laboratory study and the ISAAC study. Participants were recruited from the Portland, Oregon, metropolitan area through advertisement and presentations at local retirement communities. The study protocols were approved by the Oregon Health & Science University Institutional Review Board (Living Laboratory IRB #2765; ISSAC IRB #2353). Briefly, both studies use the same in-home sensor technology and computers to detect early behavioral and cognitive changes that occur with aging. Additional details of the sensor systems and study protocols have been published elsewhere.⁹ Inclusion criteria were: 60 years and older for the Living Laboratory study and 80 and older for the ISAAC study, living independently (living with a companion or spouse was allowed, but not as caregiver), not demented as evidenced by a Mini-Mental State Examination (MMSE)¹⁸ score greater than 24, a Clinical Dementia Rating (CDR)¹⁹ scale score less than or equal to 0.5, and in average health for age. Exclusionary criteria included chronic or poorly controlled medical illnesses. A total of 265 participants were enrolled beginning in 2007. The participants lived in a variety of settings—from apartments in organized retirement communities to freestanding single-family homes. For the present study, we report data for the 83 participants who were from single person homes or were the only computer user at home and who had available online questionnaire data in the selected one-year time frame.

Clinical Assessment Procedures

Participants received clinical assessments during annual visits in their home using a standardized battery of tests including: the Mini-Mental State Exam (MMSE),¹⁸ the Geriatric Depression Scale (GDS)²⁰ and Functional Activities Questionnaire (FAQ).²¹ Health status was further assessed by the modified Cumulative Illness Rating Scale (CIRS).²² Diagnosis of MCI was consistent with the criteria defined by Jak and colleagues²³ and with the criteria outlined by the National Institute on Aging-Alzheimer's Association workgroup,²⁴ including: (a) objective evidence of impairment on at least two neuropsychological tests within one or more of six cognitive domains, with scores falling at least 1 standard deviation (SD) or more below the mean values stratified by age based on available normative data; (b) nonfulfillment of criteria for dementia; (c) preserved general cognitive functions as confirmed by a score of 24 or above on the MMSE; (d) no significant impact on functional abilities, as confirmed by two or fewer activities marked as dependent on the FAQ; and (e) absence of severe depression as confirmed by a score <5 on the 15-item GDS. The Jak²³ criteria for classifying MCI has been shown to better characterize cognitive

subtypes, associate with AD biomarkers, show stability of diagnosis over time, and identify more patients who actually progress to dementia than conventional diagnostic methods³. Diagnosis of MCI or cognitively intact was made at each participant's annual clinical evaluation that occurred between 2011 and 2012. Longitudinal online questionnaire data was obtained for the 12 months that preceded the annual clinical evaluation in which the MCI/Intact classifications were made.

Neuropsychological tests used for assessment of MCI in the memory domain included WMS-R Logical Memory II Story A,²⁵ WMS-R Visual Reproduction II, and CERAD Word-List Recall.²⁶ Language tests included Boston Naming Test²⁷ and category fluency (animals). Executive function tests included letter fluency (CFL),²⁸ Trail Making Test Part B,²⁹ and Stroop color-word conflict.³⁰ Processing speed tests included WAIS-R Digit Symbol,³¹ Trail Making Test Part A, and Stroop color naming. Working memory tests included WAIS-R Digits Backward, WAIS-III Letter Number Sequencing³² or WAIS-IV Digit Sequencing,³³ and MMSE item WORLD backwards. Visual Perceptual/Construction tests included WAIS-R Block Design, WAIS-R Picture Completion, and WMS-R Visual Reproduction I. *Global cognition* z-scores were tabulated from cognitive tests in the domains of working memory, attention/processing speed, memory, executive function, and visual perception/construction. Cognitive domain z-scores were calculated using group mean and standard deviations of the raw test scores from all cognitively intact subjects (CDR=0) at study entry into the ORCATECH cohort (n=180). The participants in the present study are part of the original normative cohort. The individual subject scores were z-normalized, summed, and averaged.

Weekly Online Questionnaire

Participants used desktop computers with standard mice and high speed internet access that they had in their homes as part of their participation in ORCATECH research. The 12-item weekly online questionnaire was distributed through the Internet on Monday mornings at 5 am (Figure 1). The questionnaire was the initial webpage a participant would see when they used their internet browser during the week. The questionnaire would remain there until the participant completed it for the week. The questionnaire includes questions about physical and mental health and activities within the past week including medication changes, falls, injuries, health changes, emergency room visits, mood, changes to living space, vacations, and visitors. Instructions were located at the top of the questionnaire. Each item was presented as a yes/no question and participants used their mouse to click on the appropriate response bubble. Text boxes were located below each item where participants were required to provide additional details if they responded 'yes' to an item. Event start and end dates were also required and chosen from a drop-down calendar if an item was endorsed. Questionnaire response parameters such as date and time it was initiated and completed were automatically time stamped. Missed questionnaires over two weeks late were flagged for a member of the research team to follow up with a phone call. Research assistant telephone completed questionnaires were not included in analyses of embedded questionnaire measures. The majority of participants in the present study started completing the weekly online questionnaires at the same time in 2007.

Statistical Analysis

Cross sectional group comparisons of demographic and clinical variables were made using Students t-test or Wilcoxon ranked sum test for continuous variables and the Pearson chi-square test for categorical variables at participants' 2011–2012 annual clinical evaluation. Longitudinal generalized linear mixed models were generated with three online questionnaire variables: *completion time*, measured in seconds; *start time in the day*, measured in minutes from 5 AM; and *research assistant completed questionnaire* (yes/no) as unique outcomes, adjusted for age, education, depression, and number of questionnaire items endorsed. The outcome variable completion time was log transformed to obtain a normal distribution. Halfway through the 12-month study period, two questions about pain were added to the original 10-item questionnaire, increasing the total number of items to 12 (Figure 1). To account for how these additional questions might have influenced questionnaire completion time, we used only the questionnaires that included the pain questions (about 2/3 of all questionnaires submitted over the study period) for the analyses of completion time. For exploratory post hoc analyses, MCI participants were subclassified as non-amnesic MCI if they had no memory impairment on objective testing or amnesic MCI if they had memory impairment on testing at their 2011–2012 annual clinical evaluation. Analyses were performed using SAS software 9.3 (Cary, NC).

Results

Demographic and clinical characteristics between MCI and cognitively intact groups are presented in Table 1. MCI participants performed more poorly than the Intact group on the MMSE, endorsed more items on the annual self-report mood scale (GDS), and were less educated than intact older adults (all $p < 0.05$). There were no significant group differences in the average number of questionnaire items endorsed. MCI participants submitted an average of 32 out of 52 possible weekly questionnaires, and cognitively intact participants submitted 40 out of 52. MCI participants needed more staff assistance to complete their online questionnaires compared to cognitively intact participants ($p = 0.0029$).

Longitudinal analyses showed that after adjusting for covariates (age, education, depression, and number of questionnaire items endorsed), time to complete the online questionnaire decreased over one year in both MCI and cognitively intact participants ($p = 0.006$) (Table 2) (Figure 2). Specifically, at the beginning of the 12-month study period, the median time to complete the questionnaire for both groups combined was 225 seconds ($SD = 165$) and at the end of the study period, the median time to complete the questionnaire was 179 seconds ($SD = 155$). *Over time*, the MCI participants began submitting their questionnaires later in the day ($p = 0.024$) (Figure 3) and needed increased staff assistance as compared to cognitively intact participants ($p < 0.0001$). Specifically, at the beginning of the study period, the MCI group's median questionnaire start time of day was 1:40pm ($SD = 269$ minutes) and the cognitively intact group's median start time of day was 12:29pm ($SD = 302$ minutes). At the end of the study period, the MCI group's median start time of day was 4:06pm ($SD = 309$ minutes) and the cognitively intact group's median start time of day was 1:41pm (283 minutes).

In the exploratory post-hoc analysis of the 7 amnesic and 17 nonamnesic MCI cases (Table 3), amnesic MCI participants took longer to complete their online questionnaires than the cognitively intact participants ($p=0.03$). The nonamnesic group did not reach significance ($p=0.62$). *Over time* the nonamnesic MCI participants began submitting their questionnaires progressively later in the day ($p=0.02$) as compared to cognitively intact participants. In this model, the amnesic MCI group did not reach significance ($p=0.42$).

In correlational analyses with all 83 cognitively intact and MCI individuals, participants' median time to complete the questionnaire during the one year period and median questionnaire start time of day were both significantly correlated with their global z-scores adjusting for age, education, GDS and median number of items endorsed (median time to complete $p=0.0069$; median start time $p=0.0113$). In addition, a multivariate linear regression model showed that number of staff-completed questionnaires during the one year period was a significant predictor of global z-score adjusting for age, education and GDS ($p=0.023$).

Discussion

MCI and cognitively intact older adults completed a brief weekly online questionnaire of life events and health on their home computers for 12 months. As expected, MCI participants needed more assistance from research staff to complete the online questionnaire compared to cognitively intact participants. Consistent with a prior study that showed computer use is an IADL impacted by MCI (Kaye et al., 2013), one explanation is that due to their mild cognitive deficits MCI individuals had relative difficulty navigating and using an online interface.

The MCI group did not take more time to complete their questionnaires than cognitively intact older adults initially, and over time, both groups actually became quicker to complete their online questionnaires. This finding was unexpected given several studies showing that MCI individuals perform complex tasks more slowly than cognitively intact older adults (e.g., multitasking, medication taking, telephone use).^{17, 34} However, as shown in Table 2, the positive coefficients for both "MCI vs. Intact" and "MCI*time" suggest that while not reaching statistical significance, the MCI group did take longer to complete the online questionnaire and, in light of the "Time, weeks" coefficient, also improved less over time than the cognitively intact group. The MCI group improved slightly (effective coefficient of -0.00019). The lack of significance could be related to a subtle effect (small effect size) with high variability, the fewer number of MCI participants in the model to robustly estimate the effect, the varying levels of MCI along the cognitive continuum with more individuals at the earliest stage of MCI, and/or the fact that Model 1 did not stratify by amnesic and nonamnesic MCI. It is likely that given a longer follow-up period, as progression of MCI occurs, MCI participants' completion times would at least plateau and become more noticeably slower than the cognitively intact.

Results from the post hoc analysis suggest that different patterns of cognitive deficits differentially impact performance on a complex computer based activity. For example, the amnesic MCI group took longer than the cognitively intact group to complete their

questionnaires, while the non-amnestic group submitted their questionnaires later in the day over time compared to the cognitively intact group. It is possible that mild memory difficulties might drive slower activity completion in amnestic MCI; for example, forgetting dates or details of the life event endorsed (e.g., recent hospital visit) could result in having to take additional time to fill out the required text box and drop down calendar. The repeated questions could also tend to be less well remembered or familiar from session to session, resulting in having to take additional time. Other possible explanations that will be examined in future studies are whether amnestic MCI individuals inadvertently skip items or omit information and then spend time going back to correct their errors, or if they write longer text responses to 'yes' endorsed items than cognitively intact older adults.

Interestingly, over time, MCI older adults began starting the online questionnaire progressively later in the day as compared to cognitively intact older adults. The post-hoc analysis showed that it was the nonamnestic MCI group that contributed to initiating the task progressively later in the day, although lack of power for the amnestic MCI group is also a possible reason. In nonamnestic MCI, changes in executive functioning, processing speed, and attention over time could contribute to less efficient completion of routine tasks throughout the day, and this phenomenon could have a cumulative effect resulting in some tasks being completed later and later in the day. Another possible explanation to examine in future studies is whether MCI individuals sleep in later in the morning over time, thus impacting the time of day to complete the questionnaire. There are other possible reasons for this finding, including lack of motivation on the part of MCI individuals, although we did control for depression which can impair motivation. In future studies, it will be important to explore whether MCI individuals begin initiating other routine tasks later in the day as well (e.g., wake up, go to the kitchen or bathroom, take medication, time to first leave the house, make telephone calls). Overall, the exploratory post-hoc findings suggest that the MCI subtype differentially impacts activity performance (e.g., initiation later in the day vs. reduced speed of performance) and further study is warranted. Across the spectrum of healthy aging to MCI, we found significant correlations between our three online questionnaire response measures and a global cognitive z-score derived from conventional cognitive tests. These results provide preliminary evidence that ambiently assessed, passive measures of questionnaire responding are clearly related to established cognitive constructs, and support the interpretation that differences in these performance measures between MCI and cognitively intact individuals are related to mild cognitive deficits.

The current conclusions must be interpreted with some limitations in mind. The cohort is a relatively homogenous sample of predominately Caucasian (80%), well-educated community dwelling volunteers with low levels of depression and health co-morbidities. This may reduce the generalizability of our findings. Studies with more diverse samples would address these concerns. In addition, as noted above, we had limited power to examine the relative performance characteristics of MCI amnestic and nonamnestic subtypes; larger samples sizes of amnestic and nonamnestic MCI are needed to confirm these findings. We did not classify into single versus multi-domain MCI subtypes. This could be done in future studies to better characterize how individuals across the spectrum of MCI perform on ambiently assessed, passive everyday cognitive measures.

In an earlier ORCATECH study of daily computer use, we showed that over time individuals with MCI spend less time on their home computer and have more inconsistent usage patterns.¹³ In other functional domains, we have shown that the ability to adhere to a medication regimen,¹⁴ the number of incoming phone calls,¹⁶ and conversation length³⁵ are all sensitive to mild cognitive changes associated with MCI or aging. Data from the current study are consistent with these previous studies and demonstrates that cognitively demanding routine daily activities in the home can be monitored to detect subtle cognitive deficits in older adults.^{13, 16, 36, 37} Ambiently assessed, passive performance measures in an online questionnaire such as completion time, number of missed or overdue questionnaires, and submission time of day are promising early markers of cognitive change that could be tracked in the home over time to monitor for subtle cognitive changes in a non-threatening and non-taxing way. Future research will focus on further validation of these and other unobtrusive cognitive assessments embedded within remotely monitored home computer use as well as other everyday activities. In the current study, we have demonstrated that these embedded online questionnaire measures can discriminate between MCI and normal cognition in a one-year longitudinal study. We will next use up to 7 years of our online questionnaire data to determine whether the embedded performance measures can be used to improve the prediction of future cognitive decline in cognitively intact and MCI older adults.

This novel real world cognitive assessment paradigm integrates remote sensing and pervasive computing technologies to unobtrusively assess and monitor high level, complex everyday activity performance in one's home environment over extended periods of time. This approach addresses limitations inherent to available measures of everyday cognitive functioning. For example, it is ecologically valid and assesses the person every time they access their weekly online questionnaire at home. Increased frequency of intra-individual assessment of multiple daily activities may result in greater sensitivity to capture meaningful cognitive change at its earliest stage when intervention is most important. Remote monitoring of everyday activities is noninvasive and allows inclusion of those not readily assessed repeatedly (e.g., individuals living in rural or remote areas or who have physical limitations that prohibit travel). Further, high frequency assessment of real world cognition which increases the precision of the estimate of cognitive change can translate to reduced clinical study sample size requirements, ultimately facilitating more effective intervention studies.

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Oregon Technology and Aging Study

Health and Activity Questionnaire

Please note that we have made changes to this weekly questionnaire to make it easier to complete. If you have any questions about how to fill this out, please call your Research Assistant for assistance. Again, we thank you for your valuable contribution.

Please give your mouse a click on YES or NO to indicate if there have been any changes in your health or activities in the past week. If you answer YES to any of these questions, please explain them briefly in the space designated. All of your responses will be confidential.

In the past week have you:

1. YES / NO	Been away from home overnight? If so, what dates?
Start Date: _____ End Date: _____ Please provide details here: _____	
2. YES / NO	Had visitors that have stayed for more than one day in your home? If so, what dates?
Start Date: _____ End Date: _____ Please provide details here: _____	
3. YES / NO	Had a change in your medication (for example, have you started or stopped a medication or had a change in your dosage or prescription)?
Please provide details here: _____	
4. YES / NO	Have you had a fall, including a slip or trip, in which you lost your balance and landed on the floor, the ground, or a lower level?
Date: _____ Please provide details here: _____	
5. YES / NO	Had any other injuries? If so, what type of injury and what date did it occur?
Date: _____ Please provide details here: _____	
6. YES / NO	Had any hospitalizations or emergency room visits? If so, what caused those visits and what date did it occur?
Start Date: _____ End Date: _____ Please provide details here: _____	
7. YES / NO	Has your physical health limited you more than usual (for example, stress, pain or activity kept you in bed or has kept you less active)? If so, please explain.
Please provide details here: _____	
8. YES / NO	Had any changes in home space or living situation (for example, repair or renovation projects, moved or rearranged furniture, or someone has moved in or is no longer living with you)? If so, what date or dates did these occur?
Start Date: _____ End Date(s): _____ Please provide details here: _____	
9. YES / NO	Have you felt disoriented or blue for more than three days? If so, has there been a specific reason?
Please provide details here: _____	
10. YES / NO	In the past week I felt lonely.
Please provide details here: _____	
11.	Please rate your pain by indicating the number that best describes your pain on average in the last week (0 = no pain, 10 = worst imaginable) 0 1 2 3 4 5 6 7 8 9 10
12.	During the past week, how much did your confidence with your normal activities or work (including both work outside the home and housework)? Not at all 1 2 3 4 5 6 7 8 9 10 Completely

I have entered this information for MYSELF ☐ I have entered this information for myself AND others in the household.

Form completed by (enter legible name): _____

Signature: _____

Figure 1.
ORCATECH Online Questionnaire

Figure 2. Longitudinal scatter plot of differences in median questionnaire completion time (in seconds) by week for MCI (blue) and cognitively intact (red) participants. Points are the median completion time for the group during each week.

Figure 3.

Longitudinal scatter plot of differences in median questionnaire start time of day (minutes from 5am) by week for MCI (blue) and cognitively intact (red) participants. Points are the median start time of day for the group during each week.

Table 1

Demographic and clinical data according to cognitive status

Variables	Intact Mean (SD)	MCI Mean (SD)	<i>p</i> -value
<i>N</i>	59	24	
Age (years)	86.2 (7.0)	87.9 (6.8)	0.28
Gender (% Women)	88%	75%	0.18
Education (years)	15.3 (2.4)	13.7 (2.9)	0.03 *
Non-white (%)	19%	21%	1.0
Mini-Mental State Exam	28.8 (1.2)	27.4 (1.6)	<0.001 **
Geriatric Depression Scale	1.0 (1.9)	2.2 (2.5)	<0.01 **
Cumulative Illness Rating Scale	20.1 (2.0)	20.5 (2.5)	0.42

*
 $p < 0.05$;**
 $p < 0.01$

Table 2

Results of longitudinal generalized mixed effects models

Covariate	Model 1		Model 2		Model 3	
	Questionnaire Completion Time ^a	p-value	Questionnaire Start Time of Day ^b	p-value	Staff-assistance needed	p-value
MCI vs. Intact	0.17	0.31	47.03	0.40	2.54	0.0029**
Time, weeks	-0.00068	0.018*	-0.02	0.70	0.0079	<0.0001***
MCI * time	0.00049	0.37	0.25	0.024*	-0.0047	0.082
Age (yrs)	0.017	0.034*	7.98	0.014*	0.12	0.015*
Education (yrs)	-0.051	0.020*	4.48	0.61	-0.078	0.50
GDS	-0.00084	0.98	3.18	0.76	-0.048	0.73
Items endorsed (#)	0.64	<0.0001***	14.28	0.022*	1.04	<0.0001***

^a Measured in seconds; log-transformed to obtain normal distribution

^b Measured in clock time (minutes from 5am)

* p<0.05,

**

p<0.01,

***

p<0.0001

aMCI= amnesic MCI; naMCI=nonamnesic MCI

GDS= Geriatric Depression Scale

Table 3

Results of post-hoc longitudinal generalized mixed effects models (MCI subtype)

Covariate	Model 1		Model 2		Model 3	
	Questionnaire Completion Time ^a		Questionnaire Start Time of Day ^b		Staff-assistance needed	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
aMCI vs. Intact	0.49	0.03 *	69.29	0.42	2.83	0.015 *
Time, weeks	-0.00042	0.03 *	-0.02	0.70	0.0087	<0.0001 ***
aMCI * time	-0.00033	0.37	0.18	0.36	-0.0049	0.129
naMCI vs. Intact	0.08	0.62	37.06	0.56	2.35	0.015 *
naMCI * time	0.00068	0.10	0.27	0.02 *	-0.00441	0.120
Age (yrs)	0.014	0.043 *	7.94	0.016 *	0.11	0.018 *
Education (yrs)	-0.045	0.023 *	4.29	0.63	-0.071	0.51
GDS	-0.01638	0.51	3.50	0.74	-0.032	0.81
Items endorsed (#)	0.65	<0.0001 ***	14.26	0.022 *	1.02	<0.0001 ***

^a Measured in seconds; log-transformed to obtain normal distribution

^b Measured in clock time (minutes from 5am)

* p<0.05,

** p<0.01,

*** p<0.0001

aMCI= amnesic MCI; naMCI=nonamnesic MCI

GDS= Geriatric Depression Scale