



## Featured Article

# Weekly observations of online survey metadata obtained through home computer use allow for detection of changes in everyday cognition before transition to mild cognitive impairment

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**Abstract**

**Introduction:** Subtle changes in instrumental activities of daily living often accompany the onset of mild cognitive impairment (MCI) but are difficult to measure using conventional tests.

**Methods:** Weekly online survey metadata metrics, annual neuropsychological tests, and an instrumental activity of daily living questionnaire were examined in 110 healthy older adults with intact cognition (mean age = 85 years) followed up for up to 3.6 years; 29 transitioned to MCI during study follow-up.

**Results:** In the baseline period, incident MCI participants completed their weekly surveys 1.4 hours later in the day than stable cognitively intact participants,  $P = .03$ ,  $d = 0.47$ . Significant associations were found between earlier survey start time of day and higher memory ( $r = -0.34$ ;  $P < .001$ ) and visuospatial test scores ( $r = -0.37$ ;  $P < .0001$ ). Longitudinally, incident MCI participants showed an increase in survey completion time by 3 seconds per month for more than the year before diagnosis compared with stable cognitively intact participants ( $\beta = 0.12$ ,  $SE = 0.04$ ,  $t = 2.8$ ;  $P = .006$ ).

**Discussion:** Weekly online survey metadata allowed for detection of changes in everyday cognition before transition to MCI.

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**Keywords:**

Everyday cognition; Activity monitoring; Longitudinal; Aging; Computer use; Preclinical AD; Older adults; In-home technology; Ecological validity

**1. Introduction**

Early detection of cognitive and functional decline in mild cognitive impairment (MCI) and prodromal Alzheimer's disease (AD) is critical for effective optimal

clinical management as well as large-scale screening and implementation of disease-modifying treatments as they become available. Jedynak et al. [1] examined the timing and course of biomarker changes with data from 687 participants in the Alzheimer's Disease Neuroimaging Initiative (ADNI) study. A neuropsychological word list memory task was found to be the earliest marker to become abnormal, followed by hippocampal volume and concentration of amyloid  $\beta$ . In another ADNI study, Edmonds et al. [2] found that amyloid accumulation and subtle cognitive decline were equally common first signals of change in

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healthy older adults who later transitioned to MCI. Tarnanas et al. [3] showed that two computerized simulated complex instrumental activities of daily living (IADL) tasks accounted for a significant amount of the variance in early progression from normal to MCI, above and beyond other common biomarkers. Verlinden et al. [4] found that individuals who later developed AD started declining on an IADL measure 5 to 6 years before dementia diagnosis. Taken together, these studies suggest that subtle cognitive and IADL changes may be among the earliest signals of meaningful change in those who later develop MCI and AD. Given the high cost, invasive nature, unclear clinical utility of in vivo biomarker imaging, and weak association between biomarkers and clinical outcomes [5], there is a continued need to identify sensitive cognitive and IADL markers that are clinically relevant, cost effective, and scalable to reach the growing population of older adults.

Measurement of subtle insidious decline in complex higher order daily function (e.g., everyday cognition), a hallmark of neurodegenerative disease, is hindered by the current episodic and clinic-based assessment paradigm. Infrequent administration of functional tests does not allow for tracking of subtle within-person variability over time, which has been shown to be a powerful and sensitive predictor of incident cognitive decline [6,7]. Although older adults with MCI demonstrate slower, less efficient, and less accurate completion of daily activities than their cognitively intact counterparts [8–10], these aspects of daily performance are not typically captured by conventional IADL tests and questionnaires.

Advances in wireless technology, pervasive computing, and high-dimensional data analytics have made it possible to unobtrusively and continuously monitor cognitively demanding routine activities in one's own environment through commonly used devices [10–16]. Computer use is a highly complex functional activity that is becoming increasingly common among older adults, with 59% of individuals' aged 65 or older reporting daily online use and 47% having a high-speed broadband connection [17]. With the goal of assessing everyday cognition directly within the IADL domain of home computer use, we took advantage of a weekly self-administered online health survey that is deployed in our longitudinal aging studies. Specifically, we derived online survey "metadata" metrics based on survey engagement patterns of MCI and cognitively intact participants, with the idea that subtle cognitive difficulties seen in early MCI (e.g., slower, less efficient, less consistent performance on tasks) would be automatically captured and reflected in participants' self-administration, engagement with, and conduct of the online survey over time. In an initial study, we showed that weekly online survey metadata could be used to discriminate between MCI and cognitively intact groups [10].

In the present study, we extend these findings by first examining baseline period cross-sectional group differences between healthy older adults who later transitioned

to MCI (incident MCI group) and healthy older adults who remained cognitively intact (stable cognitively intact group) using the first 3 months of available online survey metadata on survey completion time (in minutes), survey completion time of day, and survey adherence. On the basis of the results from our previous study, we were interested to see if there would be identifiable differences in the survey metadata metrics between the two groups.

Our second aim was to examine cross-sectional associations between the online survey metadata (using the first 3 months of data), conventional neuropsychological tests, and a functional (IADL) questionnaire. On the basis of the available research [18], we expected that our survey metadata metrics would be significantly associated with neuropsychological and functional test scores. Our third aim was to examine whether there were within-person changes in the online survey metadata in incident MCI individuals in the 12-month period before diagnosis of MCI based on annual neuropsychological test scores. We hypothesized that incident MCI older adults would manifest subtle changes in online survey engagement in the 12-month period leading up to MCI diagnosis compared with stable cognitively intact older adults' last 12-month period of available data.

## 2. Methods

### 2.1. Participants

All participants provided written informed consent and were already enrolled in ongoing longitudinal studies of in-home monitoring ([www.orcatech.org](http://www.orcatech.org)). Participants were recruited from the Portland, Oregon, metropolitan area through presentations at local retirement communities. The study protocols were approved by the Oregon Health & Science University Institutional Review Board (Life Laboratory IRB #2765; ISSAC IRB #2353). Additional details of the sensor systems and study protocols have been published elsewhere [11,16]. Inclusion criteria for the present study were 60 years and older, living independently (living with a companion or spouse was allowed, but not as caregiver), cognitively intact at baseline as evidenced by *not* meeting criteria for MCI based on comprehensive MCI criteria of Jak et al. [19] and with the criteria outlined by the National Institute on Aging-Alzheimer's Association workgroup [20], and in average health for age without poorly controlled medical illnesses as confirmed by a score of <4 in every category on the modified Cumulative Illness Rating Scale [21]. For the present study, we report data for 110 participants who were cognitively intact at baseline and had available online survey data in the selected time frame (2011–2015). In 2011, all participants included were nondepressed (Geriatric Depression Scale [GDS]-15 item [22] ≤5) and cognitively intact (mean [*M*] age = 84.8 years; 77% female). Of these individuals, 29 (26%) transitioned to

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