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Use of in-home activity monitoring technologies in older adult veterans with mild cognitive impairment: The impact of attitudes and cognition

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Abstract

Background: As researchers incorporate in-home technologies to identify and track changes in older adults' cognitive and daily functioning that could lead to early interventions, the attitudes of older adults across the continuum from normal cognitive aging to mild cognitive impairment (MCI) must be assessed to ensure technology adoption and adherence in each unique group.
Objective: This exploratory pilot study incorporated both quantitative and qualitative approaches to examine mild cognitive impairment (MCI) and cognitively intact older adults' attitudes (i.e., usability, acceptability, digital readiness, barriers) and adherence to in-home technologies after undergoing 7 months of in-home activity monitoring.
Method: Participants were 30 older adult veterans who were classified as cognitively intact (n = 15) or having mild cognitive impairment (MCI) (n = 15) and participated in a longitudinal aging and technology study that monitored their physical activity and computer use.
Results: While MCI older adults endorsed reduced digital readiness (p =.041) and required more in-home technology maintenance visits (p =.041) from staff as compared to cognitively intact older adults, there was no difference in adherence to the study technology (p >.05). Usability and acceptability attitudes in the entire sample predicted adherence to the physical activity monitoring technology employed in the study (p =.008).
Conclusion: Findings highlight the potential gap between technology developers and older adult end users, and technologies designed specifically for older adults with MCI should be developed with direct input from older adults with MCI to promote usability and long-term adoption in this clinical population. Larger studies are needed to replicate and increase the generalizability of the current findings.

Keywords: Remote monitoring technology, military veterans, mild cognitive impairment, attitudes, adherence

Introduction

As of 2020, an estimated 5.8 million Americans over the age of 65 are living with Alzheimer's dementia (AD; Alzheimer's Association, 2020). Predicted increases in dementia incidence and healthcare burden have resulted in the exploration of technology-based solutions for aging independently (Kaye et al., 2011). In-home monitoring technologies and digital web-based interventions have been used by researchers to detect meaningful changes in physical health and cognitive decline over time (Kaye et al., 2011). Specifically, everyday consumer devices such as pedometers and online surveys have been used to monitor these cognitive and physical health changes longitudinally (Bernstein et al., 2021). Using a pedometer, past work suggests that those with better cognitive performance take more steps on a daily basis (Calamia et al., 2018). With regard to computer use, online surveys have been used to help show that those with poorer cognition complete their surveys later in the day and take longer to complete their surveys than cognitively intact older adults (Seelye et al., 2018). Identifying individuals who are in the earliest stages of AD will allow for the implementation of early interventions, which could slow disease progression and reduce the number of affected individuals (Alzheimer's Association, 2020).

Mild cognitive impairment (MCI), often considered the prodromal stage of AD and other related dementias, may be associated with subtle difficulties performing instrumental activities of daily living (IADLs), including the use of everyday technology (Farias et al., 2017; Petersen, 2004; Seelye et al., 2018). Passive in-home monitoring of IADL performance is a promising approach to detect early changes in IADLs and signal the progression from normal aging to MCI (Chen et al., 2017; Jekel et al., 2015; Seelye et al., 2018). While traditional clinic-based assessment methods are limited in their ability to capture the earliest signals of IADL decline, sensor-based assessment technologies allow for frequent assessment in real-time, which can pick up subtle yet potentially meaningful changes in functional domains important to independent living such as medication taking and driving (Kaye et al., 2011; Seelye et al., 2017; Seelye et al., 2020).

The successful application of in-home monitoring technologies depends on the receptivity of potential users (Peek et al., 2014), and research is needed to understand factors related to the successful adoption of these technologies before they become available for widespread use (Kaye et al., 2011; Liu et al., 2016), particularly for older adults with MCI. Models of technology acceptance (e.g., Technology Acceptance Model [Davis, 1989]; Unified Theory of Acceptance and Use of Technology [Venkatesh et al., 2003]) and researchers who study the effectiveness of technology in older adult populations (Cavallo et al., 2014; Holthe et al., 2018) propose that both usability (i.e., ease of use of the technology) and acceptability (i.e., the degree of primary users' predisposition to carry out daily activities using the intended device) are strong predictors for the adoption of new technology (Holthe et al., 2018; Thordardottir et al., 2019). Qualitative in-home monitoring research has shown that older adults' usability, feelings of safety, familiarity with the technology, and feelings of support during implementation may impact technology adoption and adherence (Thordardottir et al., 2019). Digital readiness (i.e., the idea that one is confident and prepared to engage with existing technologies and digital tools) and perceived barriers have also been theorized to influence adoption and adherence among older adults. Only 26% of Internet users over the age of 65 are confident in their readiness and ability to use computers, smartphones, and other electronic devices (Anderson & Perrin, 2017), which may impact adherence and technology use. Perceived barriers, such as loss of privacy, security, and ethical concerns may also hinder the implementation of in-home monitoring technology (Botros et al., 2019; Lee & Coughlin, 2015; Liu et al., 2016). In-home monitoring technologies have the potential to be sensitive, early indicators of cognitive decline; however, user's attitudes (i.e., usability, acceptability, digital readiness, barriers) must be assessed in order to ensure adoption and adherence.

To date, few studies have examined attitudes about in-home activity monitoring to detect health changes in older adults who have direct experiences using the technology they are evaluating or who have experienced using the technology longer than 1-2 days (Claes et al., 2015; Mitchell et al., 2020). With few exceptions (e.g., Boise et al., 2013; Botros et al., 2019), these studies rely on focus groups or qualitative approaches alone to assess factors that influence technology adherence (Peek et al., 2014; Thordardottir et al., 2019). Further, few studies have examined differences in attitudes towards activity monitoring between those with MCI and persons with normal cognition (Boise et al., 2013). Despite the fact that aging military veterans are at an elevated risk for developing dementia (Sibener et al., 2014; Weiner et al., 2013) and digital disparities (Luger et al., 2016), these studies are limited to largely civilian samples. Thus, a better understanding of technology attitudes among a broader population of older adults, including veterans, individuals with MCI, and those who have direct and longer-term experience using in-home monitoring technologies, using a mixed-methods approach, is an important next step for understanding how these novel technologies can be successfully implemented and used in this important and growing population.

The current research was an exploratory, mixed-methods pilot study that examined attitudes about activity monitoring technology in a small sample of MCI and cognitively intact older adult military veterans who had in-home activity monitoring technology installed for 7-months. The first aim was to measure older adults' attitudes (i.e., usability, acceptability, barriers, and digital readiness) regarding in-home monitoring technologies and to explore how attitudes differ by cognitive status, informant-rated daily functioning, and demographic variables. Based on prior research suggesting that MCI participants are more willing to accept activity monitoring than healthy controls (Boise et al., 2013), we hypothesized that MCI individuals would have more positive attitudes about the in-home monitoring platform as compared to the cognitively intact group. We also hypothesized that those with lower levels of functional status, educational attainment, and SES would have less positive attitudes about the in-home monitoring technology given that these are all considered barriers to technology adoption (Choi & DiNitto, 2013). The second aim was to examine how attitudes predict adherence to study in-home activity monitoring technologies. Given prior research on associations between greater perceived barriers and poor adherence (Jack et al., 2010), we hypothesized that more positive attitudes would predict better adherence to study technologies. The third aim was to explore MCI and cognitively intact older adults' ability to independently trouble-shoot study technology when technology updates or resets were required. Based on prior research suggesting that people with MCI have difficulty engaging with everyday technology (Nygard et al., 2012), we hypothesized that MCI individuals would need more in-person technology maintenance visits from research staff than the cognitively intact group. The final aim was to evaluate participants' open-ended feedback about their experiences and any concerns with in-home monitoring technologies.

Method

Participants

Participants were 30 community-dwelling older adult military veterans from a metropolitan area and provided written informed consent for study participation. Of this group, 15 were classified as cognitively intact and 15 were classified as MCI using established clinical and research measures consistent with the National Institute on Aging-Alzheimer's Association (NIA-AA) workgroup criteria for MCI (Albert et al., 2011). Inclusion criteria were 65 years of age and older, living within 30 miles of a large VA medical center in a metropolitan area, living independently in their home, having a broadband internet connection, owning a computer and using it at least once per week, and being relatively healthy for their age. Individuals with moderate to severe anxiety or depression (i.e., Generalized Anxiety Disorder-7 questionnaire [Spitzer et al., 2006] score >5 or Geriatric Depression Scale-15 [Yesavage et al., 1982] score >7), impaired global cognition (Montreal Cognitive Assessment [Nasreddine et al., 2005] sex, age, and education adjusted z-scores <-2 or global Clinical Dementia Rating Scale [Morris, 1993] score >.5), or a dementia diagnosis were not included in the study.

Clinical assessment procedures

Participants completed a battery of clinical and cognitive measures at baseline and at 12 months follow-up. The standardized battery included an informant-rated functional questionnaire and mental health measures (e.g., Functional Assessment Questionnaire [FAQ, Pfeffer et al., 1982], Geriatric Depression Scale [GDS, Yesavage et al., 1982]) as well as validated neuropsychological tests assessing multiple cognitive domains: attention and processing speed, memory, language, executive functioning, and visuospatial construction that are part of the National Alzheimer's Coordinating Center (NACC) Uniform Data Set (UDS) (Weintraub et al., 2018) along with additional validated tests. Cognitive domain and global cognition z-scores were calculated using group mean and standard deviations from the NACC UDS clinically normal cognitive group (Weintraub et al., 2018).

In-home activity monitoring study technologies

All participants were a part of an ongoing longitudinal pilot study on aging that assessed sensor-monitored IADL function in older adults' physical activity (movement, number of steps, and the variability of these measures over time), nighttime activity (total time in bed, times out of bed, and the variability of these measures over time) and interactions with their home computer (engagement with the weekly online health questionnaire, performance on the Survey for Memory Attention and Reaction Time [SMART; Dorociak et al., 2021], mouse cursor movements, and the variability in these measures over time). Study devices (described in detail in the following sections) collected data solely for research rather than clinical purposes. Additional details of the technology platform and study protocol have been published elsewhere (Seelye et al., 2020).

Wrist-worn fitness tracker watch

Each participant received a Nokia Steel watch (Issy-Les Moulineaux, France), a fitness tracker that kept time, and collected physical activity data (e.g., steps taken, time spent sleeping). Participants were asked to wear the watch daily and nightly and allowed to take the watch off to shower. Research technicians monitored the watch on a weekly basis and uploaded the watch data to secure research servers. Participant effort and burden were low due to the passive nature of the data collection.

Web-based health update questionnaire (Weekly Health Survey; 5-10 min per week)

Each participant was asked to complete a brief, self-administered weekly web-based health update questionnaire, which asked questions about events and behaviors over the prior week (i.e., emergency room visits, depression, vacations, and visitors). The Weekly Health Survey was administered every Monday at 9 AM and participants were given 3 days to complete the survey before receiving a reminder call.

Survey for Memory Attention and Reaction Time (SMART; 5-10 min per month)

Each participant was asked to complete a brief, self-administered monthly web-based cognitive assessment, the Survey for Memory Attention and Reaction Time (SMART; Dorociak et al., 2021). The SMART consists of 4 face-valid cognitive tasks available in the public domain assessing visual memory, attention/processing speed, and executive functioning. Participants were given 3 days to complete the SMART before receiving a reminder call. The SMART was administered via the Qualtrics Survey Platform and sent out on the last Monday of each month at 9 AM.

Survey development and administration

The Technology Perception Survey (TPS) was an experimental survey developed by our research group to assess participants' attitudes toward the in-home monitoring system deployed in our research program. The survey was developed based on the review of relevant literature (Boise et al., 2013; Braun & Clarke, 2006; Creswell et al., 2011; Mitchell et al., 2020; see Appendix I for Survey Items). The first part of the TPS assessed participants' attitudes including usability, acceptability, barriers, and digital readiness about the specific technologies used in the study and are outlined below. For each study technology, participants were asked the degree to which they agreed with each statement on a Likert-type scale. Item responses ranged from (1) strongly disagree to (5) strongly agree. This part of the survey also included one free-response item for each study technology (i.e., wrist-worn fitness tracker watch, web-based Weekly Health Survey, web-based cognitive assessment called the SMART) which asked, *"If you have any questions/comments/concerns about the [wrist-worn fitness tracker watch, web-based Weekly Health Survey, web-based cognitive assessment called the SMART], please write them in the space below."* The second part of the TPS asked participants about their general attitudes about in-home health monitoring technology (i.e., digital readiness, perceived barriers). The TPS was administered after 7-months of using the in-home technology via the Qualtrics Survey Platform and took participants 30-45 minutes to complete.

TPS survey domain: Usability

Participants were asked about the usability of the watch, Weekly Health Survey, and the SMART survey on a scale from (1) strongly disagree to (5) strongly agree. There were 5 questions to assess usability of the watch (e.g., *"The hands-on the watch are easy to read,"* α = .74), 6 questions for the usability of the Weekly Health Survey (e.g., *"The survey text is large enough and easy to read,"* α = .89), and 5 questions regarding the usability of the SMART survey (e.g., *"The instructions on the SMART survey are easy to understand,"* α = .87).

TPS survey domain: Acceptability

Participants were asked about their acceptability of the watch and SMART Survey on a scale from (1) strongly disagree to (5) strongly agree. There were 4 questions to assess the acceptability of the watch (e.g., *"The watch is comfortable,"* α = .82), and 2 questions regarding the acceptability of the SMART survey (e.g., *"The SMART survey doesn't take too much time,"* α = .64).

TPS survey domain: Barriers

Participants were asked about potential barriers to in-home monitoring technologies, in general, using a rating scale of (1) strongly disagree to (5) strongly agree. There were 6 questions addressing barriers to implementation of the technologies (e.g., *"It takes too much time to use in-home monitoring technologies,"* α = .78).

TPS survey domain: Digital readiness

Participants were asked about their current knowledge, experience, and comfort level engaging with Internet devices using a scale from (1) strongly disagree to (5) strongly agree. There were a total of 16 questions regarding digital readiness (e.g., *"I am confident in my ability to use computers,"* α= .93).

In-home monitoring study technology adherence metrics

To examine study technology adherence cross-sectionally, 3 months of available study technology use data were used, encompassing the month before, during, and after the TPS administration. A total of 3 adherence metrics were collected (wrist-worn fitness tracker watch, web-based health update questionnaire, web-based cognitive assessment). Watch adherence was calculated by dividing the number of days in the 3-month monitoring period with watch data by the total number of days (92) multiplied by 100. Current literature suggests that having 10 or more hours of watch data is considered a valid day of activity data (Tudor-Locke et al., 2012). Thus, days with less than 10 hours of watch data were removed prior to analysis. Weekly Health Survey adherence was calculated by dividing the number of times participants did not need reminder phone calls by the total number of surveys in the 3-month monitoring period (13) multiplied by 100. SMART adherence was calculated by dividing the number of times participants did not need reminder phone calls by the total number of surveys in the 3 months (3) multiplied by 100.

Technology maintenance visits

To examine participant's ability to problem-solve and trouble-shoot study technology independently when technical needs arose, 3 months of available technology maintenance visit data were used, encompassing the month before, during, and after the TPS administration. Research staff monitored technology on a weekly basis through an online interface to ensure that all study technologies were working properly. In the event of technical difficulty (e.g., software updates or watch resets, checking email spam folder for online surveys), research personnel called participants to troubleshoot issues over the phone.

If technical issues were not solved remotely, research staff traveled to participants' homes in order to repair or replace the technology. Total technology maintenance visits were aggregated for each participant over an available 7-month monitoring period prior to TPS administration.

Statistical analysis

Pearson correlations were conducted to examine the relationship between technology attitudes (i.e., usability, acceptability, barriers, and digital readiness) with demographics, functional abilities, and cognition. Cross-sectional comparisons of the technology attitudes, technology maintenance visits, and watch adherence variables for the MCI and cognitively intact groups were made using Student's t-tests. Of note, given the limited number of time points for Weekly Health Survey (13) and SMART Survey (3) adherence and the skewed distribution (i.e., skewness value >3; e.g., Kline, 2009), these adherence metrics were dichotomized into *"100% adherent"* (no reminder calls needed) or *"non-adherent"* (reminder call needed at least once). However, the small cell sizes (i.e., <5 individuals) precluded any additional statistical comparisons for the MCI and cognitively intact groups on these variables. Cohen's d and f2 were used as measures of effect size.

To examine whether technology attitudes predict adherence, simultaneous multiple regression using the total sample explored whether watch usability and acceptability predicted watch adherence. Binary logistic regressions were performed to determine whether technology attitudes (i.e., Weekly Health/SMART usability, SMART acceptability) predicted Weekly Health Survey and SMART adherence (i.e., 100% adherence versus non-adherence). All summaries and analyses were performed using SPSS version 24.

To examine the qualitative data, the first and second authors used thematic analysis to code all open-ended responses into themes (Braun & Clarke, 2006). Both coders read all responses and generated a set of coding categories independently. The coding schemas were then discussed between the two coders and adjusted as needed. The research team kept documentation detailing how the data were collected and managed to ensure transparency and credibility.

Results

Participant characteristics

Demographic data for the MCI and cognitively intact groups are presented in *Table 1*. The sample consisted of white (N = 30, 100%), primarily male (n = 28, 93.3%) military veterans (enlisted n = 23, 76.67%; officer n = 7, 23.33%) with an average age of 73.46 years (SD = 5.16) and 14.93 years of education (SD = 2.03). Average individual annual earnings fell in the range of $25,000-$34,999, with a normal distribution of income scores. Means, standard deviations, range, skewness, and kurtosis values for adherence and attitudes data are presented in *Table 2*.

Relationship between technology attitudes, adherence, cognition, functional independence, and demographic variables

There was a negative correlation between the FAQ and digital readiness, such that lower digital readiness was correlated with higher FAQ scores (i.e., worse functional performance; r = -.40, p = .030). Regarding cognition, increased digital readiness was correlated with better global cog-

Table 1. Group differences in demographics and baseline cognitive scores.

Variable	Total (*N* = 30) M (*SD*), N (%)	MCI (*N* = 15) M (*SD*), N (%)	Cognitively Intact (*N* = 15) M (*SD*), N (%)	*p*-value
Age at baseline (years)	73.46 (5.16)	74.12 (5.54)	72.80 (4.85)	.49
Sex (% male)	28 (93.3%)	14 (93.3%)	14 (93.3%)	--
Race (% white)	30 (100%)	15 (100%)	15 (100%)	--
Education (years)	14.93 (2.03)	14.87 (2.26)	15.00 (1.85)	.86
Earnings (individual)	5.30 (2.37)	5.73 (2.22)	4.87 (2.40)	.32
MoCA	24.63 (2.27)	23.00 (1.73)	26.27 (1.39)	<.001
GDS	1.33 (1.32)	1.53 (1.51)	1.13 (1.12)	.42
FAQ	1.00 (1.60)	1.60 (1.84)	0.40 (1.06)	.037
Global cognition	-.42 (.58)	-.77 (.59)	-.06 (.25)	<.001
Memory	-.62 (.57)	-.83 (.60)	-.40 (.44)	.033
Language	-.16 (.58)	-.43 (.52)	.10 (.53)	.010
Attention and processing speed	.21 (.43)	-.03 (.39)	.45 (.32)	.001
Executive functioning	-.23 (.59)	-.60 (.52)	.15 (.40)	<.001
Visuospatial perception/ Construction	-.39 (.76)	-.67 (.81)	-.11 (.61)	.041

Note: Participants were asked how much they earned (Earnings [Individual]) before taxes and other deductions, during the past 12 months (For reference, 1=less than $5,000, 2=$5,000-$11,999, 3=$12,000-$15,999, 4=$16,000-$24,999, 5=$25,000-$34,999, 6=$35,000-$49,999, 7=$50,000-$74,999, 8=$75,000-$99,000, 9=$100,000 and greater).

Table 2. Adherence and attitudes data.

Adherence/Attitude metrics	M (*SD*); N (%)	Range	Skewness	Kurtosis
Watch adherence (% of days worn)	80.07% (20.61%)	31.25% -100%	-1.08	-.028
Number of individuals with 100% Weekly Health Survey adherence	n = 23 (77%)	--	--	--
Number of Individuals with 100% SMART adherence	n = 26 (87%)	--	--	--
Technology visits	2.43 (1.72)	1.00-7.00	1.50	1.64
Watch usability	18.20 (3.84)	11.00-25.00	-0.38	-0.38
Watch acceptability	13.33 (3.21)	7.00-20.00	0.29	0.06
Weekly Health Survey usability	27.10 (3.06)	18.00-30.00	-0.97	0.77
SMART usability	21.80 (2.61)	15.00-25.00	-0.37	-0.23
SMART acceptability	8.17 (1.09)	6.00-10.00	0.34	-0.48
Barriers	14.50 (3.53)	8.00-22.00	-0.01	-0.59
Digital readiness	53.87 (11.58)	25.00-76.00	-0.48	0.24

Note. The Weekly Health Survey and SMART Adherence metrics were treated as dichotomous variables (100% adherent, non-adherent). For the attitude metrics, greater scores reflect greater attitudes.

nition (r = .50, p = .005), attention (r = .41, p = .026), and executive functioning (r = .47, p = .008). Technology barriers were correlated with memory (r = .43, p = .018) and global cognition (r = .36, p =.049), such that those with better cognitive performance endorsed more technology barriers. Greater SMART Survey usability scores were correlated with better visuospatial skills (r = .38, p = .038).

Correlational analyses were also used to examine the relationship between technology maintenance and watch adherence visits with demographics, functional questionnaires, and cognition. Greater number of technology maintenance visits was related to higher FAQ (i.e., worse functional performance; r = .50, p = .003). Technology maintenance visits were also negatively correlated with executive functioning (r = -.41, p = .026) and global cognition (r = -.38, p = .038), such that poorer cognitive performance was associated with increased number of technology maintenance visits. Watch adherence was not related to cognitive or functional performance.

MCI and cognitively intact group differences in technology attitudes (perceived barriers, digital readiness), technology maintenance visits, and adherence

The MCI group endorsed reduced digital readiness as compared to the cognitively intact group, t(28) = 2.14, p =.041, d = .79, 95% confidence interval [CI] 0.36 – 16.71 . The MCI group had significantly more technology maintenance visits (M = 3.07, SD = 1.94) than the cognitively intact group (M = 1.80, SD = 1.21; t(28) = -2.14, p =.041, d = .78, 95% CI .056 – 2.48,). There were no differences in watch adherence (p = .54) or perceived barriers (p = .088) between groups.

Relationship between attitudes and adherence

Simultaneous multiple regression analysis explored whether watch usability and acceptability were associated with greater watch adherence. The overall model significantly predicted adherence, F(2,29) = 5.82, p = .008, f^2 =.07, explaining 25% of the variance in watch adherence. However, neither watch usability (β = .28, p =.14) nor watch acceptability (β = .36, (p =.059) alone were individual predictors of adherence. For the binary logistic regression analyses, neither the overall model nor the SMART usability and acceptability variables was significant predictors of SMART adherence groups, X^2 (2) = .14, p = .93. Finally, Weekly Survey Usability did not predict membership in the Weekly Survey adherence groups, X^2 (2) = .06, p = .81.

Participant feedback about experiences with study technologies

Open-ended comments or concerns about the study technologies were examined. There were 3 open-ended questions for each individual pertaining to the use of study technology. A little less than one-third of possible responses were completed (n = 27; 30.0% of questions). Through this process, 4 common themes were identified: technology design issues, adjustment issues, cognitive barriers to participation, and study design limitations. The largest number of responses (n = 16) was related to technology design issues (e.g., *"I don't like the watch because it's hard to see the hands on the clock and there are no numbers"*). A second set of participants (n = 5) reported difficulties adjusting to the technology and incorporating it into their daily routine (e.g., *"I had not worn a watch for the past few years so it has been difficult getting used to wearing one again"*). An additional theme (n = 4) raised concerns about the potential impact of cognition on engagement with the technologies (e.g., *"I must admit that the color tests on the SMART can be a bit confusing, even for someone who is intelligent and alert"*). Finally, 2 participants reflected a limitation of the current study design being that researchers did not give participants' reports on their progress throughout the study (e.g., *"I would be interested in my readings of movement over the course of the study"*).

Discussion

This exploratory mixed-methods pilot study was the first to assess attitudes, use, and adherence toward in-home activity monitoring technologies in a sample of MCI and cognitively intact older adults who had activity monitoring technologies installed in their homes for 7-months. Results showed that MCI status significantly impacted individuals' technology attitudes and trouble-shooting abilities, but not adherence to the in-home study technologies. Specifically, individuals with MCI endorsed reduced digital readiness, which is consistent with prior self-report research on the perceived difficulty of everyday technology in MCI (Nygard et al., 2012). This has important implications for incorporating technology in the context of MCI or other cognitive deficits. Researchers may consider including technology training workshops for study participants earlier in the course of the research project, with a special focus on individuals with MCI or earlier stages of cognitive decline. Furthermore, the MCI group required significantly more technology maintenance visits as compared to the cognitively intact group. Trouble-shooting study technologies rely on several high-level cognitive abilities, including executive functions, visuospatial skills, memory, language, and processing speed, and thus may be impacted by an individual's cognitive functioning. Future in-home activity monitoring research should investigate whether digital readiness and technology-related maintenance visits may serve as sensitive early indicators of cognitive decline.

Although results suggest that individuals with MCI might be more reluctant and may have greater difficulty using everyday technologies, adherence did not differ for MCI and cognitively intact participants. Remembering to wear a watch or complete web-based surveys are routine behaviors, require less active problem-solving skills, and may be less sensitive to MCI. While not significantly different between groups, perceived barriers were significantly correlated with memory and global cognition. The significant relationship with cognition is consistent with Boise et al. (2013) who found that individuals with MCI were more willing to be videotaped in their own home and reported fewer concerns about privacy than those who were cognitively intact. Individuals with reduced cognition may be less attentive to the privacy risks associated with Internet use and less able to predict future risks regarding technology engagement. Alternatively, older adults with cognitive difficulties may be more inclined to adopt at-home technologies and have fewer concerns about barriers in order to preserve their independence for longer periods.

Watch usability and acceptability were significantly associated with the watch adherence metric. The relationship between watch attitudes and adherence is consistent with research demonstrating that greater usability and acceptability are strong predictors of technology adoption (Davis, 1989; Lee & Coughlin, 2015). Of note, the combination of usability and acceptability predicted watch adherence rather than either attitude alone, suggesting that future researchers should account for multiple aspects of technology attitudes in order to optimize successful adherence in older adult populations. In contrast, usability and acceptability of the web-based surveys (i.e., SMART and Weekly Health Survey) did not predict survey adherence. The differential impact and importance of technology attitudes on watch adherence may be related to the more time-intensive nature (used daily/nightly throughout the entire study period) of this technology as compared to the weekly and monthly web-based surveys (5-10 minutes once a week or per month).

Informant-rated functional abilities were associated with lower digital readiness and required a higher number of technology maintenance visits. It is likely that the individuals with lower functional abilities have poorer subjective and objective cognition, impacting their self-perceived digital readiness and ability to problem solve technological issues. Contrary to what was hypothesized, demographic variables (i.e., SES and educational attainment) did not predict attitudes or adherence to study technologies. The present sample of participants may represent a select group of older adults open to technology given their decision to participate in a study focused on in-home monitoring technologies and the use of their personal computers or other Internet devices.

Open-ended responses about the study's technologies provide additional insight into how activity monitoring technology may be improved to meet the needs of older adults with MCI. Several recommendations from participants mentioned that small design adjustments to the study's technologies can ensure it fits the needs of its end users. In-home monitoring technology developers and researchers should consult older adults with and without MCI to adapt future product designs for each unique group. Further, researchers should consider giving participants feedback on their activity monitoring data throughout the study in order to encourage continued use and engagement. In response to adjustment issues and cognitive barriers to participation, researchers may consider monthly check-in calls with participants to reduce frustration, especially when learning to use the new technology. Both qualitative and quantitative analyses highlighted that future activity monitoring studies should recognize the importance of assessing user attitudes given their corresponding impact on technology adherence.

Our small, primarily white male veteran sample who lived near a major metropolitan area reduces the generalizability of our findings. Future studies should incorporate older adults with a larger range of economic, educational, and technological backgrounds to better understand how demographic factors influence attitudes in the broader aging population. The TPS was an experimental measure developed by the research team to assess participant attitudes towards study-specific in-home monitoring technologies. While beyond the scope of the current pilot study, rigorous investigation of the psychometrics of the attitude subscales is needed to demonstrate the reliability and validity of the measure and validate the findings. Additionally, we acknowledge that there are many in-home monitoring technologies that are more passive in nature (e.g., in-home motion sensors, driving monitoring sensors) than the technology used in the present study. Future studies should investigate the difference in attitudes between a wide variety of in-home monitoring technologies and how these attitudes influence adherence and adoption.

Results highlight that researchers and developers should consider older adults' attitudes and level of cognitive functioning (MCI versus cognitively intact) in the design of in-home monitoring technologies so that these devices better fit the current and future needs of older adults across the continuum of cognitive functioning. In the context of the COVID-19 pandemic, which has limited older adults' access to non-essential, in-person medical care given the increased risk of virus contraction (Centers for Disease Control and Prevention, 2020), we are learning that future clinical work and research will require in-home, technology-based assessment and intervention with older adults. There is still more to learn about how cognitive status affects the adoption and adherence to technology, which is relevant to the development of activity monitoring and assistive technologies and their adoption in older adult and cognitively impaired populations.

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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Appendix I: Technology perception survey (TPS) items and attitude scores

Item	Total (*N* = 30) *M (SD)*	Cognitively intact (*N* = 15) *M (SD)*	MCI (*N* = 15) *M (SD)*
Watch usability	18.20 (3.84)	18.33 (4.58)	18.07 (3.08)
It was easy to adjust to wearing the watch	4.03 (.96)	4.07 (.96)	4.00 (1.00)
The hands on the watch are easy to read	3.23 (1.19)	3.27 (1.22)	3.20 (1.21)
The watch keeps accurate time	3.87 (1.07)	4.00 (1.00)	3.73 (1.16)
I have had trouble with my watch band[a]	2.87 (1.33)	3.07 (1.53)	2.67 (1.11)
It's easy for me to take the watch on and off	3.93 (.83)	4.07 (.96)	3.80 (.68)

Watch acceptability	13.33 (3.21)	13.53 (2.88)	13.13 (3.60)
I enjoy wearing the watch	3.20 (1.03)	3.27 (.96)	3.13 (1.13)
The watch is comfortable	3.47 (1.01)	3.47 (.99)	3.47 (1.06)
I don't mind sleeping with the watch on	4.00 (.64)	4.07 (.59)	3.93 (.70)
I don't mind showering with the watch on	2.67 (1.30)	2.73 (1.22)	2.60 (1.40)
Health Survey Usability	27.10 (3.06)	28.00 (2.45)	26.20 (3.41)
It is easy to find the ORCATECH Weekly Health Form email in my inbox	4.50 (.82)	4.67 (.49)	4.33 (1.05)
It is easy to go through all the questions on the ORCATECH Weekly Health Form	4.47 (.82)	4.73 (.46)	4.20 (1.01)
The survey text is large enough and easy to read	4.63 (.49)	4.80 (.41)	4.47 (.52)
The instructions on the ORCATECH Weekly Health Form are easy to understand	4.63 (.49)	4.73 (.46)	4.53 (.52)
The drop-down boxes and calendars within the survey are easy to use	4.47 (.51)	4.53 (.52)	4.40 (.51)
The questions on the ORCATECH Weekly Health Form are easy to understand	4.40 (.56)	4.53 (.64)	4.27 (.46)
SMART usability	21.80 (2.61)	22.47 (2.59)	21.13 (2.53)
It is easy to find the Monthly ORCATECH SMART Survey email in my inbox	4.43 (.68)	4.60 (.51)	4.27 (.80)
The survey text is large enough and easy to read	4.43 (.68)	4.67 (.49)	4.20 (.78)
It is easy to go through all of the activities and find the Monthly ORCATECH SMART Survey	4.47 (.63)	4.60 (.63)	4.33 (.62)
The words and pictures on the Monthly ORCATECH SMART Survey are large enough and easy to read	4.40 (.50)	4.47 (.52)	4.33 (.49)
The instructions on the Monthly ORCATECH SMART Survey are easy to understand	4.07 (.69)	4.13 (.83)	4.00 (.54)
SMART acceptability	8.17 (1.09)	8.27 (1.10)	8.07 (1.10)
The practice items on the Monthly ORCATECH SMART Survey that come before each activity are helpful	3.93 (.79)	3.93 (.70)	3.93 (.88)
The Monthly ORCATECH SMART Survey doesn't take too much time	4.23 (.43)	4.33 (.49)	4.13 (.35)
Technology barriers	14.50 (3.53)	15.60 (3.68)	13.40 (3.11)
It takes too much time to use in- home monitoring technologies	1.70 (.70)	1.87 (.74)	1.53 (.64)
It costs too much money to use in-home health monitoring technologies	2.13 (.86)	2.27 (.80)	2.00 (.93)
Using in-home monitoring health technologies makes me feel self-conscious	2.00 (.95)	2.27 (.96)	1.73 (.88)
I worry that other people might judge me for using in-home health monitoring technologies	1.40 (.56)	1.53 (.64)	1.27 (.46)
I am concerned that my information could be given to people/organizations that do not have a right to it[ab]	2.33 (.92)	2.20 (.86)	2.47 (.99)

I am concerned about my privacy in relation to in-home monitoring[ab]	2.40 (1.04)	2.13 (.99)	2.67 (1.05)
Technology readiness*	53.87 (11.58)	58.13 (8.90)	49.60 (12.64)
I feel confident about troubleshooting issues with my home internet and connected devices (modem/router, computer, smartphone)	3.00 (1.17)	3.00 (1.25)	3.00 (1.13)
I feel knowledgeable enough about my home internet and my connected devices, and how they all work together	3.03 (1.00)	3.07 (.96)	3.00 (1.07)
If I have a problem with my home internet or device in my home, I am confident that I can solve the problem	2.77 (1.22)	2.53 (1.30)	3.00 (1.13)
If I have a problem with my home internet or device in my home, I am confident that I can call somebody for help to solve it	4.27 (.58)	4.33 (.49)	4.20 (.68)
I feel at ease with computers*	3.53 (.97)	3.93 (.70)	3.13 (1.06)
I feel confident about looking for information on the internet*	4.30 (.84)	4.67 (.49)	3.93 (.96)
I feel confident about using e- mail	4.40 (.86)	4.67 (.49)	4.13 (1.06)
I feel confident that I can find an e-mail in my Spam folder*	3.87 (1.28)	4.47 (.83)	3.27 (1.39)
I feel confident about creating separate user accounts on my computer*	3.13 (1.31)	3.60 (1.18)	2.67 (1.29)
I feel confident about filling out forms and entering information on the Internet*	3.83 (1.05)	4.27 (.70)	3.40 (1.18)
I am confident in my ability to use computers*	3.73 (1.05)	4.27 (.59)	3.20 (1.15)
In general, I am among the first in my circle of friends to acquire new technology when it appears*	2.43 (.97)	2.80 (.94)	2.07 (.88)
I can usually figure out new high-tech products and services without help from others	2.53 (1.04)	2.87 (.99)	2.20 (1.01)
I keep up with the latest technological developments in my areas of interest	2.83 (.91)	3.13 (.83)	2.53 (.92)
I prefer to use the most advanced technology available	2.70 (.92)	2.93 (.80)	2.47 (.99)
Technology gives me more independence	3.50 (.90)	3.60 (.63)	3.40 (1.12)

Note. Responses were on a 5-point Likert-type scale unless otherwise noted.

[a]Item was reversed scored when calculating the total score.

[b]Likert-type scale: 1 = very concerned; 2 = somewhat concerned; 3 = not very concerned; 4 = not concerned at all

**p* < .05, ** *p* < .01