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Six-Month Effectiveness of Remote Activity Monitoring for Persons Living With Dementia and Their Family Caregivers: An Experimental Mixed Methods Study

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Abstract

Background and Objectives: This study aimed to evaluate if and how remote activity monitoring (RAM) improves caregiver outcomes for family members providing care for persons living with Alzheimer's disease or a related dementia (ADRD).

Research Design and Methods: We conducted an embedded experimental mixed methods study of 132 persons living with ADRD and their family caregivers ($n = 64$ randomly assigned to RAM treatment condition). In addition to baseline and 6-month quantitative survey data on context of care, primary objective stressors, resources, self-efficacy/competence, and distress collected from caregivers, 6-month RAM review checklists contained open-ended, qualitative information on perceived acceptability of the technology.

Results: The RAM system did not exert statistically significant effects on caregiving outcomes over a 6-month period. However, qualitative analyses identified several potential moderators of RAM technology effectiveness that were subsequently tested in post-hoc repeated measures analyses of variance. Caregivers who utilized RAM technology and cared for relatives with: (a) less severe cognitive impairment; and (b) difficulty navigating around the home were more likely to indicate statistically significant increases in competence and self-efficacy, respectively.

Discussion and Implications: We found that the early months spent calibrating and modifying RAM are potentially challenging for families, which may prevent this technology from improving caregiving outcomes during initial months of use. Remote activity monitoring may work optimally for caregivers of persons living with ADRD in specific situations (e.g., earlier stages of dementia; wandering risk), which suggests the need for appropriate needs assessments that can better target such innovations.

Keywords: Alzheimer's disease, Technology, Smart home, Family caregiving, Informal caregiving, Stress, Depression, Randomized controlled trial, Evaluation, Passive monitoring

The aging of the U.S. population and the sheer costs of delivering health care to older persons have led to the development of technological solutions designed to maintain or improve quality of life for older persons (Chippis,

Jarvis, & Ramlall, 2017; Czaja, Boot, Charness, Rogers, & Shant 2017; Lindeman & Gladstone, 2018; Schulz et al., 2015). The provision of long-term care, particularly for individuals living with Alzheimer's disease and related

dementias (ADRD), is labor intensive, complex, and largely assumed by families (Gaugler & Kane, 2015; Wolff et al., 2017). It is unclear how technology can either replace or enhance the delivery of family care for persons living with ADRD. Current sociodemographic trends indicate the number of family caregivers available to care for older relatives is expected to decline in the upcoming decades (National Academies of Sciences, Engineering, Medicine, 2016; Redfoot, Feinberg, & Houser, 2013; Stone, 2015). Concurrent with this trend is the ongoing geriatric workforce shortage, which would further exacerbate the “family care gap” (Gaugler & Kane, 2015; Stone, 2015).

A critical scientific as well as policy and practice question, then, is whether the use of technology can sustain and support ADRD family care (Demiris, 2015; Schulz et al., 2015). The current study aims to address this question by evaluating whether and how remote activity monitoring (RAM) technology improves key family caregiver outcomes over a 6-month period.

Background: Efficacy and Effectiveness of Remote Activity Monitoring

Remote activity monitoring (RAM) involves the use of sensors (e.g., motion detectors, or sensors worn on the body) to monitor the movement/activity of a person living with ADRD, generally in the home or in an assisted living facility (Block et al., 2016; Bossen, Kim, Williams, Steinhoff, & Strieker, 2015; D’Onofrio et al., 2017). Monitoring systems issue alerts to professional or family caregivers if adverse events (e.g., falls) or abnormal behaviors/activities (e.g., wandering) occur. Remote activity monitoring technology may also generate reports of activity patterns over time, allowing caregivers to track changes in activity that may indicate a health problem (e.g., using the restroom more frequently).

The information provided by RAM may contribute to more accurate information on daily activities, improved communication, early identification of problems, and facilitation of caregiving (Nauha, Keranen, Kangas, Jamsa, & Reponen, 2016; Nijhof, van Gemert-Pijnen, Woolrych, & Sixsmith, 2013; Wild, Mattek, Austin, & Kaye, 2016; Williams, Arthur, Niedens, Moushey, & Hutflés, 2013). There are several barriers to implementing and utilizing RAM, including cumbersome devices (Matthews et al., 2015), a lack of user-friendly interfaces (Nauha et al., 2016; Preusse, Mitzner, Fausset, & Rogers, 2017), frequent false alarms (Mitchell et al., 2018; Nauha et al., 2016; Nijhof et al., 2013), and unanticipated technological difficulties (Mitchell et al., 2018; Nauha et al., 2016; Williams et al., 2013). Beyond technical problems, the trade-off between privacy and usefulness of monitoring is an important ethical issue (Mitchell et al., 2018; Mulvenna et al., 2017; Wild, Boise, Lundell, & Foucek, 2008; Williams et al., 2013). Nonetheless, many older adults are interested in the potential of monitoring technologies to improve and maintain

their health status and independence (Chaudhuri et al., 2017; Preusse et al., 2017; Shreve, Baier, Epstein-Lubow, & Gardner, 2016; Wild et al., 2008).

Though research on the acceptability and utility of RAM has advanced, there are few randomized controlled studies of the effectiveness of RAM for adults living with ADRD or their family caregivers (Gagnon-Roy et al., 2017; Reeder et al., 2013). Available randomized controlled trials feature smaller samples ($N \leq 60$), but suggest potentially positive effects of RAM for family caregivers and older adults (Rowe et al., 2009; Torkamani et al., 2014). A recent, larger controlled evaluation implied positive (albeit not statistically significant) trends on RAM users’ health care costs (Finch, Griffin, & Pacala, 2017).

Conceptual Model

To evaluate RAM, the current study relied on The Stress Process Model (SPM). The SPM has been used extensively to study the manifestation of negative outcomes in dementia caregiving (Pearlin, Mullan, Semple, & Skaff, 1990) and is aligned with conceptualizations of intervention effectiveness in the health information technology literature (Jimison et al., 2008). The SPM is based on the mechanism of “proliferation,” where the emotional stress of care provision to a person living with dementia (primary stress) spreads to other life domains that are then posited to negatively influence global caregiving outcomes such as caregiver mental health or the person living with ADRD’s institutionalization. Psychosocial resources or formal service use may help curtail stress proliferation and protect ADRD caregivers from negative outcomes.

The conceptual framework for the current project integrates constructs from the SPM. Context of care variables represent sociodemographic and background characteristics that may influence outcomes for persons living with ADRD or their family caregivers. Similarly, resource variables such as perceptions of socioemotional support are considered as covariates in the current study’s conceptual model that could potentially alleviate negative outcomes. A final domain of covariates includes primary objective stressors, or indices of ADRD severity that may require greater day-to-day care provision on the part of family members. The proposed conceptual model positions RAM technology as a key resource for family caregivers of persons living with ADRD that could improve caregiver self-efficacy and competence (e.g., being able to handle caregiving problems) and reduce caregiver distress (subjective stress and depressive symptoms).

Research Focus

The current study relies on preliminary 6-month outcome data from a parent mixed methods, randomized controlled evaluation of RAM technology for persons living with

ADRD at home. The current study tested the following quantitative hypotheses:

- 1) At the 6-month follow-up, family caregivers randomly assigned to receive RAM technology would experience significant ($p < .05$) improvements in self-efficacy and sense of competence when managing a relative's ADRD compared to caregivers not assigned to receive RAM technology.
- 2) At the 6-month follow-up, families randomly assigned to receive technology compared to those who did not would report significant reductions in caregiver distress (e.g., subjective stress, depressive symptoms).

An additional question was used to guide the analysis of available qualitative data among family caregivers of persons living with ADRD who utilized the RAM technology over a 6-month period:

- 1) What made a difference in how RAM was received by participants?

If qualitative themes identified specific SPM variables that could potentially moderate the effectiveness of RAM technology on ADRD caregiver outcomes, a series of post-hoc analyses were conducted to further explore the potential mechanisms of benefit (or lack thereof) for RAM technology in ADRD caregiving situations.

Methods

Design

We utilized an embedded experimental mixed methods design (i.e., collection and analysis of qualitative data within a traditional randomized controlled trial) to examine the preliminary effectiveness of RAM for family caregivers of persons living with ADRD ([QUAN+qual]→QUAN) (Creswell & Plano-Clark, 2010; p. 90). Efficacy ("performance of an intervention under ideal conditions") and effectiveness ("an intervention's importance in real-world conditions") exist on a continuum, and thus it is unlikely that any given intervention is solely an efficacy or effectiveness trial (Singal, Higgins, & Waljee, 2014, p. 1). Although we employ a randomized controlled design, the use of RAM in the everyday homes of persons living with ADRD and their family caregivers and the relatively inclusive sampling plan places the current study closer to effectiveness than efficacy trial. As we are presenting preliminary outcome data from a larger parent trial of RAM that follows persons living with ADRD and their caregivers for up to 18 months, we thus consider this study a "preliminary effectiveness" evaluation.

Remote Activity Monitoring System

The RAM system features motion sensors that are placed throughout the home in order to monitor daily activity.

The sensors operate jointly and exchange information on movement. Data collected by the sensors are analyzed using algorithms developed by the RAM provider. Once a baseline activity pattern is established, significant and persistent deviations are communicated to family caregivers, alerting them to abnormal activity patterns that may indicate a possible health condition of the care recipient.

Users can specify conditions that trigger alerts based on unexpected or potentially dangerous activity. For example, sensors can identify if the care recipient is leaving the home at unexpected times or is staying in the bathroom too long. Alerts can be customized to match the expected schedules of each care recipient as well. Caregivers can be alerted by phone or e-mail, and users can create a list of family, friends, and others to contact in the event that the primary caregiver cannot be reached. Care recipients are also given an emergency call pendant that can be worn around the neck. An online dashboard that stores and displays the data collected by RAM is available to caregivers and can be shared with health service providers. The [Supplementary Material](#) includes images of the sensors as well as data displays from the online dashboard.

Sample

Inclusion criteria for persons living with ADRD were: (a) English speaking; (b) physician diagnosis of ADRD; (c) not currently receiving RAM or similar services; and (d) ≥ 55 years of age. Caregivers of persons living with ADRD had to: (a) speak English; (b) be ≥ 21 years of age; (c) self-identify as the person most responsible for providing hands-on care to the person living with ADRD; and (d) plan to remain in the area for at least 18 months. Informed consent was obtained from the caregiver (and legally authorized representative). The person living with ADRD provided assent to participate. As of November 30, 2017, 132 ADRD caregivers were scheduled to complete 6 months of follow-up and served as the sample for the current analysis ($n = 64$ randomized to RAM treatment group; $n = 68$ to usual care control). The parent mixed methods evaluation of RAM is continuing to enroll new participants until June 2018 to follow for up to 18 months.

Procedure

Research coordinators initiated e-mail, telephone, or mail contact with ADRD caregivers on the University of Minnesota Caregiver Registry or via various newspaper advertisements, community presentations, and similar efforts. If caregivers expressed interest in participating, the research coordinators described the RAM system and explained study procedures. If caregivers agreed to participate, the research coordinators initiated a brief screening procedure. For eligible participants, signed consent and verbal assent of family caregivers and persons living with

ADRD were scheduled and obtained, and a baseline survey was administered either online or via traditional mail. Following the completion of baseline surveys, ADRD caregivers were randomly assigned to the RAM treatment condition that received the multisensor RAM system or a usual care control group. Randomization was completed via a list generated from <http://randomizer.org>; allocation was based on an a priori randomization assignment number. A follow-up survey was then administered to all participating caregivers at 6 months.

Two weeks after randomization to the RAM treatment condition, the Director of Health and Technology Services (HTS) scheduled a visit or telephone conference at the home of the person with ADRD and the enrolled family caregiver. During this initial contact, the HTS conducted a needs assessment to determine the best use and deployment of the RAM system in the person living with ADRD's home. The HTS assessed the home environment (e.g., square footage, number of bathrooms and bedrooms) and asked questions regarding health conditions and other risk factors such as concerns with eating or weight, hospitalizations, use of assistive devices, and history of falls. Following the needs assessment, the HTS discussed the results with the ADRD caregiver and reviewed how the RAM system operates as well as how to utilize the system. This included a review of the online dashboard. The RAM system was then installed in the person living with ADRD's home and the HTS programmed the expected performance thresholds and daily routines. The HTS supervised all system maintenance (battery changes, troubleshooting in instances when there was a loss of system contact) and ensured the system operated properly for ADRD caregivers. Caregivers were also free to contact the HTS at any time if an issue arose that required immediate attention (e.g., damaged or inoperable sensor).

Measures

Context of Care

Context of care variables included time since diagnosis, living arrangement of the care recipient, caregiver and care recipient demographics, and similar indicators (see [Table 1](#)).

Primary Objective Stressors

Primary objective stressors included the person living with ADRD's dependence on assistance with six *activity of daily living (ADL) tasks* and six out of eight *instrumental activity of daily living (IADL) tasks* ($\alpha = .89$, [Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963](#); $\alpha = .96$, [Lawton & Brody, 1969](#)). The six IADL items utilized were taking medication, cooking/preparing food, housekeeping/cleaning, doing laundry, transportation, and managing finances. An 8-item scale measured the intensity of relatives' memory losses, communication deficits, and recognition failures at each time point (*cognitive impairment*; $\alpha = .86$) ([Pearlin et al., 1990](#)). The frequency of *behavior problems* in the

person living with ADRD was measured with the Revised Memory and Behavior Problems Checklist (R-MBPC; $\alpha = .89$), which consists of a list of 30 common behavior problems in ADRD ([Teri et al., 1992](#)).

Resources

Socioemotional support was measured on a 5-item scale to assess the affective assistance provided to the caregiver by relatives or friends at each time point ($\alpha = .68$; [Pearlin et al., 1990](#)).

Caregiver Self-efficacy and Sense of Competence

An 8-item measure of *caregiver self-efficacy* was utilized ($\alpha = .86$; [Fortinsky, Kercher, & Burant, 2002](#)). Caregivers' *sense of competence* was measured with the 7-item Short Sense of Competence Questionnaire (SSCQ), which assesses individuals' sense of capability in providing assistance to a relative with ADRD ($\alpha = .74$; [Vernooij-Dassen et al., 1999](#)).

Caregiver Distress

It was measured using the 22-item Zarit Burden Interview ($\alpha = .93$; [Hébert, Bravo, & Préville, 2000](#); [Zarit, Reever, & Bach-Peterson, 1980](#)). Two indices of subjective stress were also utilized: a 4-item scale assessing the involuntary aspects of the caregiving role ($\alpha = .80$; *role captivity*) and a 3-item scale measuring caregivers' feelings of emotional and physical fatigue ($\alpha = .81$; *role overload*) ([Pearlin et al., 1990](#)). The 20-item *Center for Epidemiological Studies-Depression (CES-D)* scale was used to measure caregiver depressive symptoms ($\alpha = .94$; [Radloff, 1977](#)).

RAM System Review Checklist

The *RAM Review Checklist* was administered to ADRD caregivers in the treatment condition at the 6-month follow-up survey interval. The checklist consists of 22 Likert scale items and 8 open-ended questions that measure/explore acceptability, feasibility, and perceived utility of RAM (for details, see [Mitchell et al., 2018](#)). Only the open-ended questions were analyzed for themes. Example questions include "How easy was RAM to use?" and "Do you feel the alerts generated by RAM worked well? Why or why not?" Themes were mapped onto quantitative baseline variables and included in the post-hoc analyses (see below).

Analysis

Descriptive statistics were calculated for measures of context of care, primary objective stressors, and resources. Chi-square and *t* tests were used to compare participants in the treatment and usual care control groups. If baseline differences were identified, they were incorporated as covariates in subsequent quantitative analyses. Multivariate repeated measures of analyses of variance (ANOVAs)/covariance were conducted to test study hypotheses. The independent variable in each of these models was treatment assignment (RAM technology or usual care without RAM). Statistical significance was assessed using two-tailed tests

Table 1. Baseline Demographics of Caregivers and Care Recipients

Caregiver characteristics	Total (N = 132)		Treatment (n = 64)		Control (n = 68)		p-value
Age, mean (SD), years	61.71	(12.09)	61.32	(11.36)	62.07	(12.80)	.580
Female, n (%)	103	(78.0)	50	(79.4)	53	(77.9)	.843
Hispanic, n (%)	2	(1.5)	0	(0.0)	2	(3.0)	.226
White, n (%)	128	(97.0)	62	(96.9)	66	(97.1)	.951
Married, n (%)	109	(82.6)	50	(78.1)	59	(86.8)	.191
Living children, mean (SD)	2.06	(1.71)	1.86	(1.46)	2.25	(1.91)	.079
Bachelor's Degree or higher, n (%)	88	(66.7)	43	(67.2)	45	(66.2)	.902
Above median income, n (%)*	56	(42.4)	23	(35.9)	33	(48.5)	.143
Employed, n (%)	54	(40.9)	26	(40.6)	28	(41.2)	.949
Socioemotional support, mean (SD)	31.95	(4.64)	32.43	(5.18)	31.50	(4.06)	.786
Care recipient characteristics							p-value
Age, mean years (SD)	77.88	(9.23)	78.05	(9.24)	77.72	(9.28)	.993
Female, n (%)	69	(52.7)	34	(54.0)	35	(51.5)	.775
Hispanic, n (%)	2	(1.6)	1	(1.6)	1	(1.5)	.618
White, n (%)	123	(93.2)	59	(92.2)	64	(94.1)	.660
Married, n (%)	80	(60.6)	38	(59.4)	42	(61.8)	.779
Living children, mean (SD)	2.91	(2.17)	2.80	(2.28)	3.01	(2.08)	.933
Bachelor's Degree or higher, n (%)	62	(47.0)	28	(43.8)	34	(50.0)	.472
Above median income, n (%)*	78	(59.1)	36	(56.3)	42	(61.8)	.520
ADLs, mean (SD)	2.41	(2.70)	2.32	(2.40)	2.50	(2.96)	.202
IADLs, mean (SD)	7.56	(3.63)	7.36	(3.61)	7.74	(3.67)	.894
RMBPC frequency, mean (SD)	1.47	(0.57)	1.56	(0.57)	1.40	(0.56)	.906
Cognitive impairment, mean (SD)	2.55	(0.82)	2.61	(0.76)	2.50	(0.88)	.157
Medicaid, n (%)	26	(19.8)	13	(20.6)	13	(19.1)	.828
Common characteristics							p-value
CG is spouse of care recipient, n (%)	65	(49.2)	29	(45.3)	36	(52.9)	.381
Live together, n (%)	74	(56.1)	36	(56.3)	38	(55.9)	.966
First noticed memory problem in CR, mean (SD), months	48.82	(27.59)	48.47	(26.56)	49.15	(28.70)	.588
First helped CR, mean (SD), months	34.19	(23.99)	35.34	(23.93)	33.05	(24.20)	.874
Time since CR saw doctor for memory problem, mean (SD), months	41.92	(27.20)	43.20	(27.40)	40.66	(27.16)	.531

Note: n represents caregiver-care recipient dyad; p-values test if characteristic differs by treatment assignment, chi-square or T-test as appropriate. ADLs = Activities of daily living; CG = Caregiver; CR = Care recipient; IADLs = Instrumental activities of daily living; RMBPC = Revised Memory and Behavior Problem Checklist; SD = Standard deviation.

*≥80k for CG, ≥30k for CR.

with a significance level of 0.05. The sample size of 132 was sufficient to detect between a medium to small effect size using this analytic approach ($F = 0.25$ to $F = 0.10$; [IntellectusStatistics, 2018](#)).

The qualitative data ($N = 49$) were coded using [Braun and Clarke's \(2006\)](#) six steps of thematic analysis. The authors were guided by the research question: "What made a difference in how RAM was received by participants?" The first step was for the coding team to familiarize themselves with the data. To do so, five authors (L. L. Mitchell, C. M. Peterson, J. M. Finlay, R. Zmora, and H. McCarron) individually read all open-ended responses from the 6-month RAM Review Checklist. The second step was to generate initial themes that captured patterned responses relevant to the research question. The authors each took note of potential themes, writing down a tentative name and description

for each theme. The authors then discussed and compiled the codes into an initial framework of main overarching themes and subthemes (thus carrying out Braun and Clarke's third step, searching for themes). The subthemes provided a useful scaffold for the broad overarching themes and delineated a hierarchy of meaning within the data. Steps four and five involved reviewing the thematic framework and defining and naming themes and subthemes, which are part of the ongoing, iterative process of testing and refining the coding system. To accomplish these steps, the five authors each independently coded a subset of approximately 10 responses and then met to discuss discrepancies and make appropriate changes to the thematic framework. These steps were repeated three times until no further changes to the thematic framework were needed. Three authors (L. L. Mitchell, J. M. Finlay, and H. McCarron) then coded all available

data applying the finalized thematic framework. Reliability was calculated using NVivo software (Version 11; QSR International, 2015) (average kappa = 0.80, average percent agreement = 94%). To ensure agreement, four authors (L. L. Mitchell, C. M. Peterson, R. Zmora, and H. McCarron) reviewed coding results and resolved all coding discrepancies through discussion. This manuscript represents the sixth step: the write-up of our final thematic analysis.

As part of the embedded experimental mixed methods analysis, we utilized the themes identified from the qualitative analysis to inform subsequent, post-hoc quantitative analyses. Specifically, if the thematic analysis suggested potential variables that could moderate the effectiveness of RAM and were measured in the baseline surveys, they were included as interaction terms (i.e., moderator \times treatment \times time) in a series of post-hoc, repeated measure ANOVAs to further examine the mechanisms of benefit (or lack thereof). These variables were selected by five of the authors (L. L. Mitchell, J. M. Finlay, H. McCarron, R. Zmora, and C. M. Peterson), who reviewed the list of quantitative measures and came to consensus on which measures or items (if any) best reflected each qualitative theme. All quantitative and mixed methods analyses were conducted with SPSS (Version 24.0; IBM Corporation, 2015).

Results

Sample Characteristics

The enrollment process for the current project is shown in Figure 1. Compared to participants who were not lost to

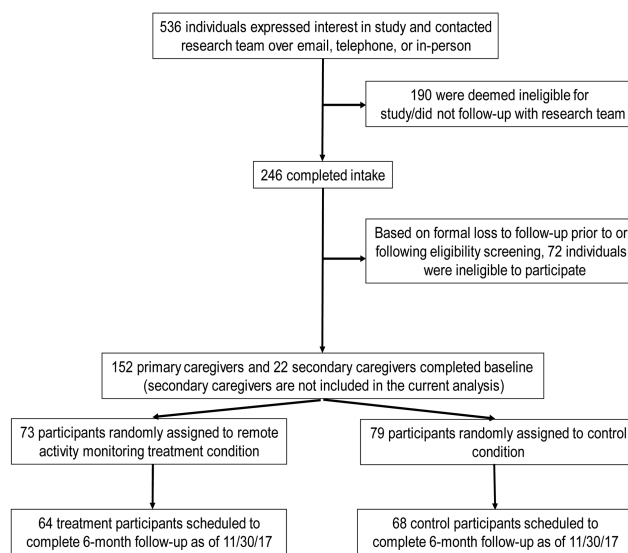


Figure 1. Participant enrollment flow. Note: One participant requested that remote activity monitoring (RAM) technology be removed from their home because the care recipient felt the technology was invasive of his privacy. Furthermore, two participants randomized to the treatment group and who received RAM technology were not included as anticipated in the randomization log; sensitivity analyses conducted without these participants did not result in meaningful differences in any of the findings.

follow up, caregivers who were lost to follow up ($n = 5$) reported higher care recipient ADLs ($M = 1.8$, $SD = 4.0$ vs $M = 0.7$, $SD = 1.7$, respectively; $p < .01$) and indicated a longer time interval since their care recipient saw a doctor for memory problems ($M = 54.4$ months, $SD = 46.0$ vs $M = 41.4$ months, $SD = 26.3$; $p < .05$). Among those with complete data at follow-up, there were no statistically significant differences between the treatment and control groups on baseline covariates (Table 1).

Effects of RAM on 6-Month Caregiver Outcomes: Tests of Hypotheses 1 and 2

Baseline and 6-month means of caregiver self-efficacy, sense of competence, and distress are included in Table 2. The use of RAM technology was not significantly associated with changes in the outcomes over the 6-month follow-up (Table 3).

Qualitative Analysis: Factors Related to Acceptability and Utility of RAM

The qualitative analysis identified three major overarching themes that determined how caregivers perceived RAM: (a) characteristics of the caregiver; (b) characteristics of the care recipient; and (c) living arrangement. Here, we discuss the subthemes within each of these three overarching themes and map them onto relevant quantitative/SPM measures available in the surveys (see Table 4 for this information and expanded quotes as well).

Caregiver Characteristics

Participants noted characteristics pertaining to themselves that affected level of personal fit with RAM, including their *time constraints and stress level* and *comfort with technology*. Six of the 49 participants who provided qualitative data indicated that time constraints interfered with their ability to make use of RAM: “[I] don’t have time to look at what he did all day...may work great for some people just not us” (wife, age 58). In these cases, the use of RAM technology was often seen as an additional task on top of the already difficult burden of caregiving or other life responsibilities. These participants indicated that it did not seem worth their time to learn the system, or that it was simply not feasible for them to use RAM. For these reasons, we identified work status as a potential context of care indicator to consider in subsequent post-hoc quantitative analyses (see Table 4 and below).

Participants’ degree of comfort with technology also appeared as an important factor in determining the usefulness of RAM. Seventeen caregivers reported a lack of comfort with technology as a barrier to their use of the system. On the other hand, eight participants commented that they were relatively comfortable using technology, and this facilitated their use of RAM. However, since no measure of comfort with technology was included in the administered

Table 2. Primary Quantitative Outcomes at Baseline and 6 Months

Outcomes	Baseline				Six months			
	Treatment		Control		Treatment		Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SSCQ	24.17	5.18	24.26	5.46	23.33	5.58	23.73	5.85
Self-Efficacy	27.94	6.00	27.62	6.01	28.39	7.38	27.59	7.06
Burden	37.59	13.26	37.01	15.24	40.40	16.15	40.93	18.54
Role Captivity	6.13	2.30	6.35	2.51	6.74	2.65	6.56	2.69
Role Overload	7.95	2.66	7.41	2.67	7.51	2.80	7.42	2.74
CES-D	33.01	12.74	32.51	11.21	38.90	16.92	35.95	13.46

Note: CES-D = Center for Epidemiological Studies – Depression; SD = Standard deviation; SSCQ = Short Sense of Competence Questionnaire.

surveys, we were not able to analyze this potential variable further in post-hoc analyses.

Care Recipient Characteristics

Characteristics of the care recipient also influenced caregivers' perceptions of RAM utility. Specifically, *care recipient behaviors* and *dementia status* were mentioned by participants as factors that made RAM more or less helpful in their particular circumstances. Twelve participants discussed specific care recipient behaviors, including sleep patterns and nighttime activity, over- or under-use of household appliances (e.g., phone, refrigerator), and wandering, which were conducive to monitoring and intervention through RAM. For example: "When I see that she is opening and closing her refrigerator more often in the system, I've learned it's probably time to go grocery shopping with her again" (daughter, age 61). Four participants also mentioned aspects of the care recipient's behavior that made RAM less useful to them. In particular, caregivers whose care recipients did not wander or who had trouble using the pendant were less likely to find the RAM system useful. To capture care recipient behaviors, an item reflecting wandering were included in the post-hoc quantitative analyses.

Eight participants also discussed their care recipient's dementia status as a factor affecting the utility of RAM. Caregivers identified that the additional supervision provided by RAM was not necessary in early stages of dementia. For caregivers of recipients in later stages of the disease, the care recipient required near-constant in-person supervision, thus obviating the need for RAM. We thus included measures of dementia severity along with ADLs and IADLs and frequency of memory and behavior problems in post-hoc quantitative analyses.

Living Arrangement

Caregivers' open-ended responses often indicated that their living situations made a difference in their perceptions of RAM utility. Twenty participants referred to the implications of their living arrangements. For example, RAM was less useful for participants who lived with their care recipient and were constantly available to monitor and care

Table 3. Repeated Measures Analysis of Variance

Effect	MS	df	F	p
Self-Efficacy				
Time	1.41	1	0.06	.801
Time × tx	0.08	1	0.00	.954
Error	22.10	113		
SSCQ				
Time	16.59	1	1.02	.315
Time × tx	5.70	1	0.35	.556
Error	16.32	115		
Burden				
Time	724.58	1	9.52	.003
Time × tx	30.14	1	0.40	.530
Error	76.09	115		
Role Captivity				
Time	10.74	1	3.34	.070
Time × tx	2.56	1	0.80	.374
Error	3.22	114		
Role Overload				
Time	3.51	1	1.00	.318
Time × tx	2.27	1	0.65	.422
Error	3.50	124		
CES-D				
Time	1335.42	1	15.03	0
Time × tx	145.20	1	1.63	.204
Error	88.86	122		

Note: Tx = Treatment/Remote activity monitoring; CES-D = Center for Epidemiological Studies – Depression; SSCQ = Short Sense of Competence Questionnaire.

for them personally. These participants felt that they had enough information about the care recipient's activity patterns and needs as a function of living with them, and so the data provided by RAM was superfluous. In contrast, participants who did not live in the same residence as their care recipients tended to report finding RAM more valuable: "Knowing my mom was safely moving around her apartment was a huge help since I do not live in the same town" (daughter, age 55). We included whether the caregiver lived with the care recipient as a moderator in post-hoc quantitative analyses.

Table 4. Mapping Qualitative Themes onto Quantitative Moderators

Analogous quantitative variable/moderator	Qualitative subthemes	SPM component	Representative quotes (see text also)
<i>Overarching Theme: Caregiver Characteristics</i>			
Work status	Time constraints and stress level	Context of care	I have not received [RAM] alerts and have not been able to go into the data. In all honesty I have been consumed with some significant health issues with my mother over the past 6 months along with making sure [care recipient's] needs are met. (wife, age not disclosed)
Not available	Comfort with technology	Resource	...impossible to use for those who are not computer savvy (husband, age 88) It's easy to use (if you have some familiarity with technology)...I like that I can check the system on any internet connected device. (daughter, age 61)
<i>Overarching Theme: Care Recipient Characteristics</i>			
ADL/IADLs Memory & behavior problems Wandering	Care recipient behavior	Primary objective stressor	When I see that she is opening and closing her refrigerator more often in the system, I've learned it's probably time to go grocery shopping with her again" (daughter, age 61).
Cognitive impairment ADLs, IADLs Memory & behavior problems	Dementia status	Primary objective stressor	[Care recipient] has not progressed in the disease to require the monitoring. (wife, age 81) Emergency alerts are tricky with a person as far into dementia as my mother was & we never found a use for them. (daughter, age 54)
<i>Overarching Theme: Caregiver and Care Recipient Living Arrangements</i>			
Whether the caregiver lives with the care recipient	Living arrangement	Context of care	I didn't use it, simply because it was time consuming to handle what I was up to, and since I lived with Mother, I felt like I know what I needed to know about her movements. (daughter, age 54)

Note: ADLs = Activities of daily living; IADLs = Instrumental activities of daily living; SPM = Stress Process Model.

Mixed Methods Analysis

The variables identified in the qualitative analysis were included as potential moderators of RAM efficacy on changes in caregiver outcomes over a 6-month period. Specifically, measures of ADL, IADL, R-MBPC, and cognitive impairment scores were dichotomized which corresponded to their highest quartile scores. As wandering was also indicated as a key concern related to RAM utility, a single item from the cognitive impairment scale (“How difficult is it for the person with memory loss to find his/her way around the house?”) was extracted and utilized as a moderator. This variable was dichotomized to compare care recipients who had no or just a little difficulty finding their way around the house to care recipients who found this more difficult. Whether the caregiver lived with the care recipient was also included.

The full results of the post-hoc repeated measures ANOVAs are reported in the [Supplementary Material](#); [Figure 2](#) displays the plotted means of the statistically significant three-way interactions (i.e., treatment × time × moderator). Severity of cognitive impairment was found to moderate the effects of RAM technology on caregivers' self-efficacy ($F = 5.61; p < .05$). RAM-using caregivers of relatives experiencing less cognitive impairment reported

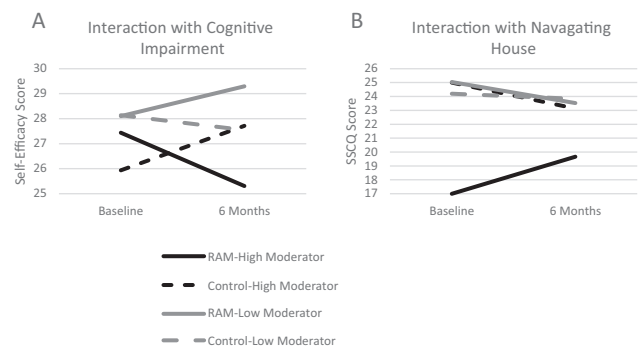


Figure 2. Statistically significant three-way interaction results. Note: Treatment in solid line, control in dashed line; high moderator (severe cognitive impairment, difficulty navigating house) in black, low moderator (less severe cognitive impairment, little difficulty navigating house) in gray. CG = caregiver; SSCQ = Short Sense of Competence Questionnaire.

increased self-efficacy over a 6-month period, whereas RAM-using caregivers of relatives with more severe cognitive impairment indicated decreases in self-efficacy; these longitudinal trends occurred in opposite fashion for controls. Caregivers who utilized RAM technology and provided help to a care recipient with difficulty navigating the

home indicated greater increases in sense of competence, indicated by higher mean SSCQ scores, whereas those in the control group and technology users who assisted relatives with fewer problems navigating the home indicated no/slight declines in competence over a 6-month interval ($F = 4.42$; $p < .05$).

Discussion

We acknowledge that it is not ideal to conduct preliminary outcome analyses in a randomized controlled trial (RCT), particularly if they were not planned a priori (see [Counsell, Biri, Fraczek, & Hackshaw, 2017](#)). Although the dependent variables selected in the present study do not represent all of the main outcomes we aim to analyze in the parent 18-month evaluation of RAM (e.g., person with ADRD health service utilization), we will incorporate statistical adjustment of p values in any subsequent evaluation of RAM effectiveness for caregiving outcomes to avoid the potential of inappropriate statistical inference. This will inhibit our ability to detect a statistically significant effect at 18 months for key caregiving outcomes, but will also avoid the risk of “fishing” for findings (i.e., p hacking).

Why proceed with disseminating these preliminary results? As noted by [Schulz et al. \(2015\)](#) and others (e.g., [Lindeman & Gladstone, 2018](#)), the classic time frame often required to complete a RCT of sufficient follow-up may not keep pace with the rapid evolution of smart home technologies such as RAM. From a societal perspective, it is critical to share findings of effectiveness to inform families, older consumers, providers, and policymakers to offer important insights as to the limits of RAM in home-based dementia care contexts, as well as under what circumstances such technologies are potentially successful ([Gitlin & Maslow, 2017](#)). As [Berridge \(2018\)](#) notes in a recent policy analysis of Medicaid (which has recently emerged as the largest third-party payer of RAM technologies): “Decisions about Medicaid reimbursement of technologies that have the potential to dramatically alter the way older adults receive supportive services are being made without research on their use, social and ethical implications, or outcomes” (p. 1).

To this end, these preliminary findings have ramifications for research, policy and practice. The lack of direct effects may reflect how the RAM technology in this study was deployed. Alerts and activity pattern data were directed to family caregivers rather than a care professional. In some ways this reflects how families would likely use RAM in “real-world” situations, particularly as RAM technologies that are simple to install and operate become more widely available in retail stores ([Moylean, 2017](#)). As both the quantitative and qualitative findings of this study imply, the initial months spent calibrating and modifying the system to meet the particular needs of persons living with ADRD and their family caregivers are potentially challenging if families are solely responsible for responding to alerts and activity pattern data (see also [Mitchell et al., 2018](#)). The mixed

methods findings also imply that RAM technologies may be best suited for persons living with ADRD in the less severe stages of the disease. In particular, this technology may be most useful when an individual is recently diagnosed with ADRD. The access to information on daily activities and early identification of problems may help caregivers feel more confident and competent when using RAM technology. For specific symptoms, such as difficulty navigating the home or wandering, RAM technology use could help to buttress the dementia caregiving situation and help enhance caregivers’ sense that dementia care receipt and delivery occurs more effectively.

From a scientific standpoint, the current paper serves as an important “lesson learned” for other researchers who intend to evaluate RAM or other technologies in the context of ADRD care. Our decision to disseminate preliminary effectiveness of RAM for caregiving outcomes illustrates the need to adequately power for such analyses at the outset; this allows for the required statistical flexibility to respond to the rapid development and evolution of smart home technologies often marketed to families. In addition, the need to optimize the fit between the individual living with ADRD and a smart home technology such as RAM may require broader conceptual/theoretical frameworks. For example, Person-Environment Fit Theory describes the interaction between the competence of an individual with ADRD (which may be characterized by dementia or functional severity) and the environment such as the home ([Iwarsson, 2004](#); [Lawton & Nahemow, 1973](#)). In this model, the use of RAM technology to bridge gaps between these two domains may reduce environmental press and promote adaptive behavior and well-being in the person living with ADRD (and their family caregivers, as well).

There are several important limitations to note in addition to those reported earlier. This is a preliminary study of effectiveness; the parent mixed methods, randomized controlled evaluation of RAM technology is currently enrolling participants with the goal of including approximately 200 persons living with ADRD and their caregivers. The study will follow these participants over 18 months and will include a wider array of outcomes (e.g., care recipient service utilization; cost analyses). For these reasons, additional findings related to caregiver outcomes are possible in subsequent analyses. Blinding did not occur in this study, which may influence risk of bias. Due to budget limitations, the purchase of RAM systems in the initial 2 years of the project precluded the hiring of study personnel to perform blinded ratings. The use of online and mail surveys to conduct data collection was implemented to mitigate these concerns. Among those caregivers and persons living with ADRD who did not provide 6-month follow-up data, there were significant differences on two covariates. Not all caregivers in the treatment condition provided 6-month open-ended responses on the RAM Review Checklist. Open-ended responses were generally brief and imprecise, thus limiting the depth and richness of available qualitative

data. Comfort with technology, which was identified as an important caregiver characteristic in qualitative analysis, was not assessed quantitatively and could not be examined in the post-hoc analyses. For additional limitations, see Mitchell et al., (2018).

A key policy goal of community-based ADRD care is to assist individuals in remaining in the community with high quality of life. This objective is often accomplished through the delivery of services and supports to family caregivers. One of the particularly exciting aspects of technology is its potential to not only support/supplement existing ADRD family caregiving efforts, but to also substitute for or even prevent the need for such care through proactive monitoring. We found that the RAM system did not improve caregiver outcomes. However, this technology may work for family caregivers of persons living with ADRD in specific situations (e.g., earlier stages of dementia; wandering risk), suggesting the imperative of appropriate needs assessment that can better target/tailor such interventions. The evolution of technology is such that it is no longer a matter of "if" RAM or similar smart-home innovations will be made available for ADRD family caregivers to purchase and use. Instead, ongoing (and more rapid) scientific evaluations of these approaches are required to guide providers, payers and families themselves to optimize decisions related to initial and long-term utilization.

Supplementary Data

Supplementary data are available at *The Gerontologist* online.

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Conflict of Interest

None reported.

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