

In-Home Assistive Technology Protects Dementia Caregivers from Worsening Sleep Efficiency

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2. A subset of caregivers from Study 1 was included in a study examining whether caregivers with the active People Power Caregiver (PPCg) system would report lower anxiety compared to caregivers without the active system (Levenson et al., 2024).

Abstract

Background and Objectives: Caregivers for people with dementia (PWDs) often experience sleep problems related to stress associated with their role (e.g., concerns about PWDs' wandering and falls). Scalable and affordable interventions that target these issues, such as in-home assistive technologies, have great potential but have not been rigorously evaluated. We examined whether People Power Caregiver (PPCg), a system using embedded sensors (e.g., motion, door openings) and artificial intelligence bots to monitor the home and warn caregivers of worrisome conditions, would benefit caregivers' sleep.

Research Design and Methods: In two randomized controlled studies, primary caregivers of PWDs (Study 1: N=70; Study 2: N=92) were assigned either to an active (fully functioning PPCg) or control condition (Study 1: limited version of PPCg; Study 2: waiting list control). In a longitudinal design, caregivers self-reported their sleep quality at baseline, three-months, and six-months.

Results: Latent growth modeling revealed that caregivers in the control condition reported significantly worsening sleep efficiency over time compared to those in the active condition. A similar pattern of results was found for caregivers' sleep duration, but this was not statistically significant.

Discussion and Implications: In the first adequately powered randomized controlled trial evaluating in-home assistive technology, we found that PPCg protected dementia caregivers from declines in sleep efficiency. Given how critical sleep is both for caregivers' health and the quality of care they provide, these findings underscore the potential benefits of in-home technologies such as PPCg.

Keywords: *Dementia Caregiving, In-Home Assistive Technology, Caregiver Sleep*

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As the population ages, the number of people diagnosed with age-related neurodegenerative disease is increasing dramatically. Recent estimates (Alzheimer's Association, 2024) indicate that 6.7 million people in the U.S. currently live with Alzheimer's disease (AD), the most common cause of dementia. People with dementia (PWD) often exhibit impairments in cognitive, physical, and emotional functioning (Levenson et al., 2014), which can increase their dependence on caregivers for assistance with activities of daily living (e.g., managing their finances and accessing healthcare; (Schulz et al., 2020). Family members often take on these kinds of caregiver roles, providing the PWD with psychological, functional, and economic support.

The impact of informal caregiving is substantial, with more than 11 million people in the U.S. providing nearly 18 billion hours of informal caregiving for PWDs (Alzheimer's Association, 2024). Despite caregiving being a positive and meaningful experience for many individuals (Doris et al., 2018; Lloyd et al., 2016; Quinn & Toms, 2019), the associated stressors and unpredictability of this role can increase caregivers' rates of depression, seeking treatment for anxiety, and suicidal ideation compared to similarly aged non-caregiving adults (Pinquart & Sörensen, 2003; Richardson et al., 2013; Schulz et al., 2020; Vitaliano et al., 2003). Caregivers often experience difficulty maintaining healthy sleeping routines, which can further exacerbate health risks and impede their ability to meet caregiving demands and provide high quality care (e.g., poor sleep can worsen processing speed and multitasking ability; (Brewster et al., 2022, 2024; Gao et al., 2019; Peng et al., 2019). Thus, there is a clear need to develop effective, scalable, and affordable interventions that reduce stress and improve sleep for caregivers.

Sleep Problems among Dementia Caregivers

There are conflicting viewpoints concerning sleep problems in dementia caregivers. According to the *perceived sleep need view*, as caregivers age, total sleep decreases but perceived sleep quality remains unchanged due to less need for sleep (Scullin, 2017). Similarly, the *caregiver empowerment model* suggests that the positive and enriching aspects of the caregiving experience should lead to sleep quality that is either unchanged or even improves (Jones et al., 2011). In contrast, the *environmental stressor view* proposes that caregivers will experience greater sleep problems due to the mounting level of stress related to their role (e.g., increasing needs and difficult behaviors on the part of the PWD; Pinquart & Sörensen, 2007).

Numerous studies have supported the environmental stressor view documenting greater reports of sleep problems in caregivers. The demands of dementia caregiving can make maintaining healthy sleeping habits challenging. Many caregivers report needing to sleep with “an open ear” or sleep “lightly” (Peng & Chang, 2013; Rowe et al., 2010) reflecting increased vigilance to PWD’s needs, whereabouts, safety, and nighttime behaviors (e.g., bathroom use). Tellingly, approximately 60% of AD caregivers fit clinical criteria for insomnia, characterized by difficulty falling asleep, waking repeatedly through the night, experiencing daytime fatigue, and having depressed mood (Bentley et al., 2022). Consistent with this, a recent meta-analysis of 35 studies with 3,268 dementia caregivers found that caregivers averaged 2.42 to 3.50 fewer hours of sleep per week and lower sleep quality compared to age-matched non-caregiving adults (Gao et al., 2019). Clearly interventions are needed that target factors contributing to caregivers’ sleep problems (e.g., reducing the need for constant vigilance). Such interventions, if successful, could help caregivers address their sleep demands, reduce downstream health risks, and improve the quality of care they provide.

Interventions to Address Dementia Caregivers' Sleep Problems

Interventions that do not require prescription medications (e.g., benzodiazepines) are often preferred for dementia caregivers given troublesome side-effects (e.g., daytime impairments in cognition, risk of falls) these medications can have in middle-aged and older adults (Bentley et al., 2022). Consequentially, there is increasing interest in evaluating the benefits of technology-based interventions for older adults and dementia caregivers (Beattie et al., 2020; Miller et al., 2022) including task reminders, behavioral management strategies, cognitive aids, fall alerts, wandering alerts, interactive telecommunication devices, and in-home monitoring using embedded and wearable sensors. These interventions can reduce caregiver stress and burden, while improving the PWD safety (Xiong, Astell, et al., 2018; Xiong et al., 2020; Xiong, Mansfield, et al., 2018). For example, in a randomized controlled trial, we found that caregivers who received an in-home assistive technology system consisting of embedded sensors (e.g., motion, door openings), artificial intelligence (AI) bots that recognized unusual patterns of activity, and a phone app had lower anxiety compared to a control condition (Levenson et al., 2024).

A recent meta-analysis (Pignatiello et al., 2022) of 15 studies of sleep interventions found that caregivers with in-home monitoring systems experienced better sleep quality (Spring et al., 2009), lesser wakefulness after sleep onset (Rowe et al., 2010), and increases in sleep time (Thomas et al., 2019) compared to caregivers without this kind of system. Of the available non-pharmacological interventions that help alleviate caregiver burden and reduce the need for vigilance, in-home monitoring and warning technologies offer considerable promise (Levenson et al., 2024; Miller et al., 2022). Yet, despite this promise of such technology, there have been few studies with rigorous experimental designs (e.g., randomized controlled trials) and

adequately powered sample sizes (Austrom et al., 2015; Guerra et al., 2013). In a critical review of caregiver interventions, assessments of technology-based interventions were characterized as pilot studies or proof of concept demonstrations (Butler et al., 2021).

The Current Project

We conducted two randomized controlled trials evaluating the ability of a new system of in-home assistive technology (People Power Caregiver; PPCg) to reduce sleep problems in people living with and serving as the primary caregiver for a PWD. Study 1 recruited a West Coast sample and was limited to caregivers for a person who had received a diagnosis of dementia. Study 2 recruited a larger national sample and included caregivers for a person diagnosed with dementia or mild cognitive impairment. Both studies had an active condition (participants received the full PPCg system) and a control condition (Study 1: participants received PPCg with only limited features activated; Study 2: participants were placed on a waiting list and received PPCg at the end of the study period). In both studies, caregivers completed a questionnaire battery that included a measure of sleep at baseline and then again at three-month intervals (Study 1 lasted for 9 months; Study 2 lasted for 6 months). We hypothesized that across the two studies, caregivers in the active condition would report better sleep than those in the control condition.

Methods

Participants

In Study 1, we analyzed data from 70 people living with and serving as the primary caregiver for a person who had received a diagnosis of dementia from a medical professional. In Study 2, we analyzed data from 92 people using similar criteria but also including those diagnosed with mild cognitive impairment. These participants all completed the three sleep

questionnaires at baseline, three months, and six months and, in the active condition, had PPCg installed and activate throughout the six-month period.

Recruitment

Study 1. In Study 1 (conducted between 2018-2020), caregivers were recruited via local advertisements, clinic referrals, community caregiver networks, and a professional recruitment company (Recruitment Partners). An initial screening was conducted to determine the following eligibility criteria: (a) the caregiver was the primary adult familial caregiver living with the care recipient; (b) the care recipient had received a diagnosis of dementia from a medical professional (people diagnosed with mild cognitive impairment were not included); (c) their home had wireless internet connectivity (e.g., WiFi); and (d) the caregiver had an iPhone with cellular service.

Eligible caregivers who indicated interest in the study were asked to complete an initial consent form (PWD consent was obtained a surrogate when necessary) and baseline questionnaire package online and an appointment was scheduled with one of our technicians to install the PPCg system in their home. The final consent was obtained in-person prior to installation. After the system was installed and verified to be working correctly, the caregiver was randomly assigned to either: (a) the fully activated condition (all sensors and associated alerts were active); or (b) the control condition (only the water leak and moisture sensors and associated alerts were active).

Study 2. In Study 2 (conducted between 2020-2021), caregivers were recruited using an online marketing campaign using mailing lists provided by national dementia organizations. Applicants were directed to a web site where they were screened for their eligibility based on the same criteria as Study 1, except that care recipients diagnosed with mild cognitive impairment

were also included (see Table 1) and caregivers could have either an iPhone or an Android phone with cellular service.

Caregivers were contacted via phone by a member of the research team to: (a) obtain consent (PWD consent was obtained from a surrogate when necessary); (b) convey information about the study requirements; (c) inform participants of study assignment; (d) ask caregivers to complete a baseline questionnaire online. Caregivers were then randomly assigned to one of two conditions: (1) the fully activated condition in which participants were provided with PPCg with all sensors and alerts active); or (2) the control condition in which participants were told that they would receive PPCg after a six-month waiting period. In the fully activated condition, PPCg was shipped to the participant's home and participants were offered a virtual session with a person from Care Daily (the developer of PPCg) who led them through the installation procedure and verified that the system was correctly installed. In the control condition, participants did not receive PPCg initially but were told they would receive it at the end of the six-month study period at no charge.

Apparatus

The PPCg system was developed by Care Daily in collaboration with the Berkeley Psychophysiology Laboratory with support from a Small Business Innovation Research Grant from the National Institute on Aging. PPCg consists of a set of wireless devices and sensors that are installed in the home to monitor motion, door openings, temperature/humidity, and water leaks. A gateway device connected to the home's internet router communicates with the sensors and uploads sensor data to Care Daily's cloud where machine learning algorithms learn typical patterns of activity within each home over the course of roughly one week. PPCg alerts caregivers via SMS text messages and notifications pushed to an associated smartphone app

when it detects worrisome and potentially dangerous situations (e.g., door openings at unusual times, levels of motion in locations and at times that differ from the home's typical patterns). If the caregiver does not respond to these notifications, the alerts can be delivered to designated family members and friends. In this way PPCg serves as a resource that can take on tasks that would otherwise require constant caregiver vigilance. The app also provided features intended to maintain social connections and reduce caregiver isolation. In Study 1, this was app-based family photo sharing. In Study 2, this was a Care Daily blog that provided educational materials regarding caregiving. In both studies, an in-app forum called "Community" allowed caregivers to communicate with each other.

PPCg Hardware

Study 1. In this study, PPCg consisted of: (a) five motion sensors, (b) three entry sensors, (c) two temperature sensors, (d) one water leak sensor, (e) six battery-operated motion sensing night lights, (f) a Google Home Mini smart speaker, (g) an Apple iPad tablet, and (h) a wireless gateway device. Once installed, the gateway device communicated with the sensors via a Zigbee wireless protocol (see Figure 1A).

Study 2. In this study, PPCg had: (a) three motion sensors rather than five, (b) two entry sensors rather than three, (c) added a push-button that could be used to call emergency services, and (d) did not include temperature sensor, water leak sensor, motion sensing night lights, Google Home Mini, or Apple iPad (see Figure 1B).

Procedures

Study 1

The study lasted for nine months, with questionnaires administered at baseline, three months, six months and nine months. At each assessment, the questionnaires were identical

except that the demographic questions were only administered at baseline and a set of user satisfaction items were added to the last two assessments.

Beyond contacting the participants when it was time to complete the questionnaire packages, the only contact they had with the research team was if they encountered a problem with the system, in which case technical support was provided by Care Daily or the Berkeley Psychophysiology Laboratory. At the end of the study, participants in the control condition were offered the opportunity to have their PPCg systems fully activated for an additional nine-month period without charge and to continue completing the questionnaires every three months (data from this period were not included in the current study). All participants were paid \$175 for participating in the nine-month study (prorated if all questionnaires were not completed). Participants in the control condition who had their systems fully activated and completed the additional questionnaires were paid an additional \$75 (prorated if all questionnaires were not completed).

Study 2

The study lasted for six months, with questionnaires administered at baseline, three-months, and six-months. At each assessment, the questionnaires were identical except that the demographic questions were only administered at baseline and a set of user satisfaction items were added to the last two assessments.

Beyond contacting the participants when it was time to complete the questionnaire packages, the only contact they had with the research team was if they encountered a problem with the system, in which case technical support was provided by Care Daily or the Berkeley Psychophysiology Laboratory. At the end of the study, participants in the control condition were

offered the opportunity to have a PPCg system shipped to them without charge and to continue completing the questionnaires every three months (data from this period were not included in the current study). All participants were paid \$75 for installing PPCg and \$25 for each completed questionnaire (including the additional questionnaires offered in the control condition).

Measures

Sleep Quality

Caregivers completed the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989), an 18-item self-report measure that assesses problems with seven components of sleep: (a) subjective quality, (b) latency, (c) duration, (d) efficiency, (e) sleep difficulty, (f) medication usage, and (g) daytime dysfunction. Individual components were scored on a scale ranging from 0 to 3 based on the authors' recommendations, with higher numbers indicative of poorer sleep. A total sleep quality score is derived by summing the component scores, with scores higher than 5 indicative of poor sleep quality. The PSQI has shown strong reliability and validity in a variety of samples (Mollayeva et al., 2016), and has been used frequently to assess sleep quality in dementia caregivers (Gao et al., 2019) and the effectiveness of interventions to improve sleep in dementia caregivers (Pignatiello et al., 2022).

Analytical Approach

To make the two studies comparable in length, we only analyzed the first three assessments from each. Latent growth modeling (LGM) was used to estimate a latent intercept (i.e., starting point) and a latent linear slope (i.e., growth or decline) based on the three observations: T1 = baseline, T2 = three-months, T3 = six-months. Compared to other within-subject analytic approaches (e.g., repeated measures analysis of variance), LGM has the advantage of accounting for individual variation in the intercept and slope.

To determine whether there was invariance across the two studies in the total sleep quality variable (Grimm et al., 2016; Liu et al., 2017), we examined the differences in the latent variables by separately regressing the latent intercept and slope on a study variable, which was dummy coded (i.e., Study 1 = 0, Study 2 = 1; see Figure 2A). Our primary analysis examining the effect of PPCg on caregiver sleep was conducted by regressing the latent intercept and slope on a condition variable, which was dummy coded (i.e., control = 0, active = 1; see Figure 2B).

In all analyses using LGM, we used full information maximum likelihood estimation (FIML) to account for missing data in the model (Jeličić et al., 2009). This approach estimates parameters based on all observed data points and their inter-relationships. We inspected the χ^2 test of model fit and the standardized root-mean-square residual (SRMR) as measures of absolute fit and examined the comparative fit index (CFI) as a measure of incremental fit. Adequate model fit is generally considered to be indicated by: non-significant χ^2 values ($ps < .05$) and CFI values greater than 0.95 (Hu & Bentler, 1999).

Results

Study Invariance

There were no significant differences in the latent intercept (range of β s = -0.12 - 0.19, $ps \geq .051$) and slope (range of β s = -0.22 - 0.58, range of $ps \geq .105$) across the two studies for total sleep quality and the seven components of the PSQI (Table 3). Due to this study invariance (Liu et al., 2017), we combined the two studies for our analyses.

Baseline Differences Between Experimental Conditions

Analyses of variance (ANOVAs) comparing the active and control conditions for the total sleep measure and the seven component scores revealed no significant differences at baseline between the two conditions (see Table 2). A χ^2 test of the percentage of caregivers

reporting significant sleep problems at baseline on the total sleep measure (i.e., scores of 5 or greater) revealed no differences between the two conditions (active: 72.24%, control: 77.38%, $N=2$ missing; $\chi^2(1) = 0.30, p = .583$).

Did Caregivers' Sleep Benefit from the PPCg System?

We examined each of the seven component scores on the PSQI to determine caregivers' sleep benefited from the PPCg system (see Table 3). All models indicated appropriate fit $\chi^2(6)$ range = 3.10 - 9.36, $p \geq .154$, CFI range = .967 - 1.00. We did not find significant differences in the latent intercept between the active and control conditions across the seven components (range of β s = -0.14 - 0.08, range of p s = .238 - .950). However, we did find significant differences in the effect of condition on the latent slope for sleep efficiency ($p = .038$), such that the active group reported less growth in sleep efficiency problems ($\beta = -0.30, SE(\beta) = 0.14$) compared to the control group ($\beta = 0.74, SE(\beta) = 0.12$; See Figure 3). Additionally, although not statistically significant at the .05 level, we did observe a trending effect of condition on the latent slope for sleep duration ($p = .105$), such that the active group reported less growth in sleep duration problems ($\beta = 0.11, SE(\beta) = 0.13$) compared to the control group ($\beta = 1.03, SE(\beta) = 0.13$; see Figure 3). No other sleep components showed latent slope benefits for the PPCg system when comparing the active and control conditions.

Discussion

In this project, we conducted two randomized controlled trials with longitudinal assessments and found that caregivers in the active conditions (fully activated PPCg system in both studies) were protected from the worsening sleep efficiency observed in caregivers in the control conditions (minimally activated PPCg in Study 1; waiting list control in Study 2). Demonstrating the value of this kind of in-home assistive technology for improving a significant

aspect of sleep quality in dementia caregivers is important given the oft-reported problems that caregivers have with sleep (Bentley et al., 2022; Brewster et al., 2022, 2024; McCurry et al., 2007, 2009). Moreover, this favorable effect on sleep efficiency may have even broader downstream benefits given the relationship that sleep problems have with other health problems (Gao et al., 2019; Peng et al., 2019) and declines in cognitive functioning (H. Ikeda et al., 2022; Y. Ikeda et al., 2022). Although we were not able to identify the mechanism by which PPCg provides this sleep benefit, we speculate that it may result from the reduced vigilance required by caregivers as they offload some of the nighttime monitoring of the PWD to the PPCg system.

We were somewhat surprised that PSQI sleep components other than sleep efficiency (and to an extent sleep duration) did not show significant benefits. However, each of these components by design measures somewhat different aspects of sleep. Sleep efficiency, is a quite direct measure of the ratio of sleep time to time in bed. As such it may be particularly well matched to PPCg's focus on allowing the caregiver to "let go" and trust the system to detect and provide alerts for worrisome situations. Consistent with this, concerns about the PWD's whereabouts during the night have been found to increase the time that caregivers lie in bed with "an open ear" (Gao et al., 2019; McCurry et al., 2007; Rowe et al., 2010). These factors may also have contributed to the trend findings that PPCg also benefitted sleep duration.

Prior research has shown that non-technology based sleep interventions such as CBT-I show improvements on sleep efficiency (Bei et al., 2015; Jacobs et al., 2004; Sivertsen et al., 2006). However, the administration of the CBT-I comes with considerable financial costs, the need for well-trained therapists, and heightened time and energy demands for caregivers as they comply with the CBT-I protocols and assessments (Bentley et al., 2022; Hughes & Martin, 2022; McCrae et al., 2023). Ultimately, it may prove most advantageous to support caregivers using

both technological (Beattie et al., 2020; Miller et al., 2022) and non-technological (e.g., CBT-I, emotional support, environmental changes; (Cheng et al., 2019, 2020).

Strengths and Limitations

This research has several strengths including: (a) conducting two randomized controlled trial longitudinal studies with similar active conditions, different recruitment geographies, expert and self-installation, and different control conditions, thus enabling a test of the robustness of the PPCg intervention; (b) recruiting participant samples that were diverse as to dementia diagnosis, geographic location, caregiver sex, and socioeconomic status (i.e., income and education; Adler & Snibbe, 2003); and (c) providing one of the few adequately powered and scientifically rigorous evaluations of a technology-based intervention for dementia caregivers. The research also had several limitations: (a) recruitment for Study 1 was hampered by the onset of the COVID-19 pandemic, which halted recruitment early (Levenson et al., 2024); (b) not being able to determine the mechanism underlying the observed sleep benefit associated with PPCg; and (c) use of self-report sleep measures that were not confirmed by more objective measures (e.g., actigraphy, polysomnography).

Conclusion

In two randomized controlled trials, we found that caregivers who received a fully activated version of PPCg, a system of in-home assistive technology, were protected from declines in sleep efficiency compared to caregivers in the control condition. Combined with our prior finding that PPCg can reduce caregiver anxiety (Levenson et al., 2024), we believe that there is considerable potential value in developing and evaluating in-home assistive technologies that can help caregivers deal with the challenges of caregiving and protect against sleep problems that represent significant risks to their health and well-being.

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Conflict of Interest

David Moss and Gene Wang are employees and own stock in Care Daily, which developed and sells People Power Caregiver (PPCg). No conflicts of interest are reported by the other authors.

Table 1*Caregiver Demographic Information with Comparison Statistics*

	Study 1		Study 2		<i>F</i> / χ^2
	Control	Active	Control	Active	
	<i>N</i> = 34	<i>N</i> = 36	<i>N</i> = 52	<i>N</i> = 40	
Age <i>M</i> (<i>SD</i>)	75.73 (8.81)	76.93 (9.95)	73.04 (9.11)	70.90 (8.17)	<i>F</i> = 0.12, <i>p</i> = .726
Sex					
Female	28	12	14	12	χ^2 = 1.21 <i>p</i> = .272
Male	5	24	37	28	
Ethnicity					
Black, Afro-Caribbean, or African American	1	4	3	2	χ^2 = 4.70 <i>p</i> = .696
East Asian, Southeast Asian, or Asian American	--	2	3	1	
Latino or Hispanic American	2	2	4	3	
Native American or Alaskan American	--	--	--	1	
South Asian or Indian American	1	1	--	--	
Non-Hispanic White or European American	26	24	40	30	
Other	3	3	1	3	
Education					
High school/GED	1	2	2	2	χ^2 = 5.34 <i>p</i> = .618
Some college experience	4	4	9	4	
2-year college	7	8	7	4	
4-year college	8	10	14	18	
Technical/trade school certificate/degree	1	--	3	1	
Master's degree	7	6	12	9	
Ph.D., M.D., or other professional degree	5	5	4	2	
Income					
Less than \$20,000	1	2	--	4	χ^2 = 14.90 <i>p</i> = .021
\$20,000 - \$35,000	3	1	6	--	
\$35,001 - \$50,000	5	4	5	2	
\$50,001 - \$75,000	5	9	7	11	
\$75,001 - \$100,000	5	7	18	8	
\$100,001 - \$150,000	7	3	9	8	
Greater than \$150,000	5	6	4	4	
Caregiving Relationship					
Spouse/partner	25	22	41	26	χ^2 = 14.27 <i>p</i> = .047
Significant other	1	--	--	--	
Child	5	12	8	13	
Grandchild	--	1	--	1	
Sibling	1	--	--	--	
Parent	1	--	1	--	
Other	--	1	1	--	

Table 2*Baseline Differences by Condition Collapsed Across Study*

Outcome	Control <i>M (SD)</i>	Active <i>M (SD)</i>	<i>F</i>-value	<i>p</i>-value
Overall Sleep Risk	7.76 (3.84)	7.22 (3.68)	0.81	.368
C1 – Subjective Quality	1.21 (0.68)	1.20 (0.75)	0.02	.881
C2 – Latency	1.36 (1.08)	1.17 (1.01)	1.25	.264
C3 – Duration	0.83 (0.76)	0.82 (0.69)	0.02	.879
C4 – Efficiency	0.77 (1.00)	0.79 (0.96)	0.01	.920
C5 – Sleep Difficulty	1.54 (0.63)	1.42 (0.55)	1.50	.223
C6 – Medications	0.96 (1.27)	0.88 (1.26)	0.17	.680
C7 – Daytime Dysfunction	1.08 (0.79)	0.95 (0.81)	1.14	.287

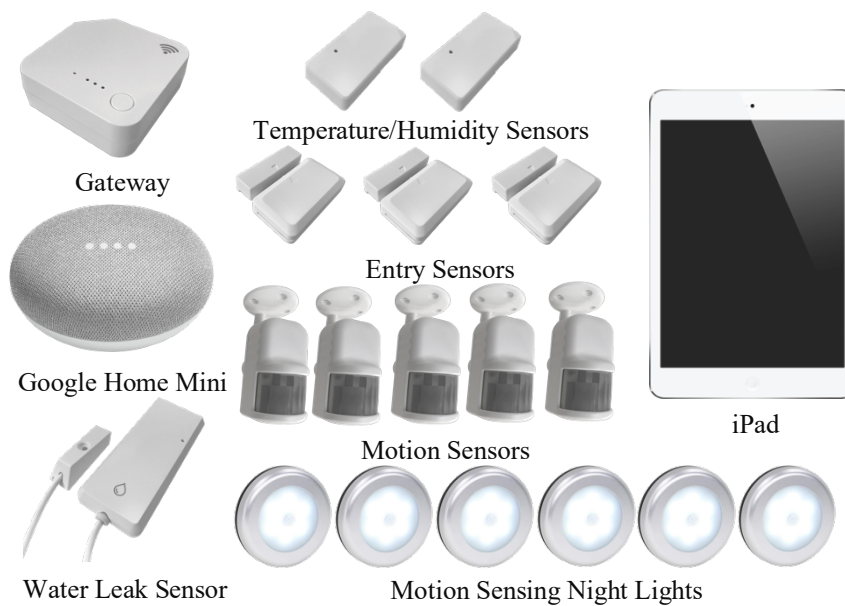
Table 3*Latent Intercept and Linear Slope Comparison by Study and Condition*

	Model Fit			Intercept			Slope		
Study Models (Study Invariance)	χ^2	p	CFI	β	SE (β)	P	β	SE (β)	p
Overall Sleep Risk	2.07	.355	1.00	0.07	0.59	.421	0.09	0.25	.490
C1 – Quality	3.26	.776	1.00	-0.12	0.36	.203	0.11	0.22	.444
C2 – Latency	0.32	.999	1.00	0.19	0.39	.051	-0.12	0.16	.701
C3 – Duration	10.60	.101	.992	0.11	0.36	.271	-0.22	0.17	.222
C4 – Efficiency	6.64	.356	.994	0.09	0.26	.453	-0.10	0.15	.731
C5 – Sleep Difficulty	1.14	.980	1.00	-0.09	0.29	.419	0.58	0.18	.105
C6 – Medications	0.91	.989	1.00	0.13	0.43	.233	0.21	0.35	.185
C7 – Daytime Dysfunction	1.09	.982	1.00	-0.05	0.36	.583	0.01	0.16	.943
Condition Models (Main Analyses)	χ^2	p	CFI	β	SE (β)	P	β	SE (β)	p
Overall Sleep Risk	3.48	.175	.994	-0.05	0.58	.586	-0.12	0.25	.354
C1 – Quality	9.36	.154	.997	0.01	0.38	.950	0.03	0.20	.839
C2 – Latency	5.07	.535	1.000	-0.11	0.37	.239	0.11	0.15	.696
C3 – Duration	3.10	.796	1.000	0.04	0.36	.715	-0.28	0.18	.102
C4 – Efficiency	9.25	.160	.967	0.08	0.28	.461	-0.38	0.17	.038
C5 – Sleep Difficulty	4.63	.592	1.000	-0.14	0.31	.238	0.11	0.18	.743
C6 – Medications	3.57	.734	1.000	-0.04	0.43	.682	0.01	0.30	.939
C7 – Daytime Dysfunction	3.81	.703	1.000	-0.10	0.35	.321	0.03	0.16	.894

Figure 1

People Power Caregiver Setup for Study 1 (A) and Study 2 (B)

A



B

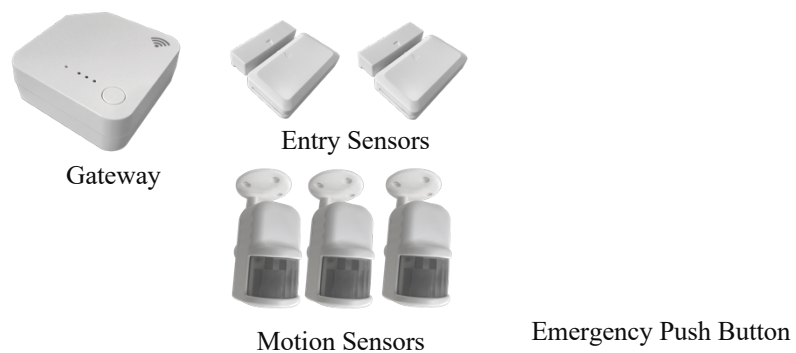
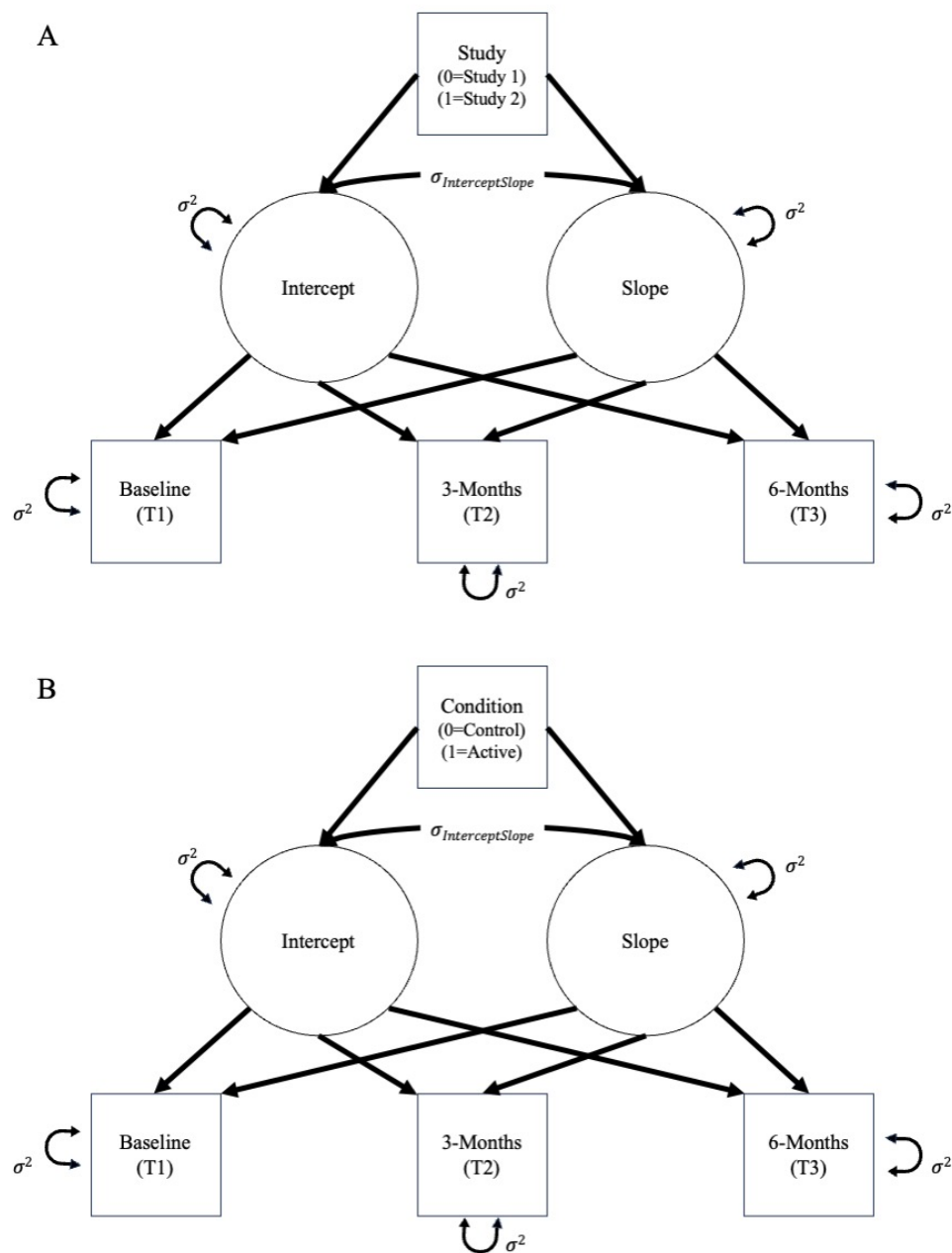
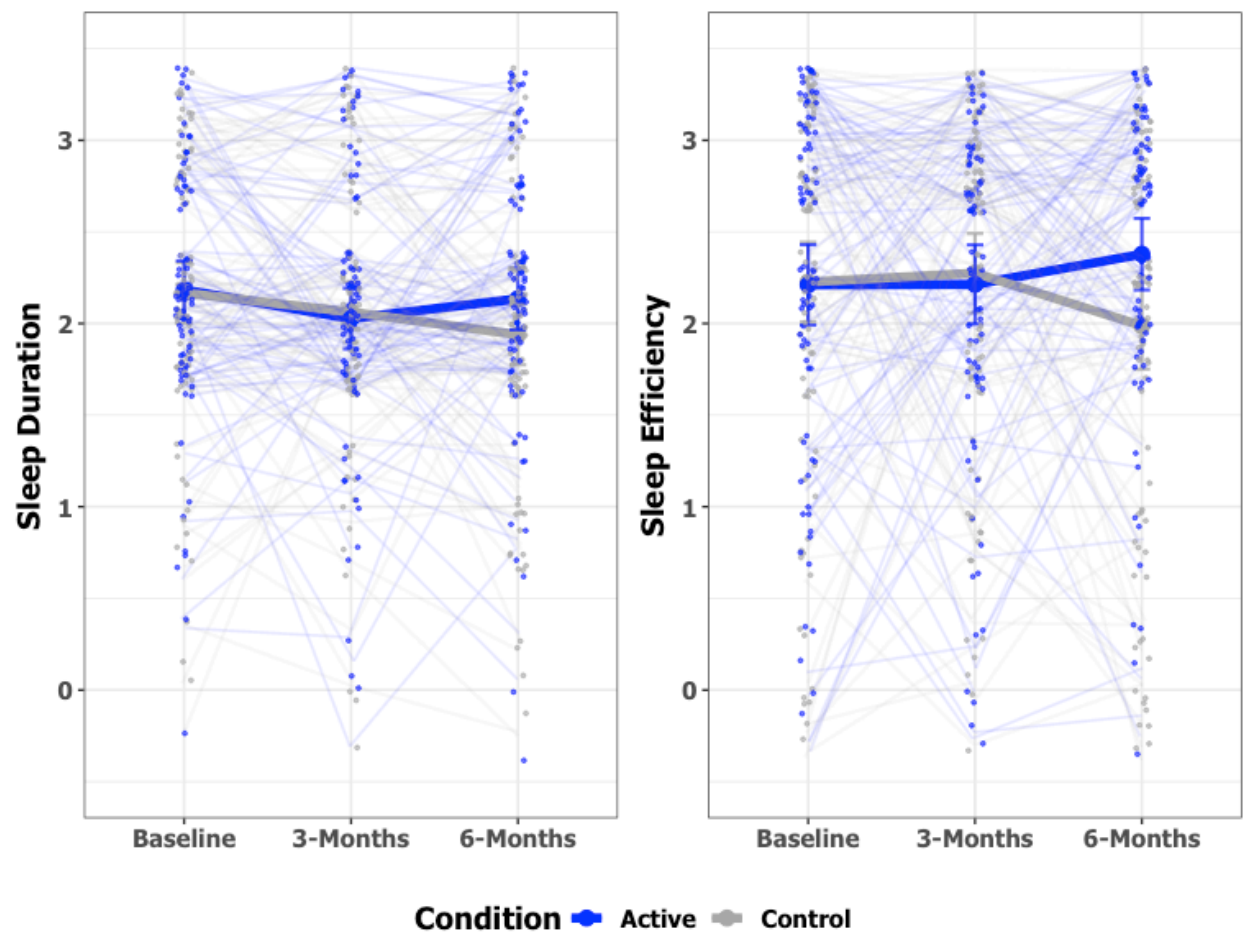


Figure 2*Latent Growth Model with Time-Invariant Dichotomous Variable (Study, Condition)*

Note. Study invariance model (A) and main analysis model for condition (B). Latent variables are represented in circles, observed variables in squares, regression paths in single-headed arrows, and variances or covariances in double-headed arrows.

Figure 3

Caregiver Sleep Efficiency and Sleep During By Condition and Assessment.



Note. The PSQI sleep efficiency condition slope effect was statistically significant at the .05 level but the sleep efficiency condition slope effect only approached significance ($p = .05$) was statistically significant. Scores are reversed for ease of display (higher scores indicate more efficient sleep). Individual raw scores are jittered in position to avoid overlap of dots, individual trajectories are displayed (transparent lines), with the active group (blue) and control (grey) group means and 95% confidence intervals displayed.