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Veteran Acceptance of Sleep Health Information Technology: a Mixed-Method Study

Jenesse Kaitz¹ · Stephanie A. Robinson^{1,2} · Beth Ann Petrakis¹ · Erin D. Reilly^{3,4} · Elizabeth S. Chamberlin⁵ · Renda Soylemez Wiener^{2,6} · Karen S. Quigley⁷

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Abstract

Sleep disturbances, including chronic insomnia and sleep apnea, are major concerns for US veterans, with rising rates and detrimental effects on physical, mental, and social well-being. Sleep disturbances in veterans are also underdiagnosed and undertreated for reasons that include limited sleep clinician availability, long wait times, and the time commitment for treatment. Greater use of sleep health information technologies could improve access to assessment and treatment of sleep disturbances. However, the assessment of acceptance of these technologies among veterans is still ongoing. This mixed-method study combines data from two separate but similar randomized controlled trials to assess acceptance of sleep health information technologies for veterans with chronic insomnia. Sleep health information technologies included in these trials were the following: (1) a WatchPAT sleep monitor for home-based sleep assessment, including detection of sleep apnea, and (2) the VA mobile app Cognitive Behavioral Therapy for Insomnia (CBT-i Coach), which supports self-management of insomnia. The combined sample of 37 veterans receiving care within one New England VA medical center completed a six-week trial using both health information technology tools. Participants completed a survey and interview at the end of the 6 weeks. Overall, participants found the tools acceptable, easy to use, and useful and reported they would use them in the future. Thus, these sleep health information technologies appear to provide an acceptable remote option for assessing and managing sleep issues for veterans. ClinicalTrials.gov NCT02392000; <http://clinicaltrials.gov/ct2/show/NCT02392000> and ClinicalTrials.gov NCT03305354; <https://clinicaltrials.gov/ct2/show/NCT03305354>

Keywords Cognitive behavioral therapy · Mobile apps · Insomnia · Sleep apnea

✉ Jenesse Kaitz
jenesse.kaitz@va.gov

- ¹ CHOIR/Bedford VA Center for Healthcare Organization and Implementation Research (CHOIR), Bedford Healthcare System, Bedford, MA, USA
- ² The Pulmonary Center, Boston University School of Medicine, Boston, MA, USA
- ³ Mental Illness Research, Education, and Clinical Center (MIRECC), Bedford Healthcare System, Bedford, USA
- ⁴ University of Massachusetts Medical School, Worcester, MA, USA
- ⁵ Geriatric Research Education and Clinical Center (GRECC), Bedford Healthcare System, Bedford, MA, USA
- ⁶ Center for Healthcare Organization & Implementation Research and Medical Service, Boston Healthcare System, Boston, MA, USA
- ⁷ Department of Psychology, Northeastern University, Boston, MA, USA

Introduction

It is estimated that 50–70 million Americans suffer from sleep disturbance (Institute of Medicine Committee on Sleep & Research, 2006) and rates continue to rise (Caldwell et al., 2017). Compared to non-veterans, veterans have even higher rates of sleep disturbance (Alexander et al., 2016; Caldwell et al., 2017) with chronic insomnia and sleep apnea two of the most common sleep disorders in veterans (Alexander et al., 2016). Almost one quarter of veterans receiving care at the Department of Veterans Affairs (VA) have a documented diagnosis of sleep apnea, and 12% have been diagnosed with insomnia (Folmer et al., 2020). Furthermore, these two disorders are highly comorbid, with approximately 30–40% of patients with insomnia meeting additional criteria for sleep apnea and vice versa (Sweetman et al., 2021). Sleep disturbances have broader health and functional impact than is often appreciated, including being risk factors for

a multitude of mental health conditions, including PTSD, depression, and suicidal behavior (Neckelmann et al., 2007; Picchioni et al., 2010; Tae et al., 2019; Wright et al., 2011). Additionally, chronic sleep disturbances can negatively impact overall quality of life by affecting work performance, social activities, and interpersonal relationships (Garbarino et al., 2016). Furthermore, sleep disturbances are associated with the development of serious health conditions such as cardiovascular disease, diabetes, and dementia (Liew & Aung, 2021). Patients with comorbid insomnia and sleep apnea also exhibit more negative mood, poorer quality of life, and worse treatment outcomes than those with either disorder alone (Sweetman et al., 2021).

Given these major negative impacts, it is concerning that these sleep disorders are both underdiagnosed and undertreated. The VA healthcare system has continued to increase its focus on assessing sleep disturbance and diagnoses continue to increase, suggesting the possibility of historical underdiagnosis of sleep disturbance in veterans (Folmer et al., 2020; Weaver et al., 2020). The VA has also aimed to increase access to cognitive behavioral therapy for insomnia (CBT-I), the gold-standard treatment for chronic insomnia, launching a national provider training program to increase the number of clinicians who can deliver CBT-I (Folmer et al., 2020). Despite these efforts, CBT-I remains underutilized within the VA (Koffel et al., 2018a). A recent review suggests that this under-utilization may arise from long wait times for veterans wanting to access in-clinic CBT-I and the difficulty of arranging frequent clinical appointments into their busy lives (Koffel et al., 2018a). Additionally, given the high rates of comorbid sleep apnea and insomnia, and their negative impact on treatment, it is important to assess for sleep apnea in those with chronic insomnia (Ong et al., 2021). However, access barriers remain to sleep apnea testing, especially for those who need to travel long distances for in-lab sleep testing (Weaver et al., 2020).

Health information technologies (HITs), including home sleep apnea testing and mobile health applications (apps), could help to increase access to sleep assessments and treatments. Consumer-facing HITs support health care for patients by enhancing access to health communication, self-management, support, and treatment. Two reviews noted that patients found HITs for a variety of conditions and goals to be highly acceptable (Or & Karsh, 2009; Tao et al., 2020). Multiple types of HITs for sleep have been developed, including sleep-tracking apps (Choi et al., 2018) and internet-based and mobile-enabled CBT-I treatments (Erten Uyumaz et al., 2021; Horsch et al., 2015). Additionally, home sleep testing helps overcome barriers to in-lab assessments (Weaver et al., 2020). Veterans prefer having multiple options for their sleep care, including the possibility of first using at-home self-management options, or

internet and mobile options before engaging with in-person treatment (Epstein et al., 2012; Koffel et al., 2021). Given this preference and long wait times for in-clinic care, there is a growing need to increase our understanding of veterans' experiences with and acceptance of specific sleep HITs, especially given the quick adoption and expansion of virtual care options in recent years due to the COVID-19 pandemic.

Several theoretical models of technology acceptance have been proposed, including the Unified Theory of Acceptance of Technology (UTAUT; Venkatesh et al., 2002, 2003) and Wilson and Lankton's model (2004), which combined the Technology Acceptance Model (Davis, 1989) and the motivational model (Davis et al., 1992). These models posit that users' acceptance and use of HITs are determined by multiple interrelated factors including individual differences, motivation, perceived usability (i.e., ease of use), perceived usefulness, and intent to use HITs (Venkatesh et al., 2003; Wilson & Lankton, 2004). Experts recommend acceptance testing for HITs before implementation (Dabbs et al., 2009); however, acceptance has not yet been widely explored for already-deployed sleep HITs with veterans. Studies have shown good feasibility and acceptability for the use of sleep HITs in veterans for the treatment and self-management of insomnia (Koffel et al., 2018b; Kuhn et al., 2022). Although sleep HITs for assessing sleep apnea have been validated (Pillar et al., 2020), no known studies have assessed their acceptance in veterans. Furthermore, given high rates of comorbidity, it would be useful to assess the use of multiple sleep HITs concurrently, including HIT-based assessments of sleep apnea in a population with chronic insomnia. Thus, in the current study, we used a mixed-method approach to assess the acceptance of HITs for sleep assessment and self-management within a veteran sample with chronic insomnia.

Methods

The current study used a convergent parallel mixed-method design, where quantitative and qualitative data were collected and analyzed simultaneously (Fetters et al., 2013). The current analysis combines sample data from two separate, but similar, randomized controlled trial studies. Sample 1 examined sleep outcomes from pre- to post-intervention of sleep HITs (Reilly et al., 2019). Sample 2 extended the work of Sample 1 and added a physical activity intervention (Reilly et al., 2021). Similarities and differences between the two are described in greater detail below.

Participants

For both samples, veterans at one small New England VA Medical Center were recruited for participation via flyers,

outreach at VA and community events, referrals from VA behavioral and sleep health providers, and recruitment letters to veterans. Interested veterans were screened for study eligibility by phone. Veterans were eligible to participate if they had the following: (1) military service after 2001 in Iraq and/or Afghanistan, (2) Insomnia Severity Index (ISI) score greater than 10 with a duration of at least one month, and (3) impaired daytime functioning measured by item 7 of the ISI. Exclusion criteria included the following: (1) moderate-to-severe cognitive impairment based on scores on the Telephone Mini Mental State Exam (Norton et al., 1999), (2) excessive alcohol use on the Alcohol Use Disorders Identification Test-Concise (Bush et al., 1998), or (3) self-report of other sleep disorders including sleep apnea, circadian rhythm disorder, or restless leg syndrome. In Sample 1, participants were excluded from the study if they had moderate to severe sleep apnea as measured by the WatchPAT home sleep monitor (see below for details); in Sample 2, participants were excluded if they had severe sleep apnea based on a WatchPAT-based assessment. Participants with severe sleep apnea were excluded because of the contraindication for CBT-I and they were referred for further assessment and treatment. In Sample 1, 50 veterans were assessed, 38 were enrolled, 18 were withdrawn due to sleep apnea, and 11 completed the full study (8 with mild sleep apnea; Reilly et al., 2019). In Sample 2, 48 veterans were assessed, 33 enrolled, 2 were withdrawn due to severe sleep apnea, and 26 completed (16 with mild or moderate sleep apnea; Reilly et al., 2021). Full information on participant inclusion and attrition has been previously published for each sample (Reilly et al., 2019, 2021). For both studies, participants were compensated \$15 for each of the first two visits and \$40 for the final visit for a total of \$70 for study completion. Sample 1 was collected from October 2015 to November 2016 and Sample 2 was collected from January 2018 to June 2019.

Study Design

This paper analyzes survey and semi-structured interview data from Sample 1 and Sample 2. Questions focused on use of two sleep HIT tools: the CBT-i Coach app and the WatchPAT. Sample 2 participants also received an activity tracker (Fitbit; San Francisco, CA) and were randomized to a CBT-i Coach-only group or CBT-i Coach plus physical activity group. Participants in this study were not instructed to use the Fitbit to track sleep. Methods and primary clinical outcomes of Sample 1 and Sample 2 are reported respectively in Reilly et al. (2019, 2021). Both studies were approved by the Institutional Review Board of the VA Bedford Healthcare System.

Health Information Technologies (HITs)

Participants in both studies received an iPod Touch loaded with the CBT-i Coach app. The CBT-i Coach app is a free, publicly available app created by the VA National Center for PTSD and DoD (Hoffman et al., 2013; Kuhn et al., 2016). The app provides sleep psychoeducation, a diary for tracking sleep duration, sleep hygiene recommendations, relaxation tools, and graphs of user data over time. The app was supplemented by worksheets based on the *Quiet Your Mind and Get to Sleep* manual (Carney & Manber, 2009), including Wakeful Activities, Coping Self-Statements, Constructive Worry, and a Relaxation Log. Participants were also provided a self-management guide with suggestions for using the app and instructions for each week on what to access and complete within the app. The supplemental worksheets and self-management guide were designed to be used in conjunction with the app. Most of the sleep health education topics were materials that participants read or tools they used within the CBT-i Coach app. The CBT-i Coach app was originally developed to be used alongside treatment with a provider. These topics and tools correspond with those standardly used in CBT-I. A newer app, *Insomnia Coach*, is now available, which includes similar sleep health education and tools (such as relaxation strategies) along with a self-management guide.

All participants received a WatchPAT home sleep monitor (Model WP200U; Itamar Medical, Inc.) for use during the study. The WatchPAT sleep monitor is an FDA-approved device that has been shown to provide valid screening for sleep apnea (Yalamanchali et al., 2013) and to provide objective data on broad sleep stage measures (e.g., rapid eye movement [REM] vs non-REM) that have been validated against gold-standard polysomnography (Herscovici et al., 2007). The WatchPAT is worn like a wristwatch with an attached cable leading to a plethysmographic-based finger-mounted probe and a thin wire leading to a small sensor on the chest to measure snoring. Participants can use the device at home using simple instructions, which were provided via a laminated pamphlet and a video on the iPod Touch. Participants viewed the video during their first visit and the video was available on their iPod Touch for later reference. The WatchPAT was used three times by each participant who completed the full study, twice within the first week of the study and once after 6 weeks of using the CBT-i Coach app. Each time the WatchPAT was used, participants were provided a sleep study report which study staff reviewed with them. The report showed total study time (calculated from when they turned on the device to when they took it off), total sleep time, an apnea-hypopnea index (AHI), respiratory disturbance index (RDI), oxygen desaturation index (ODI), and the percentage of time in REM sleep, with definitions and

normal ranges of each. The AHI and RDI measures are used to provide a proxy assessment of sleep apnea.

Quantitative Survey Measures

Demographics

Participants reported their age, gender, race, ethnicity, education, military service, and income at the first visit. Participants' height and weight were measured at the first visit.

Acceptance Measure

Participants received a measure of acceptance at the end of the study adapted from Wilson and Lankton (2004) including the following factors: intrinsic motivation to use, perceived ease of use, perceived usefulness, and behavioral intention to use HITs. Separate items for each sleep HIT tool (CBT-i Coach app and WatchPAT) were assessed using 7-point Likert scales. Participants were asked to indicate their level of agreement with each item on a scale from 1 (strongly disagree) to 7 (strongly agree). Scale scores (agreement ratings averaged across items for each construct) were calculated for each HIT for the following constructs: Intrinsic Motivation, Ease of Use, Perceived Usefulness, and Behavioral Intention to use the HIT. All subscales had moderate to high internal consistency with Cronbach's α s ranging from 0.74–0.97 for the scales applied to the CBT-i Coach app and 0.83–0.99 for the scales applied to the WatchPAT. Intrinsic motivation was assessed with three items ($\alpha = 0.84$ –0.96): I found [HIT] to be enjoyable; the actual process of using [HIT] was pleasant; I had fun using [HIT]. Perceived ease of use was assessed with three items (α s = 0.74–0.91 across the two samples): my interaction with [HIT] was clear and understandable; [HIT] was easy to use; I found it easy to get [HIT] to do what I wanted it to do. Perceived usefulness was assessed with three items (α s = 0.83–0.98): using [HIT] supported critical aspects of my health care; using [HIT] enhanced my effectiveness in managing my health care; overall, [HIT] was useful in managing my health care. Behavioral intention was assessed with two items (α s = 0.84–0.99): I intend to use [HIT]; I predict I will use [HIT].

Qualitative Interviews

Following completion of the intervention, each participant completed a semi-structured qualitative interview. Participants were asked about their experiences using the sleep HITs. Interviews lasted approximately 45–60 min. Interviews included questions about the perceived effects of the sleep HITs in terms of their perceived ease of use, perceived usefulness, intentions for future use, and suggestions for

improvement. The interview guide can be found in Appendix A.

Data Analysis

Quantitative survey data was cleaned, summary scores calculated, and descriptive analyses conducted using SPSS Version 26 (IBM Corp, 2019) with descriptive statistics calculated for each usability survey subscale. For qualitative interview data, we used a deductive approach, specifically, a qualitative directed content analysis (Hsieh & Shannon, 2005), using a priori codes based on theories of technology acceptance as well as inductive coding to capture themes that emerged from the data. We used an iterative process to develop a codebook, and several interviews were co-coded to ensure inter-coder reliability. The coding team (BAP, SR, ER, KQ) used NVivo 11 (QSR International, 2015) to code the interviews. The coders met to discuss emerging findings, resolve discrepancies, and reach consensus on coding passages where codes were discrepant. The codebook was developed using Sample 1 data and was revised as needed for Sample 2.

Results

Participant Demographics

Table 1 presents participant demographic information from both samples. Participants were primarily male (75%) with a mean age of 41 (SD = 10).

Quantitative Results

All 37 participants who completed the 6-week mobile intervention also completed the post-intervention acceptance survey. Overall, participants' acceptance ratings were similar across the two samples, with no statistically significant

Table 1 Descriptive statistics for participants in both samples

| | Combined samples (<i>n</i> = 37) | Sample 1 (<i>n</i> = 11) | Sample 2 (<i>n</i> = 26) |
|-----------------------------------|--------------------------------------|------------------------------|------------------------------|
| Mean age (SD) | 41 (10) | 48 (10) | 38 (9) |
| Gender (male) | | | |
| <i>n</i> (%) | 33 (75%) | 8 (73%) | 20 (77%) |
| Race, <i>n</i> (could select > 1) | | | |
| White | 35 | 10 | 21 |
| Black | 3 | 0 | 3 |
| Other race | 7 | 2 | 5 |
| Ethnicity | | | |
| Hispanic/Latino | 8 | 3 | 5 |

differences (Table 2). On average, participants rated the acceptance of both the CBT-i Coach app and the WatchPAT highly. For both the CBT-i Coach app and the WatchPAT, participants largely agreed that they had high intrinsic motivation to use the HITs, that they were easy to use, useful, and that they intended to use them after the study. Compared to other domains, intrinsic motivation to use was the lowest rated for both the CBT-i Coach app (Sample 1 mean = 5.03 [1.44], Sample 2 mean = 5.08 [1.67]) and the WatchPAT (Sample 1 mean = 4.58 [1.21], Sample 2 mean = 4.41 [1.83]). The highest rated domain was intent to use in the future for both the CBT-i Coach app (Sample 1 mean = 6.05 [0.93], Sample 2 mean = 5.50 [1.54]) and the WatchPAT (Sample 1 mean = 6.46 [0.72], Sample 2 mean = 6.54 [1.07]). Across the two HITs, participants rated the WatchPAT somewhat easier to use, more useful, and more likely that they would use it in the future than the CBT-i Coach app, but they had less intrinsic motivation to use it.

Qualitative Results

The qualitative coding resulted in several HIT acceptance themes, which we categorized as the following: (1) usability, (2) usefulness, (3) intended future use, and (4) suggestions for improvement.

Usability: Sleep HITs Are Easy to Use

The vast majority of participants found that these sleep HITs were easy to use. Participants noted that the CBT-i Coach app was straightforward and self-explanatory. Participants also stated that it was easy to input their sleep diaries and to self-correct earlier input errors:

“There was a help button if you had a question of what it [sleep diary] was actually asking you... So, I would go into the help for a minute and be like, oh, okay. That’s what it’s asking. And then I’d go back, and I’d be able to do whatever it asked for.”

The WatchPAT was similarly easy to use for all participants. Participants described the WatchPAT as simple and the instructions easy to follow. Even participants who had complaints, such as the device being uncomfortable, said they were easily able to endure the potential minor discomfort for a few nights:

“A little uncomfortable at first just because I’m not used to it and the actual watch part of it is pretty heavy. The first time I was like, oh, this is kind of weird with the wires and everything. And the second time it was like, okay, I’m used to this. Third time it was like, I don’t even feel it.”

Table 2 Acceptance of sleep HITs in both samples

| | Total sample (n = 37) | | | Sample 1 (N = 11) | | | Sample 2 (N = 26) | | | Cohen's d | |
|-----------------------------|-----------------------|--------|-----------|-------------------|--------|-----------|-------------------|--------|-----------|-----------|-------|
| | Mean (SD) | Median | Range | Mean (SD) | Median | Range | Mean (SD) | Median | Range | | p |
| CBT-i Coach app | | | | | | | | | | | |
| Intrinsic motivation to use | 5.06 (1.58) | 5.33 | 1.00–7.00 | 5.03 (1.44) | 5.33 | 2.00–7.00 | 5.08 (1.67) | 5.50 | 1.00–7.00 | 0.93 | -0.03 |
| Perceived ease of use | 5.58 (1.38) | 6.00 | 2.00–7.00 | 5.42 (1.29) | 5.67 | 2.00–7.00 | 5.64 (1.44) | 6.00 | 2.00–7.00 | 0.66 | -0.16 |
| Perceived usefulness | 5.14 (1.73) | 5.33 | 1.00–7.00 | 5.18 (1.41) | 5.00 | 1.67–6.67 | 5.12 (1.87) | 5.68 | 1.00–7.00 | 0.90 | 0.04 |
| Behavioral intention to use | 5.66 (1.40) | 6.00 | 2.00–7.00 | 6.05 (0.93) | 6.50 | 4.50–7.00 | 5.50 (1.54) | 6.00 | 2.00–7.00 | 0.19 | 0.39 |
| WatchPAT | | | | | | | | | | | |
| Intrinsic motivation to use | 4.46 (1.65) | 4.67 | 1.00–7.00 | 4.58 (1.21) | 4.00 | 3.00–7.00 | 4.41 (1.83) | 5.00 | 1.00–7.00 | 0.75 | 0.10 |
| Perceived ease of use | 6.14 (0.95) | 6.33 | 3.33–7.00 | 6.00 (0.75) | 6.00 | 4.67–7.00 | 6.21 (1.03) | 6.67 | 3.33–7.00 | 0.50 | -0.21 |
| Perceived usefulness | 5.53 (1.68) | 6.00 | 1.00–7.00 | 5.64 (1.32) | 6.00 | 3.00–7.00 | 5.49 (1.83) | 6.00 | 1.00–7.00 | 0.78 | 0.09 |
| Behavioral intention to use | 6.51 (0.97) | 7.00 | 2.50–7.00 | 6.46 (0.72) | 7.00 | 5.00–7.00 | 6.54 (1.07) | 7.00 | 2.50–7.00 | 0.81 | -0.09 |

p values reflect comparisons across the two samples

Usefulness: Sleep HITs Are Useful

Three sub-themes appeared around usefulness: (1) gaining new knowledge and awareness, (2) making behavioral changes, and (3) positive sleep-related and health-related outcomes.

Sleep HITs help to gain new knowledge and awareness. Participants found sleep HITs useful for helping them gain new knowledge and awareness of their sleep. This often helped to increase acceptance and reduce anxiety around sleep for participants:

“Now I’m understanding the difference between light sleep, and so I’m not getting as stressed about when I feel like I’m awake during the night because I came to realize that I’m actually getting some sleep. It’s just not as deep as at other times.”

Participants found the wakeful activity assessment at the start of the study particularly useful for deciding where to make changes and implementing them. For example, setting a regular sleep schedule:

“And actually, it’s made me aware that I need a regular schedule, and I knew that, but it definitely reminded me, and it absolutely made me change my job and get just a certain schedule, whether it’s nine o’clock at night every night or just the same every week.”

Participants reported the usefulness of objective data in the sleep HITs, such as the sleep diary data visualizations in both the CBT-i Coach and WatchPAT. Some participants remarked that by using the sleep HITs, they had a new awareness of their sleep patterns, which in and of itself was helpful. For example, some participants were relieved to find out via the WatchPAT that they did not have sleep apnea:

“Gave myself that piece of mind knowing that I don’t have sleep apnea. So, it’s nothing that I should have a concern about being, the numbers being so low. That I’m not even close to like maybe being dangerous. It’s like no, you’re really healthy.”

Others noted that the WatchPAT helped them realize that they slept more than they expected:

“It was reassuring that, though I perceive my sleep as being abnormally short, the scientific data says I’m sleeping longer than I think.”

Additionally, the visualizations of the sleep diary data in the app helped participants see how their sleep improved over time:

“You can actually see how your sleep, I mean like where your sleep went up and how it hasn’t gone up. I mean like I noticed that my sleep has gone up since

I started, even since the beginning of this month. Just that I sleep better than I did before. It’s achievement, like meeting a goal.”

Finally, participants considered it helpful to have objective data when interacting with their medical providers. Participants shared or planned to share the results of the WatchPAT testing with their primary care or other providers to inform their care in the future:

“When I go to my doctor, she can look at it. We can discuss the results and, if she thinks it’s warranted, set up a game plan.”

Sleep HITs encourage behavior change. For most participants, new knowledge, awareness, and motivation through HITs led to behavior changes that positively impacted their sleep. Participants reported engaging in a range of recommended behavior changes to improve their sleep including changing their sleep environment or bedtime routine, regulating, or changing their sleep schedule, avoiding electronics before bed, changing the timing of caffeine intake, changing stimulus control activities (e.g., avoiding activities other than sleep or sex in bed), and relaxation strategies (e.g., deep breathing exercises). For example, one participant described the changes they made as follows:

“And I think what kind of really helped me, especially to get to fall asleep, was some of the wakeful activities that were in there. I pretty much eliminated about I would say over 90% of them before I was getting ready to go to bed. So, I wouldn’t watch TV, wouldn’t do anything on my phone, wouldn’t read. I’d just have a light conversation with my spouse, and then bedtime was bedtime.”

Others had more difficulty making behavior changes, even with increased knowledge about what changes might be helpful for their sleep. These participants talked about making these changes as a lower priority in their lives:

“I wasn’t going to stop watching TV two hours. I’m not going to lay in bed and read. Like, I’m not going to do stuff like that. That’s, the hour a day to myself I get, that’s what I choose to do. And unfortunately, I can’t put that hour anywhere else.”

Most of these participants recognized that these behavior changes were necessary to improve their sleep but expressed that they were not ready yet. One participant spoke specifically about motivation and readiness: “I’m just not at that stage of action yet.”

Another spoke of recognizing the need for their own agency and change:

“So it’s ultimately up to me to maybe take in less caffeine or things like, you know, going to bed later, being

less stressed that will, I'll have to be responsible for my own sleep... So, I have to be the one to change them."

Participants associated using *sleep HITs with positive changes in their sleep and other outcomes*. Participants found the CBT-i Coach app particularly useful for seeing positive changes in their sleep and their lives overall. They associated many of these improvements with changing their sleep habits and how they thought about sleep. One participant described the change in their sleep as "longer and uninterrupted." Participants reported improvements in physical health, pain, stress, energy and fatigue, memory, concentration, overall quality of life, and social interactions. Several participants noted the potential connection between sleeping more and feeling better physically or having less pain. As one participant noted: "I think sleeping more has been helping my body heal more." Many participants felt their moods were better, with less irritability, as one participant noted: "I think I feel happier, more joyful I guess, during the day, now that I'm sleeping better." When participants slept better, they could engage in more quality-of-life activities, as one participant illuminated: "I've become more engaged in outside activities, like the baseball camp."

A few participants connected their lower use of sleep HITs with less ideal outcomes. For example, for one participant:

"I didn't really use it all that much. It's really just getting out of it what you put into it. And seeing how, unfortunately, as far as just the app goes, I didn't put that much into it, and yeah, I didn't get that much out of it."

Intended Future Use of Sleep HITs

Most participants expressed positive sentiments about using sleep HITs in the future and would recommend them to others. Most participants said they would or already had downloaded the CBT-i Coach app onto their personal devices. Some felt that they needed more time to see further improvements in their sleep:

"I might, actually [download it], just because I don't feel like I had enough time with it. But I do, from what I did see, I do feel like it is beneficial. I just wish I had more time with it, so I probably will, yeah."

Other participants felt that their time using the sleep app was sufficient and planned to stop using the app. One participant described how they had gotten what they could out of it:

"[The app] just being static information, I think I got the information I needed off of that, so. And then to me, information starts becoming old."

Some of these participants stated that they would consider using the app in the future if needed:

"Well, now that I know it's there, if I feel like I start seeing issues again, then I will definitely do that. So I'll just start monitoring myself."

Suggestions for Improvement

Participants' suggestions for improvements of sleep HITs fell into three main areas: (1) suggestions for the CBT-i Coach app, (2) suggestions for the WatchPAT, and (3) integration across devices. First, suggestions for the CBT-i Coach app often were technical improvements, including adding a military time option or the ability to choose sleep diary durations in other than 10-min intervals. Some participants would have preferred printed materials, including sleep diaries, educational materials, and progress charts. Finally, several participants suggested adding game and community elements to the CBT-i Coach app. For example:

"Maybe you could put a picture of your pajamas you're wearing for the night or the movie you're watching before bed to put you to sleep. And it might pull people in a little more. And you could have goals and maybe have little achievements. I slept eight hours yesterday. I can hit the button and ding! You get six, seven hours in a row, you get a little trophy, and then everybody knows it, and it motivates you."

Suggestions related to the WatchPAT were primarily focused on increasing comfort and ease of use, including making it wireless. Additionally, participants suggested that the WatchPAT should be easier to access for veterans outside the study so that more people could be screened for sleep apnea. Finally, participants suggested that sleep HITs could be better integrated across devices and sources of information. They wanted information from both the CBT-i Coach app and the WatchPAT to be combined and automatically sent to their health care providers.

Discussion

Overall, the combined results of these studies suggested that sleep HITs are generally acceptable, usable, and useful for veterans with chronic insomnia. The quantitative and qualitative results from these two samples were aligned and showed that veterans had broadly positive experiences with the CBT-i Coach app and the WatchPAT sleep monitor. By the end of their participation, most participants expressed that both sleep HITs were easy to use, useful, and that they intended to use them in the future, if needed. These results are expected given that the participants voluntarily agreed

to enroll in a clinical trial using these HITs. Additionally, sleep HITs helped some participants receive sleep assessment and management that was more accessible (e.g., it fit with their schedule), thereby overcoming a documented barrier to engagement in CBT-I treatment (Koffel et al., 2018a). These findings are valuable to the literature that assesses the acceptance of multiple sleep HITs. The CBT-i Coach app and the WatchPAT provided complementary tools and information that are helpful to use together. The WatchPAT was a key assessment tool in providing initial feedback on sleep apnea and baseline objective sleep data, which is important given the high comorbidity of sleep apnea and insomnia and its impact on insomnia treatment (Ong et al., 2021; Sweetman et al., 2021). The CBT-i Coach app education and tools were likely more helpful in the self-management of sleep disturbance and in supporting behavior change.

The qualitative results provide additional information on why participants found these technologies to be useful. They provided new knowledge and awareness, and support for making behavioral changes and improvements in their sleep and other areas of their lives. These findings are aligned with the key components of CBT-I: psychoeducation, cognitive restructuring, and behavior change, including stimulus control and sleep hygiene (Manber et al., 2012). It appeared that sleep HITs were most helpful at building knowledge and awareness, which then often led to behavior change. The sleep diary was a key component of building awareness of participants' sleep patterns, which participants felt guided them on how to make behavior changes. This finding reinforces previous research on self-monitoring as a health behavior intervention, including the prior use of sleep diaries that led to changes in sleep patterns (Goelema et al., 2016). Also aligned with the goals of CBT-I (Thakral et al., 2020), it appeared that learning about normal sleep patterns through psychoeducation and their own WatchPAT results reduced misconceptions about sleep, which may have helped participants make behavior changes.

A small number of participants spoke about the difficulties of making behavior changes despite acquiring new knowledge and awareness. Lack of motivation appeared as a barrier to making behavioral changes. This finding was echoed in the quantitative results, where we saw that motivation to use sleep HITs, while still relatively high, was generally lower than for other domains. Motivation is a key factor in HIT use (Venkatesh et al., 2003) and HIT effectiveness (Baretta et al., 2019). CBT-I outcomes depend on adherence to behavioral change recommendations, which are greatly impacted by the motivation to change behavior (Trochel et al., 2014). Some individuals with sleep disturbance with lower motivation for behavior change may benefit from increased support from a healthcare provider. They may also benefit from motivational interviewing

(MI) strategies, which can increase motivation for change. Research on delivering MI through technology, including mobile apps, is promising (Shingleton & Palfai, 2016), and additional research would be beneficial on the addition of MI components to further boost the usefulness of existing sleep HITs. Individuals with more difficulty making behavior changes may have also faced environmental barriers such as shift work, young children, or comorbid medical conditions, which also might be better addressed by using a more supported approach.

These findings show good acceptance, usability, and perceived usefulness of sleep HITs for veterans with sleep disturbance, but as with any study, we note several limitations. First, these studies used two small samples of veterans at a single site, and therefore, we cannot generalize to all veterans with chronic insomnia. Additionally, those individuals who elected to participate and completed the study may be more drawn to using sleep HITs and thus, more likely to find them acceptable. The findings of this study could have also been impacted by confounding variables that were spontaneously reported in interviews, such as shift work and young children, and that were not assessed systematically across all participants. Since CBT-I is contraindicated in cases involving shift work (Smith & Perlis, 2006), participants working night or rotating shifts may see minimal benefit from self-management sleep HITs. Additionally, questions about intrinsic motivation to use was not included in qualitative interviews; future qualitative work could include this factor as it was the lowest scoring aspect of acceptance of sleep HITs from our quantitative findings. Finally, these data were primarily self-report and there was no follow-up beyond the immediate post-intervention assessment. In interviews, participants often commented on their experience in the study overall and did not necessarily differentiate between information learned from different components, such as the worksheets used early in the trial versus use of the CBT-i Coach app. Similarly, a few participants in Sample 2 used the Fitbit to track their sleep, which may have impacted their perception of each HIT. Participants who used both found the WatchPAT to have more in-depth, and what they felt was more accurate feedback compared to the Fitbit, which could have resulted in a more positive view of the WatchPAT. Thus, this study primarily provides a picture of the acceptance of these sleep HITs as they worked as part of a single intervention, and thus, we have less information about the acceptance of each HIT alone. In the future, it will be important to combine self-reported app use with in-app usage data, longer-term follow-ups, and dismantling studies to further assess the best combinations of sleep HITs.

Overall, sleep HITs may help increase access to assessment and treatment for sleep disorders, which are under-diagnosed and under-treated, especially among veterans. Sleep self-management using sleep HITs may also align well with a

stepped-care approach, in which self-management methods can be used before the delivery of provider-delivered treatments. Some veterans may find these self-management approaches more accessible and even preferred (Koffel et al., 2021). This stepped-care approach can help stretch valuable healthcare provider resources, enabling care for more patients (Alessi et al., 2016). Additionally, this study confirms veteran patients' acceptance of delivering CBT-I via non-clinicians (Alessi et al., 2016). Clearly, some veterans will benefit from the additional support of working with a clinician. Future research could focus on predictive factors indicative of which patients may most benefit from an initial (or solely) self-management approach and which patients will need more support for sleep assessments or treatments.

Appendix A: Interview Guide

Past treatment experience—sleep and CBT

1. Have you seen a healthcare provider for your sleep problems before?
 - (a) [If no] Why not?
 - (b) [If yes] What did you try previously to improve your sleep? Did you ever try using technology before to improve your sleep? How did using the WatchPAT and the CBT-i Coach compare with what you tried before? [Interviewer: we want to know about what they tried previously including HOW it was delivered and by whom.]
2. Have you ever had cognitive behavioral therapy for insomnia before and, if so, was it helpful?
3. During the course of the study did you change anything about your medications? (Any new medications, changes in dosage, time you took them?)
 - (a) If yes, did you change this as part of the study or was it just something that occurred during the study

Experience/usability with WatchPAT and CBT-i Coach and Sleep Help apps

1. Could you describe what it was like using the WatchPAT sleep monitor?
 - (a) Did you have any specific sensations while wearing the WatchPAT? Did you have any discomfort while wearing it? Did you think that it changed how you slept (in other words, did it make your sleep either better or worse)?
 - (b) Was it easy to use? Was anything confusing?

- (c) How can the instructions for using the WatchPAT that we gave you at your first visit be improved?
- (d) Did you refer to the information brochure or video? [If yes] Can you tell me about a time when you looked at it? Do you have any suggestions for how the informational brochure or video could be changed?
- (e) Did you have any problems with the WatchPAT and if so, how did you solve the problem?
 - (i) Did you call anyone for assistance? [If yes] Please tell me about that experience.
 - (ii) f. How could the WatchPAT itself be changed to make it easier to use or more useful?

2. What was your overall opinion of or experience with the CBT-i app?
 - (a) What feature(s) did you like the most and why?
 - (b) Which components did you find less useful, and why?
 - (c) How could the CBT-I app be changed to make it easier to use or more useful?
 - (d) Was it what you expected?
 - (e) How easy was it to use?
 - (f) Did you have any problems with it?
 - (i) [If yes] Can you tell me about what they were and how you solved them?
 - (g) Did you enjoy using it? Why/why not?

3. What was your overall opinion of or experience with the Sleep Help app which had the worksheets on wakeful activities, coping self-statements, behavioral plan, constructive worrying and a relaxation log?
 - (a) How easy was it to use?
 - (b) Did you have any problems with it?
 - (i) [If yes] Can you tell me about what they were and how you solved them?
 - (c) What worksheet(s) did you like the most and why?
 - (d) Which parts did you find less useful, and why?
 - (e) How could the Sleep Help app be changed to make it easier to use or more useful?
 - (f) Was it what you expected?
 - (g) Did you enjoy using it? Why/why not?

Perceived impact of intervention

4. How would you describe how your sleep has changed since beginning this study? What changes, if any, have you noticed? (Examples? Ascertain if better/worse)
5. Could you tell me about any other changes to your health, or in your life since beginning this study?

- (a) Could you tell me about any changes you experienced in... (if yes, how so or is there a specific example you can share with me?) [If not mentioned, probe for:]
- (i) Pain?
 - (ii) Stress?
 - (iii) Fatigue?
 - (iv) Memory?
 - (v) Concentration/focus?
 - (vi) Daily life in general?
 - (vii) Interactions with my partner/spouse/friends?
- (b) What do you think caused these improvements? (Getting more sleep? Use of CBT for insomnia or Sleep Help worksheets? Feedback from WatchPAT? Talking with your physician about your sleep?)
6. Did you change any of your sleep behaviors since beginning the study? If so, what did you change?
7. Did you change anything about the way you thought about your sleep since beginning the study? If so, what changed?
- (iii) [If no] You said you don't use (health) apps very much. Can you tell me a little about why you don't use them?
10. How often do you use the Internet?
- (a) [If user] Can you tell me about what you typically do on the internet?
 - (b) How often do you use the internet for health-related reasons or to get answers to health-related questions? Can you give me some examples of when you have done this recently?
11. Do you plan to continue using the CBT-i app now that the research study is done? (why/why not?)
12. Would you consider using mobile apps for other health issues and if so, which health issue(s) do you think would be most helpful to you?

Final thoughts

13. Would you recommend using technology like the WatchPAT and/or CBT-i Coach to other Veterans with sleep problems? [Why/why not?]
14. Is there something else I should have asked but didn't?

Patient engagement

8. Have you spoken with your provider about your sleep since you began this research study?
- (a) [If yes] What were his/her reactions to your using the CBT-i Coach?
 - (b) What other suggestions has your doctor/clinician had to help you with your sleep?
 - (c) Do you have a follow-up visit with your provider to discuss your sleep?

Behavioral intention for HIT

9. What other cell phone tools or apps do you use? How regularly do you use them?
- (a) [If yes] Can you tell me a little bit about the things you use them for?
 - (i) Do you use any apps for health purposes? (e.g., those for tracking fitness, diet, smoking, or other health behaviors) [If yes] Can you tell me about some things you've done using health-related apps before?
 - (ii) [If yes] How did using the CBT-i app for your sleep compare with those experiences?

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Declarations

Competing Interests The authors declare no competing interests.

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