Making Space for the Quality Care: Opportunities for Technology in Cognitive Behavioral Therapy for Insomnia

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ABSTRACT

Insomnia can drastically affect individuals' overall well-being and work performance, with substantial costs to society and industry. Cognitive behavioral therapy for insomnia (CBT-I) is a psychotherapeutic treatment, which requires patients to track sleep and share the data with CBT-I clinicians. However, the number of specialists who can provide CBT-I limits the number of patients who can receive it. In this paper, we aim to identify opportunities to leverage technology to assist clinicians in delivering quality and effective CBT-I services to broader populations. Toward this goal, we conducted formative studies, including 11 CBT-I clinic observations and 17 semi-structured interviews, to understand the current workflow of CBT-I and associated challenges. We discuss how technology can assist clinicians and patients throughout the various steps of CBT-I workflow while addressing some of the identified challenges, and more broadly, how technology can make space for clinicians and patients to build quality therapeutic relationships.

Author Keywords

Cognitive Behavioral Therapy for Insomnia (CBT-I); self-monitoring data; patient-generated data; clinical workflow; observation; interview; patient engagement.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User-centered design: J.3 [Life and Medical Sciences]: Medical information systems.

INTRODUCTION

Chronic sleep and wakefulness disorders affect an estimated 50-70 million Americans, costing hundreds of billions of dollars in direct medical expenses and an estimated $150 billion yearly for businesses (e.g., from accidents, productivity losses, and employee nonattendance); furthermore, tired drivers, even without the influence of alcohol, account for nearly 20% of general population injuries from serious car crashes [23]. Cognitive Behavioral Therapy for Insomnia

(CBT-I) is a safe and effective insomnia treatment [47, 63]. CBT-I attempts to treat the factors responsible for individuals sleep problems through behavioral modifications, rather than prescription medications; it has fewer known side effects and longer-lasting effects than drugs alone [41, 42].

CBT-I could help many insomnia patients if it can be employed in a scalable and effective way, but this is difficult in practice. CBT-I requires patients to capture sleep and contextual data and share them with clinicians, often using a paper-based diary, over several in-person visits [51]. As is the case for many CBT based treatments (e.g., depression [66], anxiety [44]), CBT-I often imposes heavy data collection burden on patients [51]. Despite numerous sleep tracking devices and applications developed both from academia (e.g., [19, 34, 40]) and industry (e.g., [5, 3]), the adoption of these technologies in real-world clinical practice has been notoriously slow and often faces resistance [20, 70]. Moreover, personal attention is the most important prognostic indicator for positive outcomes in CBT-I [30]. Significant work in patient-clinician communication literature emphasizes the importance of in-person communication, which serves as a channel to convey socio-emotional support, exchange information, and make treatment decisions [49, 57]. As quality communication and patients' satisfaction towards patient-clinician communication are positively related to patient compliance [49, 53], it is difficult to simply cut back the number of sessions, reduce the in-person time, or automatize the practice.

As such, finding a balance between clinician involvement and broader delivery of efficient care by leveraging technology is an important HCI research problem. The CBT-I context offers unique opportunities for us to reflect on the existing care practice, from which we can understand the value of in-person patient-clinician communication as well as existing pitfalls and design opportunities. To this end, we want to understand what aspects of in-person CBT-I can be successfully assisted by technology as opposed to remain to be accomplished by clinicians based on a proper understanding of CBT-I workflow [60]. Our research is thus specifically oriented toward answering the following three questions:

- RQ1: What is the current workflow of clinician-guided in-person CBT-I and associated challenges in each step?

- RQ2: In the context of CBT-I, how do clinicians engage patients in the care practice?

- RQ3: What are opportunities for technologies to support clinicians and patients in the CBT-I practice?

To answer these research questions, we conducted observational fieldwork in a sleep clinic, coupled with patient and clinician interviews. Our work offers the following three contributions: 1) a detailed account of in-person CBT-I workflow, as well as the associated challenges from the perspectives of both clinicians and patients; 2) identification of the aspects of CBT-I which can specifically be leveraged by technology versus in-person interaction; and 3) design implications for CBT-I technologies based upon and sensitive to individuals' differing needs and preferences. Our work provides an in-depth understanding of CBT-I practices, and our findings could help build better therapeutic relationships between patients and clinicians.

RELATED WORK

In this section, we provide related work on how technologies used in the hospital affect patient-clinician interaction, and background literature on CBT and CBT for Insomnia.

Technologies in the Hospital Setting

Technology in the hospital setting is a double-edged sword. Notably, electronic medical records (EMR) have unintentionally resulted in reductions in time spent directly with patients [50], tensions negotiating human contact and screen-sharing [16], system-induced errors [8], and communication challenges [27]. Researchers have conducted observation and interview studies (e.g., [43, 60, 69]) to systematically explore EMR adoption, clinical workflow, and associated challenges. For example, Unertl and colleagues examined the information flow of clinicians using EMR and categorized activities into *information access*, *information input*, and *communication* [61]; they noted that clinical informatics tools are not designed with workflow comprehension, which could result in decreased clinical efficiency, increased medical errors, and missed key or subtle data. As patient-clinician communication quality is significantly related to patients' care adherence and health outcomes [58], understanding clinical workflow and information behaviors is necessary when designing tools supporting patient-clinician interactions.

Technologies are also being designed to engage patients in their care [52, 62]. Interactive tabletops for non-directive play therapy, for example, could enhance therapy without interrupting processes or hindering patient-clinician relationships, although such technologies may lessen clinician engagement [53]. Patients reacted favorably to patient-centric mobile displays of medical information (e.g., progress reports, care plans, and care teams in Emergency Departments) [52, 65]. Empowering technologies and patient involvement in care practice, through encouraging information seeking or question asking, can positively affect health outcomes [29]. Recently, virtual and augmented reality (VR and AR) technologies have been used in exposure therapy for phobias [67]. Furthermore, physical artifacts that utilize sensors and display heart rate via light patterns, pre-recorded messages that reflect personally meaningful contents, and non-digital means of distraction show promise in promoting wellbeing in complex mental healthcare contexts [59].

Patients are also using self-tracking technologies in interactions with clinicians [21, 45, 70]. Health data can be cap-

tured at home and shared with clinicians between or during visits [15, 70]. Mobile devices are promising platforms for capturing and inferring behaviors. For example, sleep behaviors can be inferred from embedded smartphone sensors (e.g., [40]), and tools like Android's widgets can lower patients' data capture burden [19]. However, how to enable patients to share data with appropriate personnel (e.g., sleep clinician) was often beyond the scope of these works. Moreover, there is little organizational support for sharing patient-generated data [70]. Many patients share by bringing data collection tools into clinics, which can disrupt patient-clinician communication [20], or increase clinicians' workload. For these reasons, many clinicians and patients still cling to more familiar, traditional means of data collection and communication (e.g. pen and paper) [39].

To minimize negative consequences of novel technology, it is necessary to understand the contexts of use by engaging with clinicians and patients during the early phase of design [10]. Conducting ethnographic fieldwork is challenging for non-clinical researchers, but it is an effective method to understand healthcare practices and contexts [11, 28]. We thus adopt this approach in our research. While we build upon extensive prior patient-clinician interaction research, we specifically fill gaps by examining how clinicians engage patients in the care practice and aim to identify opportunities for self-care technologies to help balance clinician involvement and broader delivery of efficient CBT-I care.

Cognitive Behavioral Therapy

Cognitive behavioral therapy (CBT) refers to a broad set of psychotherapeutic approaches, which aim to help mental health patients understand how thoughts and cognition affect behaviors. CBT is grounded in the premise that certain psychological problems and mental disorders are encouraged by maladaptive cognitive factors, including beliefs and schemas [31]. Although CBT produces longer-lasting benefits than pharmaceuticals alone [42], CBT access is low [24]. Waiting times for appointments are often lengthy, in part owing to a shortage of qualified CBT clinicians [33], inconveniences of scheduling and attending appointments [55], and rising healthcare costs [32]. Even if patients have had access to CBT, they have historically been unable to utilize treatment because they could not successfully engage with necessary professional services [24, 46].

To address some of these problems and extend treatment availability, researchers developed Computerized-CBT (cCBT). However, cCBT faces several barriers, including low engagement indicated by low take-up rates and varying dropout rates. Systematic reviews examining cCBT for depression report that reported take-up rates are low (ranging 3.3% to 25%) [33]. cCBT systems users also have various dropout rates from 0% to 42.9% among different studies, with little explanation of the factors that contributed to participant motivations or continued engagement [68]. In HCI, researchers specifically examined how patients engage with cCBT in mental health contexts [25, 26, 36, 54]. Rennick-Egglestone and colleagues suggested that cCBT systems should help identify and remove users not suited for the

ID	Location	Age	Sex	Professional title	Expertise	Year of practice	Interview /observe
H1	PA	35	M	Licensed Psychologist, Assistant Professor of Psychiatry	Academic Sleep Research, Clinical Behavioral Sleep Medicine	10 years	I/O
H2	WI	51	F	Licensed Psychologist, Certified in Behavioral Sleep Medicine	Mental health, depression, anxiety, sleep related disorders	8 years	I
H3	IL	43	M	Counselor	Insomnia , delayed sleep phase syndrome, circadian rhythm disorders, sleep apnea	2 years	I
H4	NY	57	M	Psychotherapist	Relationship and social issues, sexual health, sleep related disorders, psychodynamic psychotherapy	3 years	I
H5	Australia	58	M	Provisional Psychologist	General Psychology, insomnia, sleep related disorders, anxiety, depression	3 years	I
H6	CO	29	F	Occupational therapist, research associate II	Cognitive behavioral therapy for insomnia, sleep related disorders	8 months	I
H7	PA	62	M	Licensed psychologist and Neuropsychologist	Anxiety, depression, sleep related disorders	20 years +	I
H8	CA	39	F	Licensed psychologist, Clinic Director and Faculty	Behavioral sleep medicine, sexual medicine	8 years	I
H9	PA	45	F	Medical Psychologist	Addiction, behavioral medicine, sleep related disorders	10 years	I
H10	DE	47	M	Licensed psychologist, Associate Director, Internship Coordinator	Sleep related disorders, depression, anxiety, substance abuse disorder	8 years	I

Table 1: Interview and observation participant demographics: Clinicians.

intervention, respond to mental health deteriorations, tailor information presentations to the user, and support user disengagement from the intervention [54]. In another study, Doherty and colleagues conducted design workshops with key stakeholders of CBT and suggested ways to encourage patient engagement by providing interactive and graphical exercises, support from clinicians and professionals, and opportunities for social interaction [26]. Researchers also explored a game-based CBT approach [25] and a clinician-moderated web-based application [36], both aimed toward adolescents who were reluctant to attend face-to-face interventions. Coyle and colleagues noted the significance of supporting patient-clinician relationships and again raised concerns that technological interventions may disengage clinicians from therapies; they also noted that personalization, flexibility, and multimodal interaction might best support cCBT [25]. Likewise, prior work discusses the role of technology for patient-clinician relationships within mental health treatment and provide implications for designing cCBT-based technologies, which may not be applicable to in-person CBT for Insomnia. They also lack guidance on how to enable efficient sharing and collaborative sensemaking of patient-generated data between patients and clinicians, which are key components of CBT for insomnia. Therefore, we attempt to fill the gaps of prior research by examining how both patients and clinicians can benefit from technologies that specifically aid in data tracking, data sharing, and patient-clinician communication in the context of CBT for Insomnia.

Cognitive Behavioral Therapy for Insomnia
Although CBTs for various domains share similar psychotherapeutic approaches, CBT for insomnia (CBT-I) includes several unique components. CBT-I generally consists of six to eight independent treatment sessions, beginning first with intake evaluation, followed by treatment initiation usually of stimulus control therapy (i.e., avoiding clock watching in the bedroom, restricting time spent awake and set of behaviors one can engage in while in the bed or bedroom) and sleep restriction therapy (i.e., patients are limited to spending exactly an equal amount of the time they sleep in their beds), then sleep titration (i.e., clinicians gradually, incrementally adjust sleep duration) and sleep hygiene, and ending with four additional sessions which adjust sleep titration depending upon patient response, with the final session also including discussions of relapse prevention [51]. CBT-I often requires expansive information seeking through surveys, interviews, and sleep diaries, as well as education related to sleep logging, sleep behavior modification, and sleep hygiene [18]. Currently, the majority of clinicians and patients still use pen and paper to collect data. However, these factors offer the unique opportunity for computing technologies to respond to efficiency and adherence.

Several technologies have been developed to help insomnia patients employ self-guided CBT-I (e.g., CBT-I Coach [4], CBTforInsomnia [2], Somnio [31], RESTORE [32], SHUTi [56]). Notably, researchers demonstrated web-based CBT-I technologies (e.g. Somnio, RESTORE, and SHUTi) help significantly improve insomnia patients' sleep behaviors if engagement is maintained [31, 32, 56]. However, similar to other Computerized-CBT technologies, engagement and high dropout rates remain concerns, with no clear explanations of why people disengage and how to better engage them. We therefore examined how sleep clinicians engage patients during in-person CBT-I to search for opportunities related to CBT-I technological delivery systems, and how HCI researchers can help clinicians create a sensitive, stepped-care system [64].

METHOD
We conducted 11 observations of CBT-I sessions and semi-structured interviews with 17 participants (7 insomnia patients and 10 CBT-I clinicians). This research was approved by the university's Institutional Review Board (IRB).

Observations
In previous studies, researchers used direct observation to understand clinic workflow and identify existing problems [14, 22]. We conducted direct observations in the Sleep Research and Treatment Center at a university-affiliated medical center located in the U.S. Mid-Atlantic region. For each session of observations, the observer sat in the corner of the exam room, taking detailed notes of the patient-clinician interaction and treatment process. Two researchers made 6 trips to the site, staying there from 9am till 4pm each time. The clinicians we

ID	Age	Sex	disease	Status	Observed	Current status	Occupation	Previous treatment	Interview /observe
P1	58	F	Chronic moderate insomnia, snoring	New Patient	twice	Done (5 sessions)	Work from home	Sleep study	I/O
P2	18	F	Hypersomnia, Depression	New Patient	once	Ongoing (4 sessions)	High school Student	melatonin	I/O
P3	71	F	Chronic insomnia	Return Patient	twice	Ongoing (3 sessions)	Retired English Teacher	Ambien, sleep study	I/O
P4	33	F	Insomnia, anxiety	New Patient	once	Ongoing (4 sessions)	Stay at home, on disability	CBT for anxiety	I/O
P5	>30	M	-	New Patient	once	-	-	-	O
P6	>20	F	-	New Patient	once	-	-	-	O
P7	29	M	Circadian rhythm disorder, fatigue, memory loss	New Patient	once	Ongoing (2 sessions)	Ph.D Candidate	Sleep study, Melatonin, Alteril	I/O
P8	74	M	Hypersomnia, Sleep apnea, restless legs	Return Patient	once	Ongoing (3 sessions)	Retired Government Agent	Provigil, Neurontin	I/O
P9	48	M	Chronic insomnia	New Patient	once	Ongoing (2 sessions)	Attorney	Ambien	I/O

Table 2: Interview and observation participant demographics: Patients

worked with decided whether to let the researchers observe the CBT-I session depending on the patients' case. For example, we did not observe patients with comorbid conditions (e.g., insomnia and depression) because observations would negatively affect the treatment. Due to the sensitive nature of the conversation, we did not record the audio. After observing 11 CBT-I sessions (9 new patients, 2 return patients), the observers noted the recurrence of similar themes in the patients' data from this particular site. Each observation lasted from 1 (return patient) to 2 (new patient) hours.

Interviews

Additionally, we conducted semi-structured interviews with CBT-I clinicians and insomnia patients for two reasons. First, we wanted to check for external validity of our observations by interviewing CBT-I clinicians from internal and external sites. Second, we wanted to follow up with the patients whom we observed to learn their perspectives and experiences with the CBT-I process. To thank the interview participants for their time and effort, we provided each clinician participant a $50 gift card and each patient participant a $30 gift card, which is a common approach in healthcare research.

Interviews with Clinicians

Clinician participants were recruited both by word-of-mouth referrals and through the American Board of Sleep Medicine (ABSM) website [1]. The inclusion criteria for clinicians necessitated that they have experience providing CBT-I, which requires highly specialized training. We interviewed 10 clinician participants (one from the observation site, nine from external sites). Clinician interviews were done either via phone (n = 9) or Skype (n = 1). Table 1 shows our clinician participants' demographic information. We designed the interview questions for clinicians to gain an understanding of their reasonings behind each step of the treatment process, personalized treatments for individuals, their attitudes towards technology, and current challenges they face. Interview questions for clinician participants included the following: (1) What is the typical diagnosis and treatment process (workflow) for a new patient and return patient? (2) What is the best use of in-person visit time? (3) What are the strategies clinicians use to motivate and engage patients in their care practice? (4) How might technology be used to enhance various aspects of CBT-I treatments? and (5) What types of patients are suitable to utilize self-guided CBT-I versus in-person CBT-I treatment?

Interviews with Patients

Our recruiting methods for patients were restricted to those patients from our initial observations. Among the 9 patients we observed, we obtained consent to conduct an interview

with 7; one patient declined our interview request, and we lost contact with another patient. Patient interviews were conducted via phone (n = 6) or Skype (n = 1). Table 2 shows our patient participants' demographic information. We designed the interview questions to guide participants to discuss their experiences with CBT-I. Interview questions for patient participants included the following: (1) What motivated the patient to follow the sleep restriction? (2) What tools have the patient used to collect and store sleep data, and how do they reflect upon their sleep data? (3) How does the patient envision doing CBT-I remotely? (4) How was the patient's experience with the visit in terms of interacting with the clinician? and (5) What are the challenges with regard to the visit?

Dataset and Analysis

Upon clinicians' and patients' consent, we collected screenshots of patients' sleep diaries, the clinician's excel sheets for calculating the patients' sleep efficiencies (see Appendix), and the typical surveys clinicians used with their patients. We also digitized all the observation notes.

All interviews were audio-recorded and transcribed to facilitate analysis. Each interview lasted from 40 to 80 minutes. To ensure the confidentiality of participants, we assigned a unique participant identifier to refer the roles of the participant: H# to denote a clinician participant, and P# to denote a patient participant.

To develop the CBT-I workflow, we began with the clinical workflow categories reported by Ni and colleagues, who examined physical therapy consultation visits [43]. Their model consists of 3 high-level activities (i.e., *information seeking* during injury assessments, *education* during medical and treatment contexts, and *documentation* for injuries and patient progress). We further extended the model to better characterize the CBT-I workflow. For the themes relevant to RQ2 and RQ3, we used thematic analysis [12]. Two researchers analyzed transcripts from two patient interviews and two clinician interviews independently, and they used qualitative open coding to note prominent themes that were discovered across the data pool. Once the team agreed on the high-level themes identified, one researcher iteratively coded the data and updated the coding scheme. The research team gathered again to conduct axial coding to identify relationships among the high-level coding schemes.

RESULTS

In this section, we present the observation and interview results to report existing gaps and opportunities in CBT-I practices. We describe our results according to the three research questions (RQs) presented earlier.
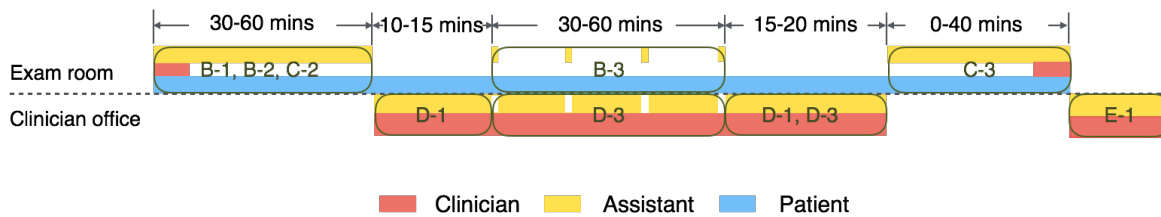
Figure 1: This figure shows a breakdown of the time and location individuals (e.g. red bars for clinicians, yellow for assistants, blue for patients) spend during different stages of workflow when clinicians see new patients. Note that new patients will spend significant amounts of time during their visits in the exam room waiting for clinicians to calculate patient survey/questionnaire scores. The labels correspond to the stages of workflow in Table 3.

RQ1: Clinical Workflow of CBT-I

Here, we describe the detailed workflow of CBT-I and differences across clinicians. We then present what we observed as the impediments to providing personalized and quality care.

Detailed Workflow of CBT-I

CBT-I practice involves patient in-home activities, clinician information seeking through surveys and interviews, sleep data sharing between clinicians and patients, intensive education components for patients to learn concepts as part of cognitive restructuring, and extensive patient documentation of sleep data. In Table 3, we describe high-level and sub categories that constitute the clinical workflow of CBT-I.

Most profoundly, CBT-I workflow extends to patients' homes, where they have to track sleep data (A-1) and follow sleep prescriptions as part of stimulus control and sleep restriction techniques (A-2). Our clinical workflow is distinguished from prior workflow models (e.g., [43, 60, 69]) by the inclusion of patients roles (i.e., patient in-home activities) and the bringing of them to the forefront of the CBT-I workflow. Information seeking includes the screening survey via semi-structured clinician interview schedule (B-1), contextual information gathering (B-2), and the pre-treatment assessment survey (B-3). Information sharing consists of sleep data review (C-1), during which a clinician and patient look at the sleep diary together and discuss progress. They also share personal experiences (C-2), bidirectionally expressing their personal emotions and stories. Patients need to learn background information about CBT-I (C-3) such as how to fill out the sleep diary, how to follow the sleep hygiene recommendation, and how to employ self-guided sessions. Clin-

icians also provide sleep prescriptions, which patients should precisely follow (C-4). Clinicians score patients' survey data (D-1), compute their sleep efficiency and total sleep time (D-2), evaluate patients' situations to prescribe (D-3), and document patients' visits on the electronic medical record (E-1). The workflow varied depending on whether the patient was a new patient or a return patient. For new patients, in-office activities include information seeking (B-1, B-2, B-3), information sharing (C-2, C-3), information assessment (D-1, D-3), and documentation (E-1) (Figure 1). The patient makes return visits consisting of a slightly different workflow pattern: for return patients, there were in-home activities (A-1, A-2, A-3), information seeking (B-3), information sharing (C-1, C-2, C-3, C-4), information assessment (D-1, D-2), and documentation (E-1) (Figure 2). The indicated duration of new patient visits was from 40 minutes to 2 hours, and the duration of return patient visits varied from 35 minutes to 1 hour. Treatment is terminated for a given patient depending upon his or her progress; a patient who closely follows his or her prescriptions will likely end treatment in fewer sessions than a patient who does not.

Differences Across Clinicians

Although most clinicians followed typical CBT-I processes, we learned from our observation and interview studies that the workflow is not completely the same across the clinicians due to variations in clinic settings and patient types. The observation of H1's practice allowed us to closely look at how clinicians access patients' data, interact with patients, and personalize treatments for different patients. We, however, complemented the observation data with interviews with 9 other clinicians (H2-H10), which helped us identify similarities and differences in CBT-I workflow (see Supplemental material). For example, because our observation took place at a training hospital, the clinician (H1) was training an assistant who helped him in collecting patients' information and documentation, which was not a typical situation for other clinicians we interviewed. The number of sessions also varied: among the 10 clinicians who participated in the study, 3 of them (H1, H4, H5) applied the standard 6-sessions of CBT-I to patients, 2 of them (H8, H9) applied 4 to 6 sessions, and for the other clinicians (H2, H3, H6, H7, H10), the number of sessions varied from 3 to 15 depending on the patients' situations (e.g., comorbidity).

In addition, there are other differences across the clinicians that are worthy of highlighting. For example, H3 asked his

Activities	Sub-activities
A. Patient In-home Activities	A-1. Sleep Data Tracking
	A-2. Sleep Restriction and Stimulus Control
	A-3. Other Assignments
B. Information Seeking	B-1. Screening Survey
	B-2. Contextual Information Gathering
	B-3. Pre-treatment Assessment Survey
C. Information Sharing	C-1. Sleep Data Review
	C-2. Personal Experience Sharing
	C-3. Education
	C-4. Prescription
D. Information Assessment	D-1. Survey Data Scoring
	D-2. Sleep Data Scoring
	D-3. Pre-treatment Evaluation
E. Documentation	E-1. Patients' Record

Table 3: Activities and sub-activities in CBT-I workflow.

new patients to complete an hour-long online survey (B-1) before their first visits so that they could have efficient face-to-face sessions and save both the clinician's and patient's time. Similarly, H6 emailed all the questionnaires (B-1) and sleep diaries with handouts (C-3) and scored the data (D-1, D-2) using a digital system before a patient's visit. H4 did a brief phone consultation before the first session to make sure that a patient is qualified for CBT-I. H5 started the very first session by educating patients on the importance of sleep (C-3). H10 met with patients who already brought medical sleep evaluations and 2-week long sleep diaries to their first visits. Lastly, H7 was an outlier among the 10 clinician participants, who only talked with patients and never employed any sleep diary or questionnaire.

Current Impediments to the quality CBT-I care

Our observation and interview data suggests that many patients made progress with regard to sleep and expressed satisfaction with CBT-I. However, both clinicians and patients faced several challenges in the CBT-I practices which might discourage engagement or negatively affect treatment results. Below, we report these challenges according to the specific activities of the clinical workflow.

A. In-home activities: Impediments in this stage concern patient sleep data tracking and difficulties with following sleep restriction schedule. Two clinicians believed that requiring patients to maintain a sleep diary produces stress which is counterproductive to the goals of relaxation inherent to CBT-I. H9 mentioned, *"sleep diary seems like it's very burdensome or putting their [patients] focus on sleep in a way that exacerbates."* Furthermore, some patients found it difficult to answer certain questions asked in the sleep diary. For example, patients had difficulty answering questions regarding time to fall asleep, or number of awakenings experienced during a night. Patients often estimated answers, so diary data were often subjective. The subjective nature of the diary data was not a problem for clinicians because patient's own perception of their sleep was what they looked for. Sleep restriction was often difficult for patients to follow; it required incredible determination and self-control: *"I had a patient not too long ago who came in and they were engaged when they were with me but then they would go home and they would give up"* [H3]. However, some patients [P1, P3, P9] were very motivated to follow their sleep restrictions; they hoped that their clinicians would add extra sleep time during future sleep titration, and they usually tried to distract themselves to maintain wakefulness (e.g. by walking around, watching TV, etc).

Challenges can lead patients to forget to record their data, fabricate data, or make mistakes, leading to unreliable data which might interfere with a clinician's ability to make proper
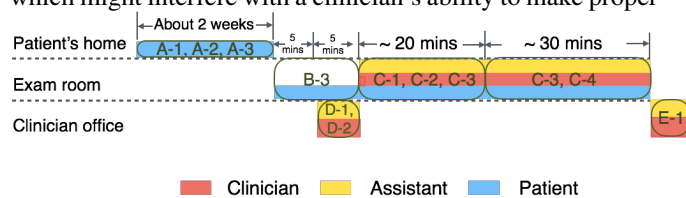

Figure 2: CBT-I workflow for return patients. The labels correspond to Table 3. Color legend can be found in Figure 1.

judgments. The first few weeks of CBT-I are a particularly difficult time for patients, as they have to adjust to the new sleep restriction schedule, which often means that they are getting a lot less sleep than before. Currently, clinicians are unable to remotely track patients' progress; at most, patients contact clinicians over email or phone call if they desperately need a clinician's help.

B. Information seeking: In this stage, patients and clinicians face various challenges regarding data capturing and sharing. Clinicians primarily retrieved patients' information through four means: surveys, sleep diaries, sensing devices, and polysomnography (sleep studies). Clinicians asked new patients to complete a Screening Survey and a Pre-Treatment Assessment during the first session. These surveys' efficacies are supported by research, but some of the questions confused patients. For this reason, H1's assistant's main job was to help some patients accurately fill out the surveys by sitting next to them and reading out the questions.

Patients typically started a sleep diary at the conclusion of the initial session, but if the clinician suspected that there were comorbid complications, such as circadian rhythm disorders, sleep apnea, or restless legs syndrome, then special devices were assigned to the patient. In such cases, clinicians trusted ActiGraph's (a validated wearable device that monitors human rest and activity; ActiGraph does not provide feedback to the patients) accuracy more than data from sleep diary. However, patients' information seeking endeavors have often been hindered by inefficient communication and contemporary practices. For example, patients lack access to their ActiGraph data, so clinicians must print the graphs to discuss results. P2 stated, *"It was a chart that he had printed out and he explained everything to me."* Some patients used mobile apps for their sleep diary, but clinicians who received this data had to manually input each data point. Clinicians also found it difficult to transfer or share patient generated data on different platforms. Because commercial sleep tracking technology did not support data exporting or sharing, many clinicians continued to use paper sleep diary.

C. Information sharing: CBT-I sessions are highly structured and precisely-designed. Clinicians followed the CBT-I manual and provided patients with the handouts that contain the same information regardless of applicability. Some patients felt that the charts and handouts involved are overly generalized. P3 remarked, *"she gave me a new one for cognitive restructuring [worksheets]. I'm having a little trouble seeing how relative that is to what I'm going through at this time. It doesn't seem to me that I need that."* Because of the lack of technological support, clinicians often printed and provided patients generic templates as examples. P7 noted, *"I think it might have been something from previous patient."* However, contrary to common patient perceptions, clinicians tended to personalize treatments in general. Our observation data suggests that the clinician and his assistant spent a great deal of time discussing proper prescriptions for patients with comorbid diseases, and that clinicians in all circumstances provided patients with a personalized sleep prescription. To find patients' ideal sleep durations, clinicians engaged pa-

tients over the course of multiple back-and-forth communications, utilizing the shared data to make gradual adjustments in sleep titration and sleep restrictions. These prescriptions often proved difficult for patients (*"I feel it's difficult to follow, cause it's out of my norm"* [P9].) Although, clinicians knew just how challenging this process was for most patients, patients could quickly lose motivation to continue participating; as H5 noted: *"...when [patients] were really struggling to stick with the prescription of their bed time. That would be the point at which they walk away."*

D. Information assessment: Current information assessment practices do not properly utilize electronic means of data collection and assessment, leading to missed opportunities for communication between patients and clinicians. The sleep diary is critical for most CBT-I clinicians to diagnose and evaluate patients. Clinicians use it to calculate sleep-efficiency and sleep duration, evaluate the patient's weekly progress, and decide if a patient needs to have further treatments. Paper-based sleep diaries offer many benefits over digitized versions. For example, paper-based sleep diaries allow for easy data recording, support self-reflection, and have detailed questions. However, we observed that clinicians usually spent an average of 5-10 minutes during the visit digitizing a patient's sleep diary for a single week to calculate various measures such as sleep efficiency. However, clinicians often did not share the digitized sleep diary (e.g., weekly progress, graph) with patients: *"I don't think I actually did [see the graph]. It was there on his computer I was listening to his interpretation of it"* [P8]. Even though data collection is critical for CBT-I, clinicians often provided prescriptions based on estimations, as H9 remarked, *"It's more impressionistic based on the diary because I think it [calculate the sleep efficiency] takes too much time."*

These inefficiencies and missed opportunities are not just present in information assessments for patient-generated data; they are built into current clinician practices and workflow. Surveys are commonly utilized by clinicians to screen patients who can most benefit from CBT-I. Patients required between ten minutes and an hour to complete these surveys. Once completed, clinicians returned to their offices and scored the surveys, while leaving patients in the exam room. As seen in Figure 1, patients can spend a long time waiting alone during these early information seeking processes. *"[I]t's like I'm just sitting here filling out questionnaires for like an hour. So I don't see any immediate benefit, but I'm assuming that there is a benefit in the future..."* [P7]. Because the questionnaires are handwritten, clinicians had to manually input patient data into an excel spreadsheet to calculate scores while the patient was waiting in the room. In-person visits lasted approximately one hour, but a great deal of work, including information seeking, information sharing, assessment, and education, needs to be completed in this short time. Clinicians must often make quick estimates of results instead of precise calculations. *"I'm not sure she even looked at more than a page or two of [sleep diary] for just a brief—she looks over them no more than two minutes"* [P3].

Other Challenges: Both observation and interview data indicated that scheduling an appointment with a CBT-I clinician is the most common challenge for patients. Some patients waited 2-3 months for their initial appointments. During this time, patients may experience fluctuations in their sleep conditions and might resort to continuing pharmaceutical treatments or unguided self-experimentation to ease their problems. Furthermore, scheduling problems often persisted throughout the treatment period. Our data indicated that periods between visits are typically between 2 and 4 weeks in duration. Despite the difficulty of scheduling an appointment, people commonly cancelled and dropped out of ongoing treatments once scheduled. We note that the high patient dropout rates and the shortage of qualified CBT clinicians are also common challenges in other CBT-based therapies.

We also found challenges specific to the CBT-I therapy. For example, technology is often a contributing factor in sleep problems [13]. Sufferers of insomnia also may have low motivation or may opt for easier pharmaceutical-based treatment options. Furthermore, some clinicians, especially primary care doctors, would not refer to clinicians who provide CBT-I because they still consider insomnia a secondary disease.

RQ2: Strategies for Encouraging Patient Engagement

Despite the impediments inherent to the in-person CBT-I (e.g., difficulty with scheduling due to the small number of qualified clinicians), a vast majority of patients and clinicians felt that in-person communication is irreplaceable in many situations. In this section, we describe what elements of CBT-I encourage patients to engage in the care practice.

Patients' Motivators (C-2, C-3)
Patient motivations for staying engaged after initial CBT-I sessions arise from several factors. The first factor is that of socially shared or personally experienced success. Stories about successful treatments and personally perceived improvements, whether from general feelings or trends in sleep diary data, are motivational. P2 noted: *"The fact that I'm going to feel better when I wake up motivates me because I'll do anything for that."* A patient's success can also be motivating for clinicians, as H5 noted, *"it was good experience for me as well... that's very rewarding to see how well it worked at the end of the treatment."* The second factor stems from motivational messages provided by clinicians. CBT-I sleep compression and sleep restriction prescriptions require determination and self-control to follow. Clinicians employed the motivational interview technique to promote patient engagement, which is illustrated in the following example: *"so instead of me telling them what they're doing and how they should change it, I try to elicit that from them as I find that they can tell me what they're doing and why that's impacting them in a negative way and why that should be changed"* [H6]. Lastly, a patient's own data collection practices, combined with the knowledge that their data would be shared with clinicians, empowered and motivated patients. Recording data in a sleep diary increases a patient's awareness of his/her own behaviors and makes him/her feel accountable for his/her actions. P9 stated that *"once I put in the data, I know that the doctor will ultimately see that. So it serves as a motivation or incentives to be compliant with the doctor's orders."* Patients are

accountable to their clinicians for a sleep diary which contains a record of relevant actions; they may thus try to avoid negative clinician judgments by providing incomplete or false records, or they may foster feelings of pride when they successfully complete difficult prescriptions.

Personalization (B-2, C-2, C-4)

Clinicians demonstrate personalized approaches in various ways—by fine-tuning treatment, by building inter-personal bonds, and by assessing whether patients qualify for CBT-I treatment. Clinicians selectively choose and emphasize which aspects are more important than others, thus providing patients personalized and relevant information. Clinicians also personalize sleep prescriptions based on each patient's circumstances. For example, in employing sleep restriction, some clinicians may initially allow extra time on a bed to encourage patient retention, especially for resistant or comorbid patients. For example, recognizing P4's anxiety, H1 "negotiated" with P4 over her sleep schedule by allowing her to both initially have a fixed wake up time, and to only gradually shift her to-bed time. Not all clinicians agree with this negotiation methodology, including H3, who notes: *"So if you think about CBT-I as a dosage, if someone's not getting a strong enough dose of CBT-I, like if I'm giving them seven hours when they need six, then what's happening there is I'm under dosing them."*

Building alliances with patients makes them feel supported, which can increase engagement. Clinicians thus attempt to portray a collaborative relationship with patients. Patients also prefer the "personal touch" provided by clinicians in traditional in-person visitations, specifically during discussions, when asking questions and receiving answers, and when receiving explanations. P3 remarked, *"Having a personal relationship with someone really improves because I trust them more, because I understand them more"*. Clinicians have the ability to instantaneously provide feedback, the knowledge, and experience to direct necessary conversations, and the ability to build inter-personal bonds.

One strength of in-person CBT-I is the clinician's ability to diagnose insomnia comorbid with other conditions and interact with patients in a flexible manner: *"A certain number of people that I see are probably suffering from a more generalized anxiety disorders. Some of them may have depressional problems. Part of what I'm doing is trying to rule out other possibilities or at least to understand sleep problem in the context of a large difficulty"* [H7]. Clinicians were particularly sensitive to patients with comorbid conditions; sometimes, they referred those patients to another department because treating an underlying condition was necessary to treating insomnia.

Setting up expectations (A-2, C-3)

During the initial CBT-I session, clinicians tell patients what to expect: if they follow the prescription, treatment will be successful, but they will feel worse before they get better. Knowing what to expect often has profound effects on patients. Techniques taught to patients during visits likely persist in the patients' memories, and if a sleep disorder should arise later they will have the experience, knowledge, and confidence to solve the problem. P1 stated, *"It's educating me to*

think differently, and to identify triggers that might be inhibiting my sleep. There were relaxation techniques and things like that. Try to turn off those negative thoughts and the worry before bed, try to let things go, a lot of education about that."

Reflection (C-1)

Recording and tracking sleep data using paper-based or application-based sleep diaries can help patients maintain engagement and awareness. Paper-based sleep diaries have a row labeled "comments," which affords patients the opportunity to record additional contextual information which may or may not have contributed to positive or negative sleep experiences. P3 stated, *"couple of nights ago we had like 60 miles an hour winds here. The whole house just like shook all night long. That definitely had an effect on me. I just wrote that in there so that he would know why I didn't have such great night."* This contextual information is also extremely important for clinicians, as it may change how particular data should be interpreted. *"There was one client who was really sick one day and I just deleted that data from that week, because it was going to distort all the figures"* [H5]. When compared to digitized sleep diaries, which usually have a small screen, paper-based sleep diaries often have a much larger physical form which allows some patients to easily see numbers and comment details. Three clinicians suggest that using pen and paper can give a patient an overall picture and facilitate patient reflection.

RQ3: Opportunities for Technology to Support CBT-I

Utilizing technology for in-person CBT-I could have both positive and negative effects on clinicians and patients. The patient could become accountable to the clinician and be less likely to drop-out of his or her treatment. Contrarily, technology could also invite problems with patient engagement and attrition if the patient perceives that he or she is receiving less clinician attention. Below, we provide workflow-based design opportunities for leveraging technology to preserve the gist of in-person CBT-I while easing clinicians' and patients' burdens with mundane tasks.

Support patient in-home activities

The patient's tracking of sleep data, such as by capturing sleep and contextual factors using pen and paper, is a significant part of in-home activities. Despite the existence of many available sleep tracking technologies—such as mobile [35] and consumer wearable technologies (e.g., [3]) as well as validated medical devices (e.g., [7]), we found that these technologies were rarely used in practice. Only one clinician (H1) had used Actigraph in one case to get data for comparison to a patient's sleep diary. In fact, all clinicians opposed the idea of utilizing automated capture of sleep data (e.g., wearable sensing or pressure sensing) in CBT-I because the patient's own perceptions of sleep and reflections upon sleep data are key components of CBT-I. We suspect that existing sleep tracking tools mainly focus on lowering people's capture burden without fostering self-awareness and reflection that occurs in paper-based sleep diary use. We therefore see opportunities in designing semi-automated sleep tracking tools [17], which leverage manual input for subjective measures (e.g., sleep quality) to enhance awareness, while simultaneously utilizing

sensing technology for capturing rich contextual information [34] and automatically calculating important measures such as sleep efficiency, which used to be calculated by hand in the clinician's office.

Semi-automated sleep diaries can provide many opportunities for patients to reflect on behaviors by providing opportunities to collect and review data. They can also allow clinicians to remotely monitor patients' progress and intervene to customize sleep prescriptions and treatments when necessary. Although we were worried about information overload, clinicians such as H3 expressed the desire to receive data when it becomes available: *"I absolutely want to get the data as quickly as possible because it makes it less likely that the patient will forget and then do the whole thing like the day before they come in to see me."* Reminders with encouraging messages can also be employed to alert people to track sleep and follow the sleep prescription. As H5 mentioned, *"Some fun technology just to pop up and say, 'Hey, you're doing great. Keep going.' Have that little, you know. Encouragement-type technology."* Furthermore, patient awareness that a clinician will view and utilize his/her logs will increase the patient's motivation to track, data accuracy, and accountability. Also, having timestamps of when the diary logs were entered can increase clinicians' trust of patient-generated data, thus making them confident in their assessments based on diary data. Finally, while allowing clinicians to remotely prescribe sleep regimens (e.g., wake up time and to-be time), we need to further examine how to balance personalizing remote treatment plans and in-person visits to increase patient motivation and engagement.

Support information seeking
Technology can also be used to support information seeking and assessment. Notably, for some patients, surveys can be filled out prior to patient visitations: *"Yeah, that would be ideal if we could have them have an interface where they were able to complete questionnaires in their sleep log, and it automatically dumps that into the EMR and then notify our clinicians of your patients completed their questionnaire"* [H8]. If patients can complete surveys or questionnaires on their own outside of the visitation times, clinicians benefit by having time to see more patients, which was a theme expressed by several clinicians. Patients will also benefit from having quality in-person time to discuss treatment options and rationale during those visitations instead of filling out the questionnaire or waiting in the room during the scoring and assessment. This approach however will not work for people with limited health literacy.

Support information sharing
One of the benefits that technology can provide in the current CBT-I workflow is the ways in which it can support information sharing across time and space [21, 38, 48]. Technology's ability to allow for asynchronous (not at the same time), distributed (not in the same location) data sharing between clinicians and patients to support patient in-home activities has been mentioned previously in this paper; such methods include the sharing of electronic sleep diary and environmental contextual data via web-based platform. Currently, some of our clinician participants kindly let patients share their

weekly sleep data via email or over phone calls and promptly respond to patients' urgent needs (e.g., patient is having a very hard time falling asleep, difficulties with following sleep prescription) without compensation, but this altruistic model might not scale in the future. Additionally, there are various points in the CBT-I workflow where information sharing is needed during the in-person visit (C-1 through C-4). For example, automated data sharing and data visualizations could help both the patient and the clinician readily understand the patient's state and progress, while reducing the time a clinician spends digitizing the paper-based diary entries to calculate sleep efficiency and draw graphs.

Support information assessment
Once the patient and clinician have established a trusted partnership during the initial phase of CBT-I, the patient's treatment plans can be supported through technology, with potential for aspects such as automatic generation of the patient's sleep prescription and remote sending of prescriptions. However, it would be important for the clinicians to have an ability to fine tune the generated prescription based upon patients' individual needs. Furthermore, H8 suggested: *"maybe having modules the clinician can assign like having them do a breathing exercise, or having them do a worry log on the technology or something like that. Then assign these modules as it applies to that particular patient if it applies to that patient."* In both cases, clinician burden can be lessened and patients can receive personalized treatment plans especially when they are unable to visit in-person, or when they are making good progress such that they do not need to have an hour-long, in-person session with the clinician. To ensure treatment efficacy and improve patient accountability and adherence in the home, clinicians should be equipped with an ability to remotely monitor patients' involvement and progress, although such monitoring might pose privacy concerns [21], which might discourage some patients.

DISCUSSION
Here, we discuss what it means to "make space for the quality care" in CBT-I contexts; we focus on how to enhance therapeutic relationships between the clinician and the patient, and what aspects of in-person CBT-I care should be emphasized further with the help of technology.

Making Space for the Quality Care
Technology cannot suitably solve every issue in CBT-I care, but we argue that it should be used to address the inefficiencies of the current care practice. Utilizing technology in these circumstances could allow clinicians and patients to focus on important tasks such as building a trustful relationship and sharing and reflecting upon experiences. These activities are crucial for promoting the development of effective personalized treatments. To our knowledge, the bulk of research regarding sleep technology is focused on supporting patient in-home activities (e.g., sleep tracking). Some research in CBT-I specifically discusses how patients on waiting lists for in-person CBT-I therapy or with less severe cases of insomnia may utilize cCBT-I to sufficiently meet their needs [64]. Researchers can utilize our CBT-I workflow model (patient in-home activities; information seeking; information sharing;

information assessment; and documentation) to locate under-researched themes and tasks, and examine them deeply to find novel opportunities to utilize technology.

For example, supporting information sharing with technology in CBT-I care is one under-explored area. Clinician attitudes towards leveraging technologies for accessing patient-generated data appear to be mixed; while recognizing that summarization techniques and visual analytics could help them quickly identify insights from data and encourage data reflection, they also have concerns over having access to too much data in real time [70]. As the efficiency of sharing, quality of reflection, and patient satisfaction would largely depend on how the visualization tool is designed, it is therefore important to involve both patients and clinicians during the design process to create easily understandable visualizations that support their goals and priorities.

The ability for clinicians to provide personalized care throughout every CBT-I workflow stage for each patient, such as by allowing for flexibility in sleep times for new and return patients, was another strength of in-person CBT-I care. Recent studies suggest that personalization plays an important role in improving treatment efficacy [6, 9, 26]. Although Beun argues that a virtual mobile coach can exercise automated personalization (i.e., "adaptation") when providing sleep prescriptions to treat insomnia patients [9], our study suggests otherwise; our clinician participants provided structured CBT-I treatment in a personalized yet strict manner to ensure treatment efficacy. Alankus and colleagues also emphasized the role of clinicians in customizing key aspects of treatments—such as in adjusting difficulty levels of rehabilitation games for stroke patients [6]. We believe that clinicians' sensitivity to patients' unique and individual situations and personalization based on these contextual data are the keys in successful delivery of in-person CBT-I treatment.

Support Patients with Varying Levels of Motivation
Although our research concerns with improving the in-person CBT-I practice, some of our findings relate to Computerized CBT-I. As mentioned earlier, the high dropout rate is a known problem of Computerized CBT-I, and not everyone can benefit from it. Our clinician participants suggested that people who benefit most will have strong motivations, confidence, and both the willingness and capability to learn and act upon the CBT-I manual's instructions; this is consistent with findings in other literature [64]. Furthermore, our data suggests that self-employed Computerized CBT-I will require mental stability with few comorbid diseases and adequate technical aptitude. Our findings are consistent with Maclean and Pound [37] in that a clinician presence can positively affect patient motivation to complete therapy due to personalized treatment and rewards, clarification, and support especially during the initial treatment sessions. Participants believed that Computerized CBT-I would not provide as precise, individualized, and personal treatments as human clinicians. P9 described, *"Doctor would take into account my sleep history for the three years prior to starting the CBT-I... my job obligation and profession, height, weight, blood pressure—all those types of things and come up with an overall evaluation rather than just simply plotting information into a matrix and then giving a number kicked out by an equation."* Given the respective advantages and drawbacks of in-person and Computerized CBT-I, we envision a decision support system that helps clinicians at the earlier stage of care to identify those individuals who will most benefit from in-person CBT-I versus Computerized CBT-I. For example, based on survey instruments and in-person interviews, clinicians can assess patients' emotional, physical, and psychological states to identify those who are unmotivated or who have comorbidities (thus needing more face-to-face time with clinicians) versus those who are motivated and reliable (thus needing less face-to-face time with clinicians). Clinicians can then direct the motivated patients to the Computerized CBT-I solution and occasionally check their progress while offering more sensitive care and attention to those who desperately need the in-person supervision. In the long run, we see the potential for combining in-person CBT-I and Computerized CBT-I to accommodate diverse needs and varying comprehensive abilities of the patients, but future work remains to design how to best combine these two separate models to provide quality care in a scalable way.

Limitation
This study was conducted in the U.S. and as such, comments and discussion about the hospital billing mechanism might not apply, or will be less of a concern in other countries. We also note that we could not observe as many late-stage CBT-I sessions in comparison to the earlier sessions despite our visits to the hospital occurring over the course of 3 months. We therefore complemented our data with clinician interviews.

CONCLUSION
In this study, we described the clinical workflow of CBT-I practice and proposed ways that technology could be utilized to enhance the quality of in-person care. Our findings suggest that CBT-I workflow consists of the following five categories: patient in-home activities, information seeking, information sharing, information assessment, and documentation. Our work represents an expansion of the prior clinician workflow model [43], in which we uniquely incorporate the patient's roles and activities in a CBT-I context. These elements are significant for creating quality care, but as of yet have remained under-utilized in workflow models. In analyzing the CBT-I workflow, we identified several elements that make the in-person therapy effective, such as what encourages patient engagement (e.g., socially shared or personally experienced success, self-reflection) and how clinicians motivate patients (e.g., personalized treatment, motivational messages). We also identified challenges in the CBT-I practice that make therapy ineffective and exhausting. Based on the in-depth analysis of the CBT-I workflow, we provide workflow-based design opportunities for leveraging technology to help clinicians and patients build therapeutic relationships while easing their burdens with mundane tasks.

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