Using a Key Informant Focus Group, Formative User Testing, and Theory to Guide Design of a Sleep Health BCSS

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Abstract

Designing effective applications is an important goal for software development researchers as well as practitioners. Researchers in the field of Persuasive Technologies have contributed significant theories intended to guide software developers. Yet due to the comprehensive nature of these theories as well as their recency, many aspects have not been studied—especially aspects that require integration of multiple theoretical perspectives. This paper applies a design science research approach to develop a sleep health app for use by college students. We use this setting to demonstrate how requirements gathered via a key informant focus group and formative user testing can be mapped to both persuasive system design and behavior change support system theories with the result of producing clear guidance for subsequent app design and assessment.

1. Introduction

We are in the process of designing and developing a smartphone app to support better sleep health among college students. College students are frequently sleep deprived, which in turn affects their ability to remember and concentrate, and thus their performance. Because most college students have some form of smartphone with which they engage every day, this technology provides a possible way to reach them and influence their health practices.

From our prior experience in designing and developing apps to support healthy behaviors [29][30], we have encountered two key challenges. First, the purpose of health support apps for individuals differs significantly from software developed to help organizations, and individuals in those organizations, to perform the tasks needed to accomplish organizational goals. Health support apps function in a context where use is entirely voluntary, rather than an organizational context where use is largely mandatory for accomplishing work tasks. This means that engaging users over time by providing an excellent user experience is critical for health apps. Furthermore, users differ so that apps must be designed to accommodate the needs and preferences of a variety of users.

Second, the target users are not domain experts. Medical and health professionals provide the expertise in any particular health domain, e.g., experts in the areas of sleep and student sleep deprivation and its effects in our case. Students, while being the expected app users, are not themselves sleep experts, although they may (or may not) have a good sense of their own sleep patterns. Thus, collecting requirements from the expected app users is not sufficient for determining optimal app functionality.

These two overall challenges mean that our standard systems design and development methods are not sufficient for understanding the functional requirements for personal health support apps. While some methods may still apply, we need to rethink what will work and what should be revised. Given these challenges and our conclusion that standard methods will not be sufficient, we are taking a different approach to designing our sleep health app.

First, we draw on two theoretical frameworks from the field of Persuasive Technologies [14]—*Persuasive System Design* (PSD) [25] and *Behavior Change Support Systems* (BCSS) [23][24]—to support our study in the context of voluntary use of health apps designed to engage users and promote changing their behaviors toward more healthy behaviors. Second, we employ standard requirement gathering methods to collect requirements from health experts, while employing rapid prototyping combined with formative user testing to collect requirements from users about their emergent needs and preferences. Finally, we take an overall design science approach in which we (1) iteratively design, develop, and test the app, (2) explicitly select methods and examine how well they work and (3) build and capture knowledge about appropriate health app design practices.

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2. Background

Below, we provide additional background from the literature on why sleep health is an important health problem, a brief overview of our design science research approach, and background relating PSD and BCSS to our app design process.

2.1. Sleep Health

Lack of sleep can affect an individual's performance, safety and quality of life and can have long-term negative health effects such as increased risk of diabetes, hypertension, heart attack, and obesity [3]. Sleep deprivation can also result in depression and anxiety, and it often leads to alcohol abuse [31][33].

Sleep deprivation among college students is a known health problem that affects students' performance in and outside their academic pursuits, and thus their ability to achieve their goals [21][26]. The National Sleep Foundation recommends that young adults (ages 18-25) sleep seven to nine hours per night [22]. However, sleep deprivation is common among younger populations, particularly college students. For example, 43.7% of people aged 18-24 report having unintentionally fallen asleep during the daytime, and 4.5% of the same population report having nodded off while driving [12]. Fifty percent of college students suffer from daytime sleepiness and 70% lack sufficient sleep [12].

Sleep deprivation has many other adverse effects on college students, including low grades, poor academic performance, negative moods, and increased use of stimulants. On the other hand, even brief physical activity interventions may be effective in improving adolescents' subjective sleep quality [5].

The American Sleep Association recommends that five actions are key to promote sleep health [4]: (1) keep a regular sleep schedule; (2) have a quiet and dark bedroom; (3) avoid alcohol and caffeine after five pm; (4) don't read or watch TV in bed; and (5) don't take naps. However, numerous aspects of college students' culture and lifestyle can conflict with these recommendations.

2.2. Design Science Research

The goal of design science research (DSR) is to create and evaluate IT artifacts (constructs, models, methods, or instantiations), and in doing so, contribute to a growing science of design for IT artifacts [16]. Ideally, such studies also contribute to the theories used during that design, often called *kernel theories* [15].

We follow the recommendations of [16], still acknowledged as providing the key principles for high-quality DSR. In our case, we are designing, developing, and evaluating an instantiation of an IT artifact in the form of a sleep health smartphone app.

DSR takes two primary inputs: (1) Needs determined from the environment in which the IT artifact is intended to operate and (2) knowledge bases, including *kernel theories* that meet the central requirements of theory regarding clarity of definitions, domain, relationships, and predictions [32] and provide foundations and methods for designing, developing, and testing the IT artifact [16]. For our study, needs were determined from key informants who understand sleep health of college students and from college students acting as users.

While we use a variety of standard knowledge bases for our methods of gathering requirements regarding needs, our primary kernel theories for designing the app in conjunction with the needs we identified are the PSD and BCSS frameworks.

2.3. PSD and BCSS

Health professionals started using the Internet for therapeutic interventions beginning in the mid-1990s, e.g., [28]. Since that time, Internet-supported health interventions have increased in number and expanded in scope to encompass patient education, counseling and therapy, and support software [9].

During this same period, researchers began to study how computers in the Internet age can act as persuasive technologies to change users' attitudes and behaviors [14]. This line of research led to development of the PSD framework [25], which integrated the existing persuasion and persuasive technology literatures and identified 28 design principles for improving software within categorical areas of primary task support, interactive dialogues, system credibility, and social support.

Initial reviews demonstrate that the set of persuasive features that is selected for Internet-supported interventions can vary substantially across implementations [20], and that feature selection may lead to differences in important outcomes, such as user adherence [17]. The BCSS concept [23][24] was developed in large part to guide application of PSD principles during the process of software development with the objective of improving intervention outcomes.

Oinas-Kukkonen ([23] p. 6) defines BCSS as "an information system designed to form, alter or reinforce attitudes, behaviors or an act of complying without using deception, coercion or inducements."

Specifically, the BCSS concept proposes that software developers consider both the type of change that is desired (compliance, behavior, or attitude) and the mechanism for achieving change outcomes (forming, altering, or reinforcing) in designing systems. These types of changes and outcomes are described fully in Section 4 below. We follow BCSS guidelines in the present study.

Because BCSS promote change without using deception, coercion or inducements, the focus of these systems centers on interventions where changes are desired by the intervention targets. This is particularly appropriate in the context of improving sleep health among college students, who would likely reject any intervention that is not voluntary.

BCSS theory is a recent development, thus relatively few empirical studies have addressed its central propositions. Initial tests are encouraging, e.g., [19][20], but researchers caution that a significantly wider range of BCSS factors still need study, especially research designed "to link the BCSS use to measureable and objective outcomes" ([19] p. 186]. The intended contribution of the present study is development of a DSR approach that can provide both descriptive and prescriptive forms of *useful knowledge* [15] to meet this objective

3. Methodology

We employed four different, but complementary, methods to gather and apply requirements during development of our sleep health app.

3.1. Focus Group Methods

We conducted a focus group with key informants who are student health domain experts. These were the Director of the university Student Development and Counselling Center (SDCC) and three members of the SDCC counseling staff. The focus group was convened to assess sleep deprivation among college students and to identify key challenges and success factors for reducing sleep deprivation. We conducted this focus group we as a first step to fulfill the DSR guideline to establish *problem relevance* [16]. The following results emerged from the focus group session.

Sleep deprivation is a serious problem among college students at the university and elsewhere. Students get as little as four to five hours of sleep per night vs. the recommended seven to nine hours. Inconsistent sleep patterns are common—bedtimes and wake-up times change dramatically depending on the day of the week, on workload (e.g., exams, group projects), and on social life. Results are missed classes and appointments as a result of forgetting to set an alarm or sleeping through it, excessive dependence on caffeine (including energy drinks), depression, and anxiety. Students complain to their counselors that they need more sleep or have trouble sleeping but lack the ability to adopt better sleep health practices.

A technology-based solution (e.g., a mobile app) would work well for the target population. Use of mobile devices is ubiquitous and well-accepted among college students.

Personalized solutions are needed for different populations. Focus group participants identified two populations of college students at high risk of sleep deprivation: High-achieving students who become involved in too many activities, and low-achieving students who need improved organizational skills. In addition, more first-year students complain about lack of sleep than do upper-class students, perhaps because of the new life adjustments they are going through (e.g., having a roommate and being away from home for the first time). Allowing users to personalize the form and content of sleep health solutions will likely produce better results than using the same approach for all students.

Feedback is an important component for supporting positive change. College students would benefit from being able to track their own sleep behavior in a quantifiable manner, from receiving feedback on their sleep patterns, and from observing how these patterns compare with college students in general. The focus group considered students at the university to be orientated toward quantitative analysis and to desire exercising tangible controls. They predict students will be willing to track their sleep if it is not too cumbersome for them to do so.

(e) *A community approach is likely to produce better results.* Activities that reduce sleep, including hard work and late-night socializing, are part of college culture. As a result, students may develop an inflated perception of the importance of constant activity. Recognition of social aspects of sleep deprivation and reporting of actual community statistics could help synchronize students' perceptions with community realities. Sleep health also may be improved by incorporating peer support, e.g., through an associated sleep health forum.

We conclude from review of focus group results and background literature that sleep deprivation is a serious problem among college student and that college students are likely to be amenable to a technology-based solution in the form of an app to support sleep health. We further conclude that this app should be personalizable by the user, it should provide feedback to support students' goals to improve sleep health, and it should support a community approach to better sleep health.

After consideration, we decided to focus initially on high-achieving students at the university. If we can improve their sleep health, they can potentially serve as community role models for other students.

3.2. App Review Methods

Based on recommendations by the key informant focus group regarding potential value of a mobile app, we explored existing sleep apps for Android devices, our planned development target. This was our second step to fulfill the DSR guideline to establish *problem relevance* [16]. We found popular commercial offerings ranging from simple apps that provide music or relaxation techniques to induce sleep (e.g., "Relax Melodies: Sleep & yoga", "Calm-Meditate, Sleep, Relax"), to more elaborate apps that track sleep behavior (e.g., "Sleep Better with Runtastic", "SleepBot", "Sleep as Android"). Many of these apps have been downloaded over a million times. We reviewed frequently downloaded free sleep apps with consumer review scores of at least 4 out of 5 stars and categorized the services they provide into four main groups:

- Relaxing music
- Guided meditation / relaxation techniques
- Sleep patterning (e.g., mobile device at bedside collects and summarizes movement patterns)
- Smart alarm clock (e.g., waking is based on prescribed time in the user's sleep cycle)

None of these apps provides a combined experience of personalization, feedback, and community, the three factors our key informant identified as key to engage students. Thus, we conclude there is an opportunity to design and develop a sleep health app that can meet the needs of college students beyond what is currently available.

3.3. Formative User Testing Methods

To understand the needs of student app users, we applied rapid prototyping techniques to develop a basic sleep health app. We then collected user requirements via three formative user experience (UX) tests. Each iteration corresponds to a *generate/test* cycle within the DSR guideline for conducing *design evaluation* [16]. In Iteration 1, we developed an initial proof-of-concept prototype in the form of an Android app and conducted two UX tests with it. In Iteration 2 we revised the prototype and conducted a two-week longitudinal UX test.

Formative testing is sometimes referred to as a *find-and-fix* method that focuses on identifying usability problems during product development rather than at completion [27]. Formative UX testing, in which a small number of participants perform core tasks with a technology prototype, can provide a rich source of data to guide subsequent design improvements [2]

3.3.1 Iteration 1: Proof-of-Concept Prototype. The initial proof-of-concept prototype app was developed as an undergraduate development team project completed over one semester to fulfill a university project requirement [13]. The app's functionality included basic features such as setting up an account, setting a sleep goal, tracking sleep time using a manual toggle button, setting an alarm, and choosing music to play for a fixed amount of time when going to sleep or when waking up.

The development team conducted a UX test on the initial app by observing four student users as they attempted to perform a set of basic tasks using the app. Based on this test, several improvements were made, including removing bugs that occurred when downloading the app and refining the app in areas where participants had difficulty using it, e.g., entering information during the signup process, setting an alarm, and selecting music. The team then conducted a second UX test on the refined app by observing a new pool of six student users who attempted to complete the same set of basic tasks.

At the end of both UX tests, student users were asked to rate their interaction with the app via the 10-item System Usability Scale (SUS) [2][11]. SUS is often used in industry research to assess usability of products and services [2]. Results are represented with a single SUS score ranging between 0-100. Scores below 50 indicate poor design; scores between 50 and 70 indicate an acceptable design; scores between 70 and 85 indicate a good design; and scores above 85 indicate an excellent design [7][8].The SUS scores reflected the team's refinements, moving from 56.25 (acceptable design) in the initial UX test up to 76.66 (good design) when the refined app was tested.

After the team project comprising Iteration 1 was completed, we assessed the app and the results from its testing. We came to two conclusions. First, we confirmed our idea that a sleep health app for college students is a sound approach. The app provided a proof-of-concept which was liked by the students who tested it. Second, we determined that additional development was needed in the app's user interface (UI) to add functionality and streamline operations and in the app's database to support enhance the scope and scale of data collection.

3.3.2 Iteration 2: Revised Prototype. Iteration 2 development required several revisions to the proof-of-concept prototype. These were conducted by the research team with assistance of graduate student developers.

Our first step was to decide what changes in functionality were needed to the initial proof-of-concept prototype in order to support longitudinal testing. Our goal was to decide which changes were essential immediately and which could be left to later iterations. Several immediate changes were made. We modified the app's interface by introducing three tabs (*Going to Sleep*, *Sleep Data*, and *Sleep History*) to better organize the app content that was introduced in Iteration 1. We also developed a slide-out menu that is hidden until it is triggered either by tapping a list button in the navigation bar or by swiping right on the content area. This type of menu provides users with full navigation options without permanently occupying screen space. We also redesigned the database to accommodate more nuanced information about users' sleep patterns and to improve scalability.

The revised prototype was tested in a longitudinal study of two weeks length in which student participants used the app each day. Participants for this study were selected from the Student Support Network (SSN) pool, a group of student volunteers at the university who are trained to help with the efforts of the SDCC. An email invitation was sent to this network through one of the staff at the SDCC. Six of students who responded to this invitation signed up and completed the study. We met with these participants individually at the beginning and end of the study.

In the beginning meeting, each participant downloaded the app and used it to complete the set of core tasks shown in Table 1. Researchers observed that participants were able to accomplish these tasks without needing additional instructions in order to ensure that they could use the app successfully by themselves over the following two weeks. All participants were able to use the app without any further training or specific instructions. This behavior suggested that our modified interface design was easy to use.

The objective of the end meeting with study participants was to collect information about their experiences using the app. We asked them to rate their experience of using the app over the prior two weeks, rather than a one-time interaction as assessed for the Iteration 2 SUS surveys. The average reported SUS score was 72.50, placing the experience in the "good" range.

When we asked participants to tell us about what they disliked most about the app, they mainly complained about the alarm functionality, which was not part of this current test and was not fully supported by the app. In addition to suggesting a need to fully support this functionality in the next iteration of the design, we interpret the fact that participants voluntarily explored use of the alarm feature provides a tacit demonstration of their engagement with the app.

Table 1: Core Tasks Tested in Iteration 2

- Download and install the app
- Proceed through the initial app setup procedure
  - Enter participant ID
  - Enter sleep goal
- Set up the alarm for 3 minutes from now
- Complete Epworth sleepiness scale
- Make entries on *Going to Sleep* tab
  - Enter today's caffeine intake
  - Enter today's amount of exercise
  - Check the alarm settings
  - Click the "I am going to sleep" button
- Disable the alarm
- On waking click the "I am waking up" button
- View the graph
- Edit your sleep data

When we asked participants what they liked most about the app, they all mentioned its simplicity: "it does exactly what it is expected to do", "it is easy to use", "it is not cluttered", "it is simple to use". These results suggest that simplicity is likely to play a major role in adoption of our sleep health app, a point that we will continue to monitor.

The interview data showed that 67% of participants found the sleep data to be useful, and found it easy to remember to use the app, 50% said they would like to continue using the app.

We also asked participants about several UI design options for the Main Menu, *Going to Sleep* tab, and *Sleep Data* tab. The majority of participants showed preference for one of the two designs for the Main Menu, *Going to Sleep*, and *Sleep Data* tabs. We then asked them to choose between three display designs for the *Sleep History* tab. For *Sleep History*, preferences varied substantially. Some participants preferred bar charts, some line charts, some asked for an option that would allow them to choose the way they wished to view the data. Some wanted to see data labels on the charts while others considered data labels to clutter the design.

All participants mentioned that charts in the *Sleep History* tab were helpful for tracking their sleep. Two participants mentioned that through the feedback provided by the *Sleep History* tab, they learned they are getting far less sleep than they need; "It made me very aware I am not meeting my goal". Two participants said that they would like information about their caffeine consumption and exercise patterns to be included in the charts. Overall, comments about the *Sleep History* tab support the need for user personalization of app functionalities.

Because the app stored all user interaction and data input on a server, we could also gain insight from app usage data during the two-week period of the study. We first examined use of the sleep goal. We found by the end that 67% of participants chose eight hours as their sleep goal, and 33% chose seven hours as their sleep goal. One participant changed his sleep goal from six hours to eight, and then to seven, potentially indicating a growing awareness his actual sleep patterns.

Our student participants reported sleeping between seven to eight hours on average. However, there was a great deal of variation in this data. For example, all but one participant had at least one occurrence of less than five hours sleep during the week, and four slept 11 hours or more at least once on a weekend. These data show that participants did not meet standards for consistency of sleep during the two week study.

The data also showed that the majority of participants went to sleep quite late. Over 80% of individual sleep recordings began after 1 am, and most of the remainder began not long before then. One participant compensated his six hours of overnight sleep with one-hour naps during the morning and afternoon.

Participants averaged 1.2 servings of caffeinated drinks and 25 minutes of exercise per day. Generally, caffeine consumption was higher during weekdays than on weekends. Again there were substantial variations in the data. Caffeine intake ranged from 1 to 4 servings during the weekdays, and reported exercise periods ranged from 15 minutes to 2 hours in length. Most participants reported more days without exercise than with exercise.

We concluded that feedback and personalization have strong potential for improving sleep health by supporting app users' access to personal history data that can be important to set and achieve goals (providing improvements over sometimes fallible memory) and providing them with the ability to view the data in the form that they prefer. We note that our Iteration 2 participants requested to receive more feedback on their caffeine intake and exercise patterns in addition to being able to personalize how their historical data is displayed.

4. Mapping to PSD and BCSS Theories

PSD and BCSS represent distinct theoretical approaches to persuasive technologies research, yet the two approaches are highly compatible. As Oinas-Kukkonen notes, "The Persuasive Systems Design model … is the state of the art conceptualization for designing and developing BCSSs" ([23] p. 8). Thus, we proceed by mapping our results from key informant focus group and formative user testing to the theoretical perspectives of PSD and BCSS. Sections 4 and 5 are intended to fulfill the DSR guideline to establish *research contribution* [16].

First, we address personalization, feedback, and community, which are design elements that the focus group and formative user tests indicated are useful for engaging students. Our purpose is to understand how these three design elements are addressed by PSD design principles. Second, we identify how these design elements fit within BCSS guidance for achieving behavioral changes. Because our goal is ultimately to develop an app that will lead to behavioral changes toward better sleep health, we want to see whether and how they fit within the BCSS framework.

4.1. PSD: Personalization

PSD includes within its Primary Task Support category the design principle of *personalization*, which states "A system that offers personalized content or services has a greater capability for persuasion." This principle represents a straightforward mapping of results from formative user testing in this study in which users requested varied options for interacting with the sleep health app. A prominent example we found is the high level of diversity reported by users regarding the graphical forms in which they preferred to visualize their sleep history. Accordingly, our further research will develop functionality that enables users to personalize data displays, as well as other key aspects of their interaction with the sleep health app.

4.2. PSD: Feedback

Feedback is encompassed in several PSD design principles within its Dialog Support category. These include *praise*, *rewards*, *reminders*, and *suggestion*. Within the context of our sleep health app, we interpret feedback as centering on the content of dialogs vs. issues related to appearance or timing of that dialog. An important example of feedback we found in our user study is that the app informs users of their sleep patterns, including the times they went to sleep and the length of their sleep periods. Based on results from our key informant focus group and formative user testing, we anticipated that this information would be useful to users both for setting sleep goals and for assessing goal achievement. Indeed, one participant changed his sleep goal several times, likely in response to feedback from the app.

The PSD design principles related to feedback are important and useful, however, none of these precisely fit the concept of providing feedback absent some concurrent recommendation, e.g., praise for meeting a goal. We propose such information-only feedback is better described by the concept of *informating* [34], in which information technologies automate translation of activities, objects, and events (e.g., going to sleep and waking up) into informational content (e.g., a history of how long you slept). We will further assess this proposition in our next-iteration development of feedback options.

We also intend to follow PSD recommendations to add reminder and suggestion design elements. Potentially, praise and reward design principles may be incorporated in longer-term development if justified by further user testing.

4.3. PSD: Community

PSD addresses community through a *social role* design principle within its Dialog Support category and seven additional design principles within its Social Support category: *Social learning, social comparison, normative influence, social facilitation, cooperation, competition,* and *recognition*. Results of our key informant focus group suggest that community focus will help to synchronize students' perceptions with reality of the sleep patterns among their peers and thereby minimize inflated expectations to be constantly active.

Our sleep health app prototypes, to date, have not incorporated community-related software features. In our next-iteration development, however, we propose to include features following social support, social learning, social comparison, and social facilitation PSD design principles. Potentially, PSD cooperation, competition, and recognition design principles may be implemented in future development iterations pending results of further user testing.

In conclusion, mapping the app requirements to PSD design principles provides support for our focus on personalization, feedback, and community. It also provides us with additional design possibilities for including such functionality. Furthermore, we may be able to contribute to PSD regarding feedback by further exploring the concept of feedback for *informating* purposes, i.e., providing informational feedback without recommendation.

4.4. BCSS: Outcome/Change Design

BCSS theory [23][24] focuses on two dimensions. The change dimension supports three types of change that have long been identified as central components of human action [1][18]:

- Change in *compliance* (C-Change), in which system users act to comply with a specific instruction
- Change in *behavior* (B-Change), in which users demonstrate an enduring pattern of action
- Change in *attitude* (A-Change), in which users internalize their support for behavior change

Although B-Change is the tacit objective of BCSS, effective systems must provide mechanisms for C- and A-Change as well. C-Change is a necessary first step in demonstrating a long-term behavioral change, but it is not sufficient to meet most objectives of BCSS. Regarding attitudinal change, Oinas-Kukkonen argues that "change-in-full occurs only when attitude change takes place and that a sustainable B-Change happens only through an A-Change" ([24] p. 1226). Thus, all three types constitute important components of overall change.

The BCSS outcome dimension focuses on three processes that are central to behavioral change [6]:

- *Formation*, the outcome of which is a pattern of compliance, behavior, or attitude is formed that did not exist previously, e.g., following the instruction to set an alarm in our sleep health app
- *Alteration*, the outcome of which is some alteration of an existing pattern of compliance, behavior, or attitude, e.g., reducing consumption of caffeine prior to sleep
- *Reinforcement*, the outcome of which is reinforcement of an existing pattern of compliance, behavior, or attitude, e.g., hearing from a friend that "you look really great today" following a good night's sleep

These two dimensions form the BCSS Outcome/Change Design Matrix as shown in Table 2 [23]. BCSS theory assumes that each cell in this matrix can contribute to achieving behavior *change-in-full*, thus BCSS designers should consider carefully how each instance of outcome/change can be effectively addressed. For example, the combination of Alteration Outcome and C-Change might be addressed in our sleep health app by instructing users to reset the alarm to wake them with soothing music and then monitoring that they have complied with this instruction.

4.5. Guiding Propositions

We have overlaid the Outcome/Change Design Matrix shown in Table 2 with labeling showing where we propose personalization, feedback, and community design elements will make their principal contributions. As a group, these three design elements cover all components of the matrix, thereby addressing major aspects of BCSS theory.

Table 2. Outcome/Change Design Matrix

	C-Change	B-Change	A-Change
Formation Outcome	(F/C) *Personaliz.*	(F/B) *Personaliz.*	(F/A) *Community*
Alteration Outcome	(A/C) *Feedback*	(A/B) *Feedback*	(A/A) *Community*
Reinforce. Outcome	(R/C) *Feedback*	(R/B) *Feedback*	(R/A) *Community*

First, we propose personalization will principally affect formation of changes in compliance and behavior, based on users feeling more engaged and invested in the sleep health app as they perceive themselves using its features [10].

Second, we propose feedback will principally affect alteration and reinforcement of compliance and behavior. For example, providing sleep history that is more accurate and reliable than the users' own memory should help users maintain focus on their sleep goals.

Finally, we propose community will principally affect formation, alteration, and reinforcement of attitudes. These effects will be sought through PSD social learning, social comparison, and normative influence design principles.

These propositions follow DSR *design evaluation* guidelines to support our sleep health app through its next development iteration. *Design* will be guided by the BCSS mandate to address each cell in the Outcome/Change Design Matrix. We will accomplish this using personalization, feedback, and community design elements that were identified through our key informant focus group and formative user testing and subsequently mapped to the PSD framework. *Evaluation* will be guided by measuring how effectively the implementation of each design element meets expectations in achieving change in measures of app users' compliance, behavior, and attitude.

5. Demonstration

In order to anchor our conceptual discussion in Section 4, we present a demonstration of how design and evaluation in future research can be guided by the joint results of the present study. Caffeine intake and exercise patterns are two factors that were identified by the key informants focus group as important determinants of sleep quality. In addition, participants in formative user testing explicitly requested development of app features that would allow users to track their own caffeine intake and exercise statistics as an augmentation to their sleep histories. The shared focus we find on caffeine and exercise by corroborating key informant and user sources justifies incorporating the ability to gather and track these factors into the design of the next-iteration sleep health app. We propose that this can be accomplished effectively under guidance of PSD and BCSS theories.

Our plan for the next-iteration development of our sleep health app is to support the ability for researchers to "switch on" design features through central database control in order to enable experimental conditions (full functionality) vs. control conditions (limited functionality) for each feature. This approach will allow prespecified sets of design features to be randomly assigned to participants, and it offers further potential to develop counterbalanced research designs in which participants can use and compare multiple versions of the sleep health app within a longitudinal research structure.

Table 3 describes a set of example conditions that could be applied to assess personalization, feedback, and community design features relating to caffeine intake and exercise. For example, the Feedback with personal statistics design feature demonstrates how an informating approach might be implemented, i.e., providing information absent any recommendation.

Several distinct design feature sets can be drawn from the example conditions shown in Table 3, as illustrated in Table 4. Random assignment of such feature sets will allow us to test a variety of interesting questions regarding the relative effects of personalization, feedback, and community features, e.g., on subsequent behavior rates. Although the demonstration presented here is just one example of research designs that can be drawn from our initial findings, we propose that it effectively links BCSS use to measureable and objective outcomes, as recommended by Lehto and Oinas-Kukkonen [19], using an approach that follows DSR *design evaluation* guidelines.

Table 3. Example conditions for assessing effects related to caffeine intake and exercise

Design Feature	Experimental (E) and Control (C) Conditions	Hypothesized Outcome, Change, and Rationale
Personalization of graphical display	(E) Subjects can select how caffeine intake and exercise history statistics are displayed (C) A standard display is presented	Formation of C-Change and B-Change from heightened user investment through acts of personalization
Feedback with personal statistics (informating approach)	(E) Caffeine intake and exercise history is displayed (C) No caffeine intake and exercise history is displayed	Alteration and reinforcement of C-Change and B-Change from increased focus on goals
Community statistics are available in real-time	(E) Summarized caffeine intake, exercise, and sleep history for the user community is displayed (C) No community data is displayed	Formation, alteration, and reinforcement of A-Change from learning about actual behaviors of peer users

6. Conclusion

In the next iteration of our research program we will redesign and augment our sleep health app to address the complete set of requirements gathered from our key informant focus group and two iterations of formative user testing. We also will develop further functionality based on the guiding propositions of PSD and BCSS theories. These two sources of content will support use of experimental designs with random assignment. As a bonus, our findings will generalize to other PSD/BCSS studies.

Regarding this latter point, our research strongly supports the theory-development efforts of prior researchers in the field of Persuasive Technologies. We find PSD and BCSS theories synchronize well to provide an effective, integrated framework for conducting research in voluntary use of technologies applied to improve health or to modify other behaviors. We especially appreciate the clarity and unambiguous guidance that characterize the central propositions these theories encompass as well as their fit within the DSR guidelines.

Table 4. Design feature sets developed from example conditions listed in Table 3.

Feature Set Description	Condition Implemented		
	Pers.	Feed.	Comm.
Personalization focus	Exp	Exp	Exp
Community-comparison feedback	Control	Exp	Exp
Individual feedback	Control	Exp	Control
Minimal functions	Control	Control	Control

It is not overstatement to describe the literatures that underlie persuasive technologies as exceptionally broad and diverse. It is important therefore that research conducted in this area has some means to achieve commonalities that can mitigate inherent complexity. We feel that PSD and BCSS play this role in guiding the direction of our sleep health research program, and we recommend them for similar DSR approaches.

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