

HealthAware: An Advice System for Stress, Sleep, Diet and Exercise

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Abstract—We developed a feedback-loop, user-tailored advice system to provide stress interventions and advice about improving sleep, diet, and exercise habits at the workplace. Thirty participants joined a 2 week study: in the first week, we collected their behaviors about sleep, diet, exercise and stress levels using Fitbit and surveys. During the second week we continued monitoring, and based on the participants' measurements in the previous days, we also provided interventions and advice during the workday, and evaluated their preferences. We found that participants with higher stress levels liked stress interventions more and that somatic activities were most preferred and reduced stress levels the most. We observed individual preference differences in the types of advice; however, tracking and receiving advice raised users' awareness of their stress, sleep, exercise, and dietary behaviors. We found that the largest positive impact was on our participants' dietary behaviors.

Keywords—interventions; sleep; exercise; diet; stress; behavior change

I. INTRODUCTION

The workplace today is very stressful: 83% of Americans are stressed at work [1]. The average number of hours spent at work is about 8 hours [2], and may be growing longer with the “always connected” workplace becoming ubiquitous. Organizations desire that their employees work efficiently and effectively; however, the work place can be a source that adds stress to employees and reduces their productivity, and thus, influences health negatively. For example, employees who suffered from insomnia had a significantly higher rate of absenteeism at work than those who slept well [3].

Stress and the health management of sleep, diet and exercise strongly influence physical and emotional wellbeing and can improve productivity at work. Diet, exercise, and stress interventions at the workplace have been studied [4, 5, 6, 7, 8, 9]. Paredes et al. developed a micro intervention mobile phone application system which provided user-tailored stress interventions using a machine learning algorithm for personalization and evaluated which kinds of interventions were likable and effective [10] across users. In this paper, we extended this work and developed a system to provide interventions for stress and advice for wellness (sleep, diet and exercise) to increase their happiness and productivity while they are using a desktop computer at work. This system provided user-tailored advice for sleep and diet, based on

measurements from a wearable activity tracker that monitored daytime activity levels, # of steps and sleep, in addition to user survey responses. We evaluated the system during a 2 week study with 30 participants. In this study, we focused on the following research questions:

1. Which stress interventions/wellness advice were most preferable/effective?
2. Which interventions showed large self-reported stress reduction?
3. Did participants feel the advice was user-tailored?
4. Did the participants feel that the stress interventions were provided at the right time?
5. Did activity monitoring and receiving interventions/advice change participants' awareness and behaviors?

II. METHODS

A. Study Design

Thirty participants (male: 12, female: 18, age: less than 25 years old: N=3, 25-29: 8, 30-49: 14, 50-59: 5) joined the Health Aware study. All the participants were employees at a technology company in the United States. The study consisted of two parts. The first phase was a five day stress and activity monitoring period. The second phase, also five days, continued with the monitoring and also included a personalized health advising system (“HealthAware”) installed on their computers at work.

1) First week

At the beginning of the first week, participants filled out pre-study surveys about gender, marital status, race, age, height, weight, and work. They also completed the Perceived Stress Scale (PSS) [11] and the Pittsburgh Sleep Quality Index (PSQI) [12]. Throughout the study period (both in the first and second weeks), they filled out the start and end of workday surveys (Table 1). All participants wore an activity tracker (Fitbit, USA) to monitor their activity and sleep.

2) Second week

In addition to monitoring participants during week 1, we installed our HealthAware advice application on their desktop computers. The application provides interventions (suggestions

and recommendation) for stress (Table 3), and advice for sleep, diet and exercise (Table 4).

B. Desktop Software & Intervention Design

Figure 1 shows the screen example of our desktop application. Every 4 hours the software uploaded the participants' latest Fitbit data to our server. The participant also accessed the start and end of workday surveys from the application.

Stress Interventions:

Stress interventions were designed based on previous work [10]. We increased the number of interventions to avoid boredom and grouped commonly used stress management methods into 4 categories (positive psychology, cognitive behavioral, meta-cognitive and somatic practices) and subdivided each category into "individual" (activities that people can perform alone) and "social" (activities that people do with others) interventions (Table 3). On each day in week 2, the first stress intervention window popped up between 30 and 60 minutes after the first computer activity of the day. After that, the stress interventions, chosen randomly from those that had not yet been provided to the participant, were popped up at a randomly chosen time between 90 and 150 minutes after the previous intervention. Participants were first asked if this was good timing to receive a stress intervention using a 7-point Likert scale (1: Extremely Bad - 7: Extremely Good). If they said "good timing", they were then asked to rate their stress level (1: Not stressed at all-7: Extremely stressed). They were then provided with stress intervention (Figure 2) and asked to evaluate how much they liked the advice, whether they found it effective or not, and then self-rated their stress level again.

TABLE I. START AND END OF WORKDAY SURVEYS

<i>The start of workday survey</i>	<i>The end of workday survey</i>
Mood (Positive and negative affect scales (PANAS) [13]), bed time, sleep latency, sleep medication intake, wake time, last food time, sleep duration, # of wake up, subjective sleep quality, restfulness upon waking, issues that interfere with sleep, alcohol intake, exercise duration, breakfast contents, amount and balance of breakfast, dinner contents, amount and balance of dinner	Mood (PANAS), sleepiness, anything significant that affected mood or stress, productivity ratings, # of phone calls, video massages and texts, lunch contents, amount and balance of lunch, high in processed and refined sugar or starch, caffeinated beverages and water

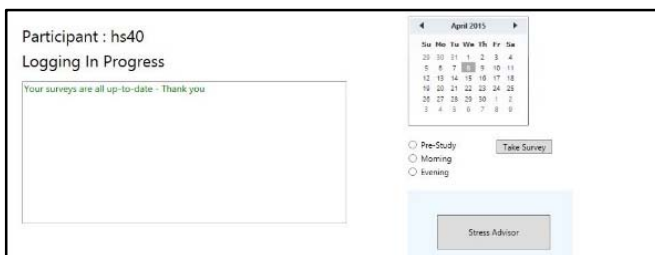


Fig. 1. Desktop application screen example

Sleep, Diet and Exercise Advice:

Sleep, diet and exercise advice was developed based on [14][15][16]. We prepared 15 pieces of advice for each category (Table 4). To provide user-tailored sleep and diet advice, we computed scores for each possible intervention/advice based on analysis of the participants' unique Fitbit measurements (sleep duration, quality, bed time, wake time, sleep latency, # of awakenings and # of steps) and survey responses from the previous five days. The scores (0-1) were computed as follows. For example, about meal balance, $\text{Score_MealBalance_}\{\text{Breakfast, Lunch, Dinner}\}$

$= (4-X)/3$ if $X \geq 4$ then 0X: answer in the start or end of workday surveys

(1: Not at all balanced – 7: Very balanced)

$\text{Score_MealBalance_Day}$

$= 1/3 * (\text{Score_MealBalance_Breakfast} + \text{Score_MealBalance_Lunch} + \text{Score_MealBalance_Dinner})$

$\text{Score_MealBalance_Past5day}$

= Average of $\text{Score_MealBalance_Day}$ in the past 5 days

Similarly for sleep, a score was developed as follows:

if (MinutesToFallAsleepFromFitBit > 15) $\text{Score_SleepOnset} = 1$

if (SleepEfficiencyFromFitBit < 95) $\text{Score_SubjectiveSleepQuality} = 1$

if (ObjectiveSleepQuality < 4) $\text{Score_ObjectiveSleepQuality} = 1$

$\text{Score_Sleep_Day} = (\text{Score_SleepOnset} + \text{Score_ObjectiveSleepQuality} + \text{Score_SubjectiveSleepQuality})/3$

$\text{Score_Sleep_Past5day} = \text{Average of Score_Sleep_Day in the past 5 days}$

If they had poor behaviors in each category, then the score in the category gets higher. Each intervention within the category applied the different metrics above in its own algorithm to determine the score for that specific intervention/advice. The HealthAware system delivered interventions with the highest scores that had not previously been provided to the participants. In week 2, the system provided three interventions per session and three sessions per day (morning, afternoon and evening) (Figure 3). After they saw each intervention, the system asked if they liked that specific exercise/sleep/diet advice and if the participant found it to be effective.

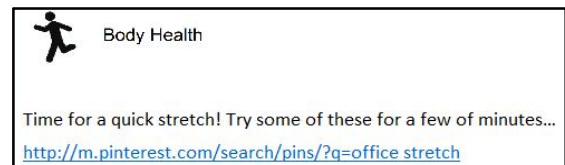


Fig. 2. Sample screen for stress intervention



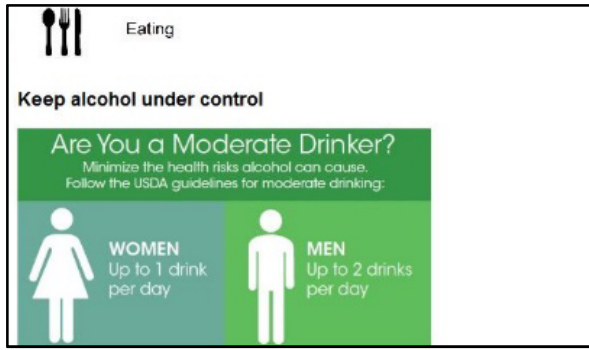


Fig. 3. Sample screens for sleep, diet and exercise advice

III. RESULTS

A. Participants Profile

We summarized participants' behaviors from pre-study surveys. 23% of the participants exercised less than one time per week. 63% of the participants slept more than seven hours per night; however only 27% of the participants had good sleep quality (PSQI < 5). Self-reported stress levels at work (mean: 4.3) were significantly higher than stress levels in personal life (average=3.5) (1: Little or no stress, 7: Extremely high stress) ($t(58)=2.3$, two-tailed, $p < 0.05$).

B. First Week

We summarized participants' sleep, diet and exercise behaviors based on their survey responses and Fitbit measurements (Table 2). For dietary habits, participants missed breakfast more frequently and had more unbalanced food than lunch and dinner. As shown in Figure 4, at the end of the first week, more than 50 % of the participants became more aware of their stress, sleep, diet and exercise through tracking their behaviors and filling out the surveys. Sleep was the behavior most participants became more aware of (76%), followed by diet (68%), exercise (59%) and stress (53%).

C. Intervention Preference and Effectiveness

Which interventions are preferable and effective?

Across all interventions and advice, we observed large individual differences. We marked the top three most liked and effective advice hints for sleep, diet and exercise (Table 4). We also analyzed the relationship between participants' scores (good/poor behavior levels) and preference/effectiveness. We found that people with poorer behaviors for sleep onset, objective and subjective quality preferred advice about bedroom environment, de-stress and soothing pre-bedtime more (correlation analysis, $r=0.59, 0.57, p < 0.05$) and found them to be more effective ($r=0.70, 0.61, p < 0.05$).

For stress interventions, somatic individual and social interventions were rated as the most preferred (50 and 52%, respectively) and effective (36 and 37%, respectively) of all; however the percentage of users who rated them as effective was much lower than that of those who liked them (Figure 5). On the other hand, the least likable and least effective interventions were social positive psychology and social meta-cognitive interventions.

TABLE II. AVERAGED BEHAVIORS ON THE WEEK 1

<i>Sleep</i>	
Duration: 7.1 ± 1.3 hours (mean \pm SD), Bed Time: $23:10 \pm 1:00$	
Last electronics usage: $22:48 \pm 1:25$, Subjective sleep quality: 4.4 ± 1.0 (1:extremely poor, 7:extremely good), Objective sleep quality: 94.8 ± 4.4 , Tiredness in the morning: 3.9 ± 1.0 (1: extremely tired, 7: extremely rested), Sleepiness of each day: 2.1 ± 0.8 (1: not sleepy at all, 7: extremely sleepy), Sleep latency: 23.7 ± 35.4 mins	
<i>Diet</i>	
Missed meals: 16.1% (breakfast), 4.7% (lunch), 2.5%(dinner)	
Amount of food: 1.9 (breakfast), 2.1 (lunch and dinner) (1: too little food, 2: about right, 3:too much)	
Unbalanced food: 61% (breakfast), 38% (lunch), 48% (dinner)	
Last food: $21:58 \pm 1:21$	
<i>Exercise</i>	
Daily steps: 7589 ± 2204 , Sedentary minutes: 807 ± 99 mins	
Lightly active minutes: 114 ± 52 mins, Fairly active minutes: 73 ± 27 mins, Very active minutes: 22 ± 16 mins	

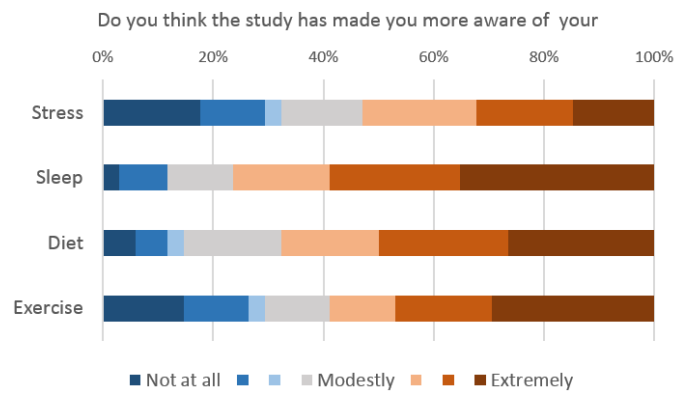


Fig.4. Awareness change at the end of week 1

D. Stress Profile vs Preference:

Participants with higher PSS scores (stress scores measured in the pre-study survey) showed higher preference scores for stress interventions (statistically significant $p < 0.05$). In other words, participants were experienced higher levels of stress did like getting the stress interventions.

E. Stress Reduction

Somatic social intervention showed the largest percentage of stress reduction, the difference between pre- and post- self-reported stress levels, followed by a somatic individual intervention (Figure 6).

F. Personalization

About 31 or 46% of the participants rated the sleep and diet advice as user-tailored, which is what we were striving toward with our design.

G. Timings for Stress Interventions

51 % of the first pop-up windows for stress interventions were rated as bad timing (Extremely/very/slightly bad timing) and 32% was rated as good timings.

H. Behavior or Awareness Change

For non-stress advice, participants found diet advice as the most helpful and sleep advice the least helpful (Fig.7 top).

Overall, more than 50% of participants felt it was helpful to be made more aware of their stress levels (50%), thought sleep advice was useful (58%), thought diet advice was useful (73%) and a large number of participants thought that exercise advice was useful (69%) (Fig.7 bottom). Participants reported that they exhibited more behavior changes around diet than for sleep (Figure 8). Importantly, about 40% of the participants ate more balanced meals and more vegetables during our study. About 20% of the participants reported avoided eating right before sleep because of our recommendations.

IV. DISCUSSIONS

Our results show that sleep habits are hard to change in users’ well-formed behaviors. Sleep tracking with Fitbit and surveys definitely increased participants’ awareness of their sleep; however, they found sleep advice was the least helpful and least influenced their sleep decisions. Our findings could lead to a further possible study on how we can improve actual sleep, in addition to increasing awareness. Combining checking what kind of problems each participant had and monitoring their daily sleep behaviors and the environmental context in addition to providing more user-tailored advice could improve the sleep choices participants might make. We have some more work to do to customize personalization even further. We believe that machine learning algorithms could go a long way here to better target activities to recommend to users to get a better grip on these health behaviors. With this 2 week study, it was difficult to evaluate how exactly the participants did or did not change their behaviors. As a next step, running a long-term study with a control group who only tracks their behaviors and a group who both tracks and receives interventions/advice will tell us more about how much a recommender system assists with behavioral change. In addition, our results showed that stressed people preferred stress interventions more than non-stressed individuals and half of the randomly provided stress interventions were provided at bad times (e.g. when typing continuously) . Designing a system to provide just in time stress relief advice, possibly using sensors like EDA (electrodermal activity) or HRV (heart rate variability) in addition to video and/or audio and computer usage monitoring could be the next step to explore for better personalization via machine learning.

V. CONCLUSION

We developed a feedback-loop, user-tailored advice system, HealthAware to promote stress, sleep, diet and exercise management which influences physical and emotional health at workplace. We ran a 2 week study with 30 individuals to evaluate the preference and effectiveness of automated advice and to observe how the system changes their behaviors and awareness. Participants found somatic (body exercise, breathing and stretching) advice as most preferred and effective for stress reduction and stressed participants preferred stress intervention more. Diet and exercise advice was more helpful than sleep advice and increased their awareness for opportunities for behavioral change.

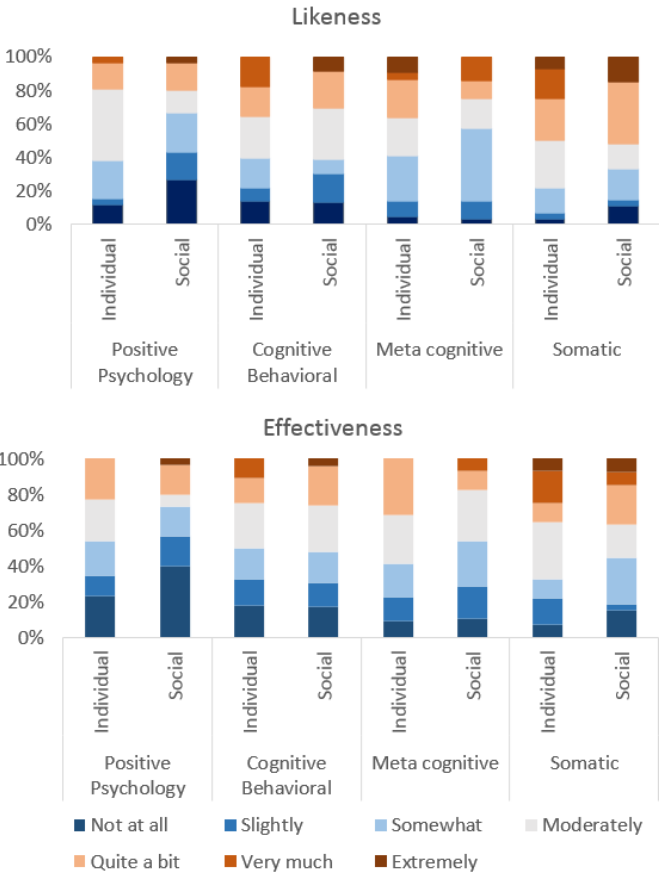


Fig.5. Likeness and Effectiveness in Stress Interventions

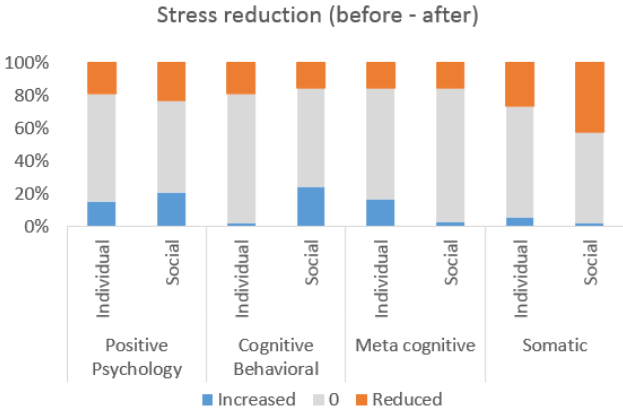


Fig.6. Stress Reduction

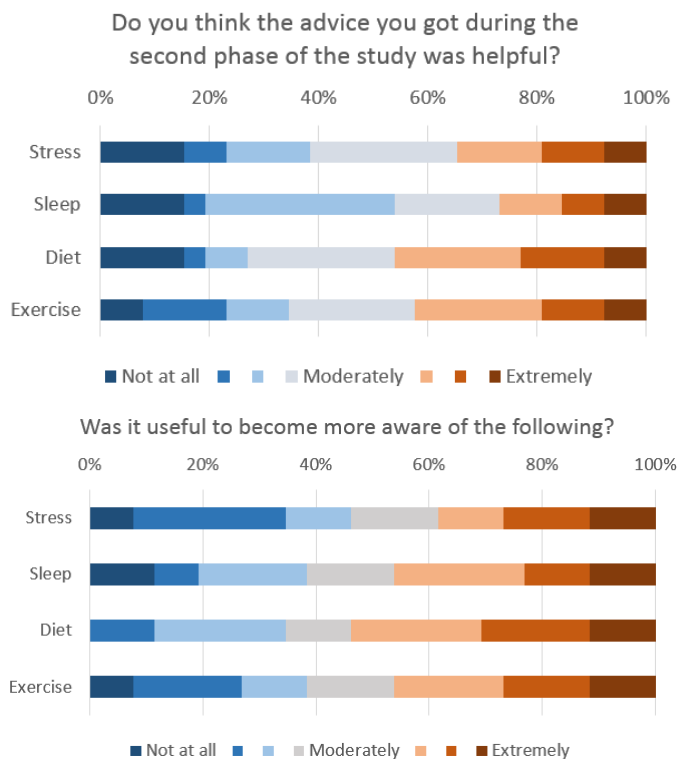


Fig.7. Evaluation of the system

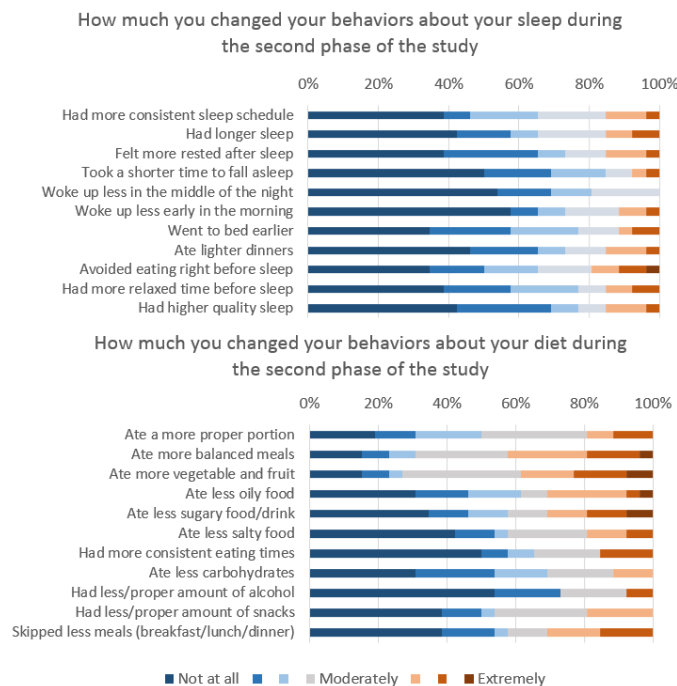


Fig.8. Behavior changes in sleep and diet

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TABLE III. STRESS INTERVENTIONS








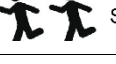



Categories	Therapy Techniques	Group Icons and Names	Examples
Positive Psychology	Three good things Best future self Thank you letter Act of kindness Strengths Affirm values	 Food for the Soul	Use a random generator from 1 to your current age and try to remember a good simple memory when you were that age http://www.random.org/
		 Social Souls	Make someone feel good! www.facebook.com
Cognitive Behavioral	Cognitive regraming Problem solving therapy Cognitive Behavioral Therapy Interpersonal Skills Visualization	 Master Mind	If you can achieve something in the next month, what would it be? http://www.shrib.com
		 Mind Meld	Think about a hard situation a friend/family is going through, and find some alternative solutions online. Send it to them http://www.wikihow.com/
Meta cognitive	Dialectic Behavioral Therapy Acceptance and Commitment Therapy Mindfulness Emotional Regulation	 Wise Heart	Look at cute things :) http://cuteoverload.com/
		 Better Together	Share one of these with friends after viewing it: http://www.inspirationalstories.eu/
Somatic	Relaxation Sleep Exercise Breathing Laughter	 Body Health	Change your posture / sit up straight (look at pics/video)
		 Social Time	Go grab a coffee or take a short walk with someone.

TABLE IV. SLEEP, DIET AND EXERCISE ADVICE

Category	Advice	Timing (M: Morning, A: Afternoon, E: Evening, Any: Anytime)	Components to calculate scores	Most Liked	Most Effective
 Sleep	Keep Consistent Sleep Schedule	E	Sleep regularity	O	O
	If you feel sleepy, go to bed soon.	E	Sleep onset/objective/ subjective sleep quality		
	Turn Your Bedroom into a Sleep-Inducing Environment	E	Sleep onset/objective/ subjective sleep quality		
	Do not concentrate on trying to fall asleep	E	Sleep onset		
	Learn ways to blank out thoughts that keep you awake	E	Sleep onset		
	Avoid bright lights, physical activity, mental activity, or anything that makes you alert in the middle of the night when you wake up	E	Awakening		
	Associate your bed with sleep.	E	Sleep onset/objective/ subjective sleep quality		O
	Exercise moderately during the day	M/A	Sleep onset/objective/ subjective sleep quality		O
	De-stress	M/A	Sleep onset/objective/ subjective sleep quality		

Category	Advice	Timing (M: Morning, A: Afternoon, E:Evening, Any: Anytime)	Components to calculate scores	Most Liked	Most Effective
	Avoid stimulants that Interfere with Sleep	A	Alcohol/Caffeine		
	Lighten Up on Evening Meals	E	Dinner amount		
	Ensure adequate exposure to natural light.	M/A	Sleep onset/objective/subjective sleep quality		
	Establish a Soothing Pre-Sleep Routine/Before bedtime	E	Sleep onset/objective/subjective sleep quality		
	Avoid exposure to bright lights for the 5-10 min or so before you retire.	E	Sleep onset/objective/subjective sleep quality	O	
	Avoid taking sleeping pills unless you absolutely must.	E	Sleep medication	O	
 Diet	Balanced food	Any	Balance		
	Mindful eating	Any	Amount		
	Keep alcohol under control.	E	Alcohol		
	Eat breakfast.	M/E	Breakfast Ate		
	Plan for a snack attack.	M/A	Sugar_carbo	O	
	Drink enough water, tea or coffee (with little or no sugar).	M/A	Water		
	Pile on the vegetables and fruit.	Any	Fruit/vegetables		
	Go for the good fats.	Any	Fat		
	Replace refined grains and potatoes with whole grains	Any	Fiber	O	O
	"Carb-check" your breads and cereals	Any	Sugar_carbo		O
	Eliminate liquid sugars	Any	Sugar_startch	O	O
	Learn to like less sodium	Any	General		
	Control Portion Size	Any	Amount		
	Be choosy about nighttime snacks.	E	Last food		
 Exercise	Cut back on solid fats	Any	Fat		
	Identify available time slots.	Any		O	
	Select activities that require minimal facilities or equipment				
	Identify inexpensive, convenient resources available in your community				
	Develop a set of regular activities that are always available regardless of weather				
	You don't need to get all your exercise at one time.			O	O
	Take lunch on the move			O	
	Make exercise fun.				
	Turn sit time into fit time.				
	Reward yourself.				O
	Select activities requiring minimal time				
	Invite friends and family members to exercise with you				
	Schedule physical activity for times in the day or week when you feel energetic.				
	Convince yourself that if you give it a chance, physical activity will increase your energy level				O
	Join an exercise group or class.				
	Take a class to develop new skills.				