

Improving Health Care with a Virtual Human Sleep Coach

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Cristina Ribeiro, Gaurav Mehrotra, Gregory Vey, Areej Alhothali, Chrysanne DiMarco

Computer Science, University of Waterloo, 200 University Avenue West, Waterloo, Canada
cribeiro@uwaterloo.ca, gmehrotra@uwaterloo.ca, gvey@uwaterloo.ca, aalhotha@uwaterloo.ca, cdimarco@uwaterloo.ca

Abstract

Persuasive technology can have a significant effect on people's health. The sleep coach application is a persuasive technology that raises student's awareness and attitudes towards getting a full night's sleep (6-9 hours) to be more positive. Students using the application to attempt changing their sleep patterns as a direct result of the application. NOTE: We will have the results of this research by the final camera-ready paper deadline. We are currently in the process of conducting the experiment.

Keywords: Persuasive Computing and Technology, Health Persuasion, Affective Model, Virtual Human Coach, Improving Sleep Habits.

1. Introduction

Persuasive technology is defined as any interactive computing system designed to change people's attitudes or behaviors [1,2]. There are certain areas where persuasive technology could be especially useful. For example, health care software applications may be developed to motivate people towards healthy behavior, and thereby possibly delay or even prevent medical problems as well as ease the economic situation in public health care.

This is where we decided to design a persuasive technology that could help students improve their sleeping habits and change their attitudes towards a more positive and realistic view of sleep. By determining the most effective way of motivating a college or university student to have healthier sleep habits, such as sleeping earlier and more consistently. Since undergraduate students typically spend most of their time sitting in front the computer to study, play, or communicate with friends, we chose to build our system in the form of a computer application that sends intervention messages to the user, encouraging them to maintain healthier sleep habits.

The sleep coach application was developed with a virtual human coach that pops up in the system window tray when the user is inactive for an extended period of time, as a means of not being intrusive and interrupting the user when they are working and being productive. The messages displayed teach the user about proper sleeping

habits, how it affects their health and ability to perform in their studies. There are three types of coaching styles to cater to different people's preferences. These styles are sympathetic, neutral and strict. Everyone is different and different coaching styles will motivate different people.

The application has a rhetorical model, which provides the basis for motivated change. Our model relies on the work of rhetorician Kenneth Burke [1], who believed a motive is shorthand for situation. The situation or motive addressed by the Sleep Coach application is the degree of sleep deprivation experienced by the user. This allows the rhetorical model to assume user engagement.

We conducted an experiment to determine the effect of a combined persuasive model of affect and rhetoric on behaviour change. We measure the effectiveness and persuasiveness of the sleep coach application, in changing student's behaviour and attitude towards getting a full night's sleep.

This paper outlines some current examples of persuasive technologies in section 2. The sleep coach application is discussed in section 3. Section 4 describes the affective model. The experimental design is outlined in section 5. In section 6 the results are shown and discussed. Conclusions are listed in section 7 and future work is discussed in section 8.

2. Background

Traditionally persuasion was limited to human communication designed to influence the judgments and actions of others. The Web, Internet, mobile and other ambient technologies created new opportunities for persuasive interactions by reaching out directly to a large number of users. In addition, the Web and other Internet-based systems are optimal for persuasive communication, because they are able to combine the positive attributes of interpersonal and mass communication.

Persuasive systems may utilize either computer-human persuasion or computer-mediated persuasion. Admittedly, the concept of a persuader is relatively complex. As computers do not have intentions of their own, those who create, distribute, or adopt the technology are the ones who plant intentions into persuasive

applications. Although computers can't communicate in the same way as humans, recent studies suggest that some patterns of interaction similar to social communication may be utilized in human-computer interaction. Computer-mediated persuasion means that people are persuading others through computers, e.g. discussion forums, e-mail, instant messages etc. The earliest signs of persuasive technologies appeared in 1970s and 1980s, when a few computing systems were designed to promote health and increase workplace productivity. One of the earliest examples is a computer system named Body Awareness Resource Network (BARN), developed in late 1970s. Gradually other interactive programs of this nature followed, most designed to address adolescent health issues or to treat psychological disorders. But it wasn't until the emergence of Internet that more than a handful of people began creating persuasive applications. Beyond the web, persuasive technology can take many forms, from mobile phones to "smart" toothbrushes to the computerized trailers that sit by the roadside and post the speed of passing cars in order to persuade drivers to abide by the speed limit.

Today, industry experts and academics are embracing a purposeful approach to persuasive design. In an industry context, designing for persuasion is becoming essential for success. In academic settings, the study of persuasive technology illuminates the principles that influence and motivate people in different aspects of their lives. The emergence of the Internet has led to a proliferation of web sites designed to persuade or motivate people to change their attitudes and behavior. Within the domain of e-health, systems such as mobile applications for managing obesity and digital interventions to overcome addictive behaviors have demonstrated the huge potential of persuasive technologies for behavioral changes.

The use of interactive persuasive technology in health sector is still in its nascent stages. Technological developments in ubiquitous computing and ambient intelligence have opened new gates in this area [3]. The latest developments in the area of context-aware computing, will make it possible to infer elements of a person's context and activity, and deliver appropriate persuasive health-related messages to that person at the right time and place when decisions are made or behavior is executed, i.e., just-in-time messaging [4]. Moreover, the embedding of computational power and interactive displays in our everyday environment [5] as well as the ubiquity of mobile computing devices worn or carried by an increasing number of users, makes it feasible to provide persuasive feedback at the appropriate place where the user is likely to benefit most.

There is immense potential for persuasive technologies when applied to the health sector. Persuasive technology can lead to a healthier lifestyle by influencing decisions related to diet, exercise, smoking etc. This in turn can lead to significant savings in healthcare costs and less

dependence on medical and healthcare professionals. A number of early explorations are available, with more ambitious applications currently being implemented by major companies (e.g., Intel, HP Labs, Philips). Examples include virtual fitness coaches for motivating people to work out in order to stay fit [6, 7]. QuitKey, a mobile application for helping people beat their smoking habit by following a gradual reduction program [8], MyFoodPhone, which promotes healthy eating habits by keeping track of food intake and biometric data, and connecting to a nutrition coach who provides personalized feedback to users [9], or the recent use of social network visualizations as behavioral feedback displays, raising awareness of social connectedness as a dynamic and controllable aspect of well-being [10].

Persuasive technology is finding its application in other areas as well. In fields like education and environmental conservation, messages giving out relevant information at the right time are a very powerful tool in motivating people to change their behavior. For example, direct feedback on energy consumption on turning the heater up, taking a shower or using a household appliance [11] can trigger a positive behavior change. Computer games such as PowerHouse [12] are quite useful in raising environmental awareness. Given the huge success of computer games amongst children and adolescents, educators are currently looking at the opportunities for motivating learning experiences through the engaging interactivity and subtle reward structure of computer games [13, 14].

3. Sleep Coach Application

The Sleep Coach system architecture consists of the following major modules: user profile and questionnaire, classifier, graphical user interface (GUI) and script database. The architecture is as shown in Figure 3.1. In addition, there is a rhetorical model used in the application. Each module is discussed in detail in the subsequent sections.

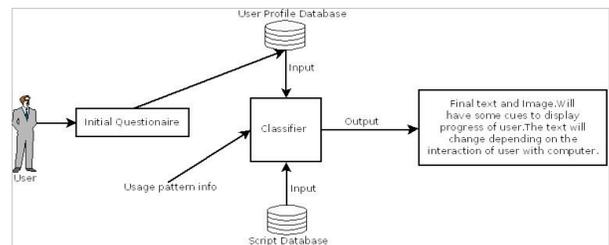


Figure 1. Sleep Coach Application System Architecture

Figure 3.1. Sleep Coach Application System Architecture

3.1 User Profile and Questionnaire

This module contains a set of questions regarding age, gender, sleep patterns, etc. necessary for building the initial user profile. These attributes are kept in the database so the user is not required to fill out the form each time. These attributes enable the application to keep track of the user's progress and history, and provide valuable data to the classifier.

3.2 Classifier

This module is responsible for deciding the message content and when the message needs to be generated. In order to decide when the message needs to be generated, a portion of the classifier keeps track of the user's activity on the computer by monitoring mouse clicks and keystrokes. The classifier also logs the current time on the user's system clock. By combining the system clock time with the user activity data, the classifier is able to determine the most appropriate time for generating messages to the user. In our current implementation, the Sleep Coach is enabled at 9 pm and runs until 6 am, assuming that the application is opened by the user during those times.

Once the decision regarding the message and the content of the message is made, the classifier relays this information to the User Interface module that displays the message using a system tray popup along with a coach image.

3.3 Graphical User Interface

The application sends the user messages through a popup window, which slides above the Windows task bar. The size of the popup window is 300x200 pixels and is divided into three main sections: a message, a picture of the coach, and a progress bar, see Figure 3.2.



Figure 3.2. Sleep Coach GUI

To ensure the user sees the message, the popup will disappear after 30 seconds. It will then reappear after 30 seconds and continue to do so until the user physically closes the popup window. The progress bar turns red in order to emphasize the seriousness of a lack of sleep, when the user's average number of sleeping hours is less than

50% of that of the normal. On the other hand, when the user's sleeping hours are above 50% of the normal sleeping hours, the progress bar will turn green to encourage them to maintain their current sleeping pattern.

3.4 Script Database

This module contains the various scripts for the sleep coach using three different coaching styles; namely neutral, compassionate, and non-compassionate, see Figure 3.3.

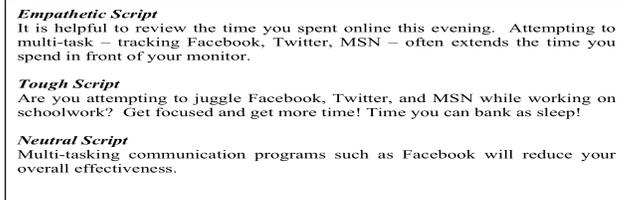


Figure 3.3. Sleep Coach Script

3.4 Rhetorical Model

The tailored messages that represent to sleep coach users relay on Kenneth Burke work, who believe who believed a motive implies situation [15]. The motive or the situation in this study is the user's degree of sleep deprivation that measured by monitoring the user's active time. Using Burke's conception of motive as situation allows the rhetorical model to assume user engagement, or in other words the user is presupposed to accept the rhetorical appeal of the application.

Burke posited that motives are addressed on three levels: rhetorical, symbolic, and grammatical [16]. We have based our rhetorical model on Burke's three-part structure. The rhetorical appeal of the application is based on the generic scripts that remain fixed for all users, excluding such personalization as tailoring for the user's first name. However, the scripts are written strategically to utilize specific figures and tropes to induce affect.

Grammatically, Burke defines a motive to be governed by a pentad of factors that align with a dramatic approach. Each motive involves an *act*, *scene*, *agent*, *agency*, and *purpose* [17]. The Sleep Coach application defines the *act* as a virtual human coach appealing to a user to live a healthier life by getting the appropriate amount of sleep. The *scene* is the user working at the computer late at night. The *agent* is a virtual human coach available to the user at the situational moment, in other words the *scene*. The *agency* is the internal design of the software, specifically the classifier. Finally, the *purpose* is to both effect and affect the motives of the user towards identification with a healthier life

Burke's final element of a motive, the symbolic, involves human representation of situational motives and identification primarily through art. Our model accounts for the symbolic appeal through our design of the virtual human coach avatar. The application's ability to alter the look and age of the coach provides a symbolic representation of what Burke would define as another mind that seeks identification with the user.

4. Affective Model

Affective computing (AC) [18] is an emerging field aimed at providing computer systems with human-like affective capabilities and emotional intelligence [19, 20, 21]. The cornerstone of AC is that the quality and effectiveness of interactions between a user and a system will be improved as a consequence of reciprocal affective exchanges [21]. As a result, research in AC is strongly focused on the recognition of the affective states of users and the corresponding generation of affective responses from systems [21].

The present work uses the Baseline Affect model [22] as the underlying affective model for the coach software agent. Baseline Affect is used to represent the general affective demeanour of a system [22]. Thus, we have employed it here to provide the coach with one of three possible affective styles; compassionate, neutral, or strict. The style assigned to individual users was determined non-invasively according to their selections of coach features during the initial application setup. The specific rationale of this assignment process is described in the previous work [22].

5. Experimental Design

Prior to receiving the Sleep Coach software all participants attended an intake session. During the intake session each participant completed a self-report questionnaire about their demographics and sleep behaviour (see Appendix A). Next, the Montreal Cognitive Assessment (MoCA) [23] was administered to obtain a pre-test measure of mild cognitive impairment, an indicator of REM sleep disturbances [24]. Immediately following the pre-test MoCA, participants were tasked with a timed proofreading exercise that appeared to part of the battery of cognitive tests. However, this was actually a high demand cognitive task administered as an anti-mnemonic device designed to impede recollection of the MoCA content, thereby minimizing any practice effects. After the intake session was completed, participants were provided with a copy of the Sleep Coach software and instructions for installation and use. After a one week period of usage, participants returned for a follow-up session. The MoCA was administered to obtain a post-test measure of mild

cognitive impairment. Participants were then provided with debriefing information about the study.

6. Analysis & Results

To determine the effect of application usage versus improvement in sleep, we performed a paired sample *t*-test where the dependent measure was the difference in MOCA score, specifically post-test versus pre-test values. Final results are pending.

7. Conclusions

Persuasive technology can serve as a useful component of application design and development. In particular, the use of affective and rhetorical models can enhance the persuasive power of these applications. This becomes especially important for domains such as health informatics where there can be a high degree of impedance with respect to changing the beliefs and behaviours of users. While the Sleep Coach application was successful in a very specific domain, it also serves as an example of the use of affect and rhetoric toward more prototypical challenges in the effective delivery of health information. Therefore, we believe that the simplified implementation presented here can serve as a useful model for more elaborate future endeavours in the field of health informatics.

8. Future work

There are many different parts of the Sleep Coach application that can be implemented more significant functionality. The first area is the system architecture discussed in section 8.1. Finally, section 8.2. covers the methodology for testing the Sleep Coach application and determining its efficacy.

8.1. System Architecture

Upon the initial use of the application, immediately after the user has successfully installed the application on their computer, the user is presented with a user profile and questionnaire screen. This screen asks the user a series of questions that helps the application classify the user, determining user motivations, tailoring information, and even identifying the possible obstacles the user faces in improving their sleeping habits.

Many of the components included in the user profile are not presently being used by the application. Currently, the application uses the user's name, age, and current number of sleep hours. The list of components, found below, could be used in the application to obtain more knowledge of the user's situation. With this added understanding of the user, the application's scripts would be displayed at opportune times, with targeted scripts that

would be highly effective in motivating the user to change their behaviour and improve their sleeping habits. It would also make the scripts much more tailored, thereby increasing the effectiveness of the application to produce affect in the user. The user would be more attentive and receptive to the messages they receive, and as a direct result they would be more motivated to take action to better their sleeping habits.

The other components included in the questionnaire are:

- Gender
- Type of user (athlete, studious, or gamer)
- Barriers
- Triggers (deadlines, exams, etc.)
- Accommodation (live with parents, in residence...)
- Noise level (low, moderate, or high)
- Coach type (Compassionate, Neutral, or Drill Sergeant)
- Energy level (low, moderate, or high)
- Number of hours spent using the computer per day
- Main reason for using the computer
- Number of courses the student is currently enrolled in
- Type of student (undergraduate or graduate)
- Number of hours the user sleeps on weekdays
- Number of hours the user sleeps on weekends
- Time the user usually falls asleep
- Time the user usually wakes up

8.2. Classifier

It would be interesting to extend the intelligence of the classifier beyond monitoring the user's keystrokes and mouse use to actually monitor all the applications being used by the user while working on the computer. This would give the application much more detail about the user's computer activity. If common applications such as Microsoft Word, Excel, Power Point, and so on are not only open but actively engaged by the user, the Sleep Coach application can conclude that the user is working on an assignment, lab, research, or school project. The application would not interrupt the user if they are actively using these applications. On the other hand, if the user is playing a game or using an application that would not be classified as related to their academic productivity, the classifier would then produce a script from the database for the particular application being engaged by the user. This makes the system more persuasive and personalized, as the classifier is able to display messages relevant to the user's individual context.

9. References

- [1] Fogg, B.J.: Persuasive technologies. *Communications of the ACM* 42(5) (1999) 27-29
- [2] Fogg, B.J.: Persuasive Technology. *Using Computers to Change What We Think and Do.*

San Francisco, Morgan Kaufman Publishers (2003)

- [3] Intille, S.S.: A new research challenge: Persuasive technology to motivate healthy aging. *IEEE Transactions on Information Technology in Biomedicine*, 8 (2004) 235-237
- [4] Intille, S.S.: Designing a home of the future. *IEEE Pervasive Computing* 1, April/June (2002) 80-86
- [5] Aarts, E., Marzano, S.: *The New Everyday. Views on Ambient Intelligence.* Rotterdam, 010 Publishers (2003)
- [6] Davis, J.W., Bobick, A.F.: Virtual PAT: a Virtual Personal Aerobics Trainer. *Proc. of Workshop on Perceptual User Interfaces (PUI'98)*, San Francisco, CA (1998) 13-18
- [7] IJsselsteijn, W.A., de Kort, Y.A.W., Westerink, J., de Jager, M., Bonants, R.: Fun and Sports: Enhancing the Home Fitness Experience. In: Rauterberg, M. (ed.), *Entertainment Computing - ICEC 2004. LNCS*, 3166, New York, Springer Verlag (2004) 46-56
- [8] <http://www.quitkey.com/>
- [9] <http://www.myfoodphone.com/>
- [10] Morris, M.E.: Social networks as health feedback displays. *IEEE Internet Computing* 9(5) (2005) 29-37
- [11] McCalley, T., Kaiser, F., Midden, C.J.H., Keser, M., Teunissen, M.: Persuasive appliances: Goal priming and behavioural response to product-integrated energy feedback. In: IJsselsteijn, W.A., de Kort, Y.A.W., Midden, C.J.H., Eggen, J.H., van den Hoven, E.A.W.H. (eds.), *PERSUASIVE 2006. LNCS*, 3962, New York, Springer Verlag (2006) 45-49
- [12] Bang, M., Torstensson, C., Katzeff, C.: The PowerHouse: A persuasive computer game designed to raise awareness of domestic energy consumption. In: IJsselsteijn, W.A., de Kort, Y.A.W., Midden, C.J.H., Eggen, J.H., van den Hoven, E.A.W.H. (eds.), *PERSUASIVE 2006. LNCS*, 3962, New York, Springer Verlag (2006) 123-132
- [13] <http://www.seriousgames.org/>
- [14] Lucero, A., Zuloaga, R., Mota, S., Muñoz, F.: Persuasive technologies in education: Improving motivation to read and write for children. In: IJsselsteijn, W.A., de Kort, Y.A.W., Midden, C.J.H., Eggen, J.H., van den Hoven, E.A.W.H. (eds.), *PERSUASIVE 2006. LNCS*,

3962, New York, Springer Verlag (2006) 142-153

[15] Kenneth Burke, *Permanence and Change*, Berkley, 1954, p. 44.

[16] Kenneth Burke, *A Grammar of Motives*, Berkley, 1945, p. 465.

[17] Ibid. p. xv.

[18] R. Picard, *Affective Computing*. Cambridge: MIT Press, 1997.

[19] J. Tao and T. Tan, "Affective Computing: A Review", *Lecture Notes in Computer Science*, J. Tao, T. Tan, and R.W. Picard, eds., First International Conference on Affective Computing and Intelligent Interaction, ACHI 2005, Berlin: Springer-Verlag, pp. 981-995, 2005.

[20] R.A. Calvo, "Latent and Emergent Models in Affective Computing", *Emotion Review*, vol. 2, no. 3, pp. 288-289, 2010.

[21] R.A. Calvo and S. D'Mello, "Affect Detection: An Interdisciplinary Review of Models, Methods, and their Applications", *IEEE Transactions on Affective Computing*, vol. 1, no. 1, pp. 18-37, 2010.

[22] G. Vey, C. DiMarco, and M. Lafrance, "Baseline Affect: Toward Non-Invasive Affective Tailoring in Multimedia Domains", *IEEE Transactions on Affective Computing*, manuscript submitted for publication (copy on file with author).

[23] Z.S. Nasreddine, N.A. Phillips, V. Bédirian, S. Charbonneau, V. Whitehead, I. Collin, J. L. Cummings, H. Chertkow, "The Montreal Cognitive Assessment (MoCA): A Brief Screening Tool For Mild Cognitive Impairment", *Journal of the American Geriatrics Society*, vol. 53, no. 4, pp. 695-699, 2005.

[24] J.F. Gagnon, R.B. Postuma, S. Joncas, C. Desjardins, V. Latreille, "The Montreal Cognitive Assessment: A Screening Tool for Mild Cognitive Impairment in REM Sleep Behavior Disorder", *Movement Disorders*, vol. 25, no. 7, pp. 936-40, 2010.