Personal ICT Ecosystem to Promote Habits that Improve Sleep Quality.

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Abstract
Poor sleep quality can cause diverse deficiencies in mental and physical health. Several information and communication technologies (ICT) systems have been developed to improve sleep quality, most of which monitor patterns in sleep epochs to determine the quality of sleep. We propose a personal ICT ecosystem (PICTE) to address the same problem through a different approach. Our work considers the integration of technology (hardware and software) to obtain data related to sleep hygiene habits. The PICTE processes these data through an inference model based on a machine learning algorithm. Besides, a persuasive system sends advice/reward messages to users, to persuade them to change their habits to improve sleep quality.

Author Keywords
Machine Learning Algorithms; Persuasive Systems; Personal Ecosystem; Sleep Hygiene.

ACM Classification Keywords
H.1.2 [User/Machine Systems]: Human information processing; J.3 [Life and Medical Sciences]: Medical information systems; I.2.6 [Learning]: Parameter learning.

Introduction
In recent years, many systems in the area of Information and Communication Technology (ICT) have been proposed

PervasiveHealth 2016, May 16-19, Cancun, Mexico

DOI 10.4108/eai.16-5-2016.2263759

The poor quality of sleep increases the risk of diseases such as:

- Diabetes.
- Cardiovascular diseases.
- Depression.
- Alzheimer.

Implementation areas for ICT systems to help people sleep better:

- Monitoring sleep patterns behavior.
- Diagnose specific sleep disorders.
- Instigating behavioral changes through persuasive systems to help people improve their quality of sleep.

to help people improve their quality of life. Researchers in sleep medicine have found that poor quality of sleep is closely related with chronic diseases, such as diabetes [10], cardiovascular diseases [9], depression [4] and mental disorders such as Alzheimer disease in the long term [3].

We propose a PICTE integrated by a set of sensors, an inference model based in Machine Learning Algorithms (MLA) and a persuasive system that interacts with users to motivate them to change their sleep hygiene (SH) habits to improve sleep quality. In the following sections we describe the related work, components of the PICTE, our methodology and current conclusions.

Related work

In the computing technology field, several systems exist for addressing sleep problems in different populations. We can find tree application areas: 1) monitoring sleep patterns during sleep epochs [4, 6]; 2) diagnosing specific sleep disorders [7]; and, instigating behavioral changes through persuasive systems to help people improve their quality of sleep [1].

Ecosystem

We propose PICTE, an ecosystem to help people improve their sleep quality as the Figure 1 shows. The ecosystem uses a set of sensors to obtain SH-related data from user, which are processed by an MLA to predict a value representing the quality of sleep (vQoS). After obtaining the vQoF, the PICTE interacts with users through a mobile application sending advices messages for areas of improvement and reward messages for goals achieved. Furthermore, the ecosystem obtains feedback from users to fit the inference model according to their preferences.

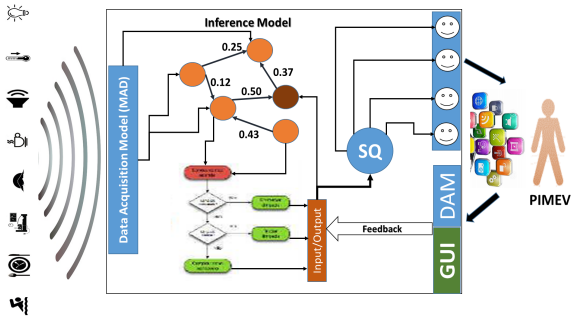

Figure 1: Model of the proposed personal ICT ecosystem

Set of sensors

The reviewed literature shows that unobtrusiveness is a desirable feature for people interested in application systems related to sleep monitoring [5]. This finding motivates us to use sensors that are already found in smartphones and mobile devices such as accelerometers, pedometers, gyroscopes, and microphones, due to users do not typically perceive mobile devices as an extra hardware [8]. Furthermore, we can place small and imperceptible sensors in users' home, to feed inference model with relevant data related to SH. This concept is demostrated in Figure 2.

Inference model

The inference model consists of a database containing SH data and a MLA to predict sleep quality. The model obtains data from the database in a supervised approach and receives feedback from users to achieve adaptations regarding their preference and feeling well. As shown in the Figure 1, the inference model obtains raw data regarding SH through data acquisition system from the users' environment. The data are processed through an MLA that predicts the sleep of quality based in the database and user feedback.

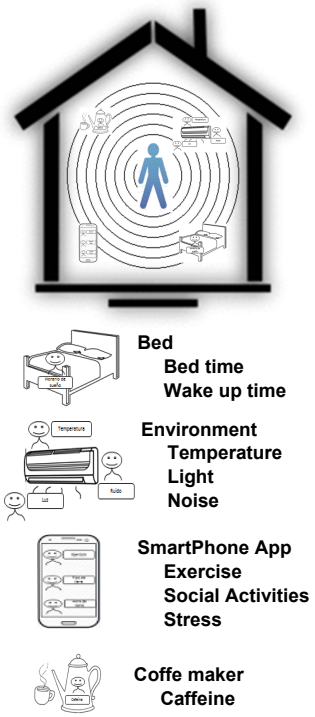

Figure 2: Set of sensors to perceive the SH factors

Persuasion System

The ecosystem obtain information from the user by employing sensors and a graphic interface. The user receive value information from the ecosystem through one application installed in their smartphone. This information is produced by agents who read the information provided by the inference model. The agents build messages according to the specific needs and characteristics of the users These messages are sent to users to motivate SH habits that improve their sleep quality. The figure 3 shows one scenario in which a dialog is established between the user and system. Two-way communication is not achieved in this sense that: 1) the system is ready to listen to the user any place, any time and as often, as necessary, but 2) the user does not have the same availability, which is limited by time and users' activities.

We plan to follow work on cognitive behavior therapy (CBT) presented by [2] to persuade users to change their SH-related habits. The aforementioned paper identifies alignment, adaptation, and motivational supports as concepts that must be implemented to persuade a subject. Although we consider the alignment concept to be the most important for our work (see Figure 3), nevertheless, we plan to design our persuasive system based on all three concepts. The persuasive system motivates the user to change their habits, and the user provides feedback to inform the system of whether the inference is accepted and effective communication is being achieved. Over time, the two entities obtain better acceptance of each other and alignment will converge.

Methodology

We performed a literature review, analyzing papers concerning technology applied to sleep problems. We found a wealth of information, with various approaches, goals, and

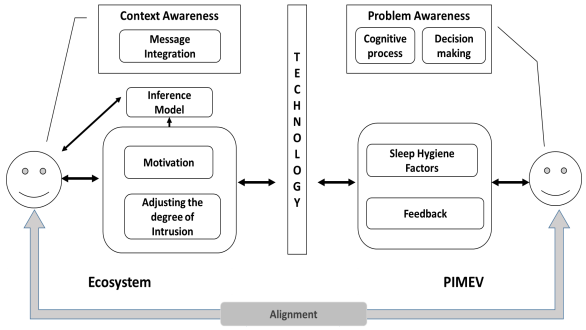

Figure 3: Conceptual model of the persuasive system

strategies. Next, we made a qualitative study on the relation between SH habits and sleep quality through a survey. We used the Pittsburg Sleep Quality Index and Sleep Hygiene Index scales to obtain data, search correlations, and determine the most important varaibles to use as input data in the ecosystem. We plan to select the appropiate MLA according to these data for our inference model. Finally we plan to design the persuasion system based on the work of Beun as Section explains.

Conclusions

We propose an ecosystem that integrates a set of sensors to acquire data regarding SH factors from users, an MLA-based inference model, and a persuasive system implementing alignment, adaptation and motivational supports as proposed by CBT theory. The choice of application was motived by the need to reduce the risks of poor sleep quality and by the lack of systems addressing this problem with a view towards prevention rather than diagnosis or treatment. Our approach is promising because it is well known that sleep quality can be improved by changing certain habits. Moreover, most people nowadays have acces to electronic devices as a part of their natural environment.

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