DREAM SWEET DREAMS: A NEW FRAMEWORK FOR SLEEP TRACKING AND BODY CHANGE PREDICTION

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ABSTRACT

This paper addresses a real-world issue, sleep insufficiency, and its health consequences, as an innovative vehicle to improve elementary education in Science, Technology, Engineering and Math (STEM). Partnering with the Catalina Foothills School District, researchers at the University of Arizona developed, implemented, and evaluated a new STEM education program that includes a database, a set of prediction and simulation models, and a set of sleep science lessons (developed in collaboration with Biological Sciences Curriculum Study). The new "MySleep" program allows for tracking of sleep patterns in the students' natural environment, and provides real-time feedback, options for communications with teachers and parents, and data analysis capabilities.

Keywords: simulation model, sleep patterns, real-time feedback, and sleep insufficiency.

1 INTRODUCTION

Due to behavioral, personal, social and environmental changes, children become the target of various chronic diseases including sleep disorders, asthma, diabetes, vision defects, epilepsy, and other chronic problems. Straining families, communities and societies emotionally and financially, child health care and development require new breakthroughs in the current healthcare systems. Chronical conditions of children are endemic in American society and largely unrecognized by health care providers, but have significant repercussions on neurocognitive growth, behavior, performance, and high prevalence disease states. The key to accurate identification and successful intervention of treatable, and in some cases

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preventable, chronical disorders and habits are reliable and valid diagnostic tools that can be used to address critical translational research gaps, provide real-time data to the user and healthcare providers, and predict future diseases. Current wearable sensors are designed for adults, yet used in children with little formal validation. With considerably diverse and variable heart rate, respiratory rate, and motion and vocal frequencies, it is well known that entirely different specifications are required to design sensors for pediatric populations to ensure measurement quality. Moreover, existing investigations of chronical disorders rely heavily on clinically based "snapshot" measurements that provide little information on the underlying dynamics of the impact of the child health disorder, possible interventions and treatments. While the availability of individual genotyping has the potential to provide each person's probability to develop a number of health problems, little is known about how infant to adolescence behavior can affect adult health. It is important to recognize that diseases are not just passed on between generations by genes, but can also acquire through behavior, social, habit, personal and environmental influences.

This paper addresses sleep insufficiency, and its health consequences, as an innovative vehicle to improve elementary education in Science, Technology, Engineering and Math (STEM). Partnering with the Catalina Foothills School District, researchers at the University of Arizona developed, implemented, and evaluated a new STEM education program that includes a database, a set of prediction and simulation models, and a set of sleep science lessons (developed in collaboration with Biological Sciences Curriculum Study). The new "MySleep" program allows for tracking of sleep patterns in the students' natural environment, and provides real-time feedback, options for communications with teachers and parents, and data analysis. In addition to the sleep pattern monitoring, school students can learn the importance of sleep through this curriculum. For the rest of this paper, we first introduce the MySleep framework. Then we discuss methods to establish a prognosis health information system for sleep. Afterwards, we introduce the sleep impact on body changes.

2 MYSLEEP FRAMEWORK

MySleep has several features: 1) ease of use; 2) real-time interactions in class; 3) many interesting games for students to enjoy the learning experience; 4) work-in-group features that allow students to work as teams; and 5) security measures to protect user identities. MySleep was created using the LAMP socket on the University of Arizona (UA) server. So far, we have developed three different portals for teachers, students and parents respectively. Figure 1 shows the entrance page for the portal. The students' portal includes a two-level sleep curriculum: one for fourth grade and the other for fifth grade students. Each curriculum has four lessons which provide knowledge about sleep and problems associated with sleep. Additional activities are also included, such as slide shows, sorting games, interview practice, etc. to promote student interest in learning. Some activities allow the involvements of teachers and parents. Teachers can read their students responses and actigraphy data in real-time in the class through their portal. Parents can also review their children's response, follow the research progress and communicate with the UA team by the parent portal. Two elementary schools have joined this research: one will be the experiment group while the other is the control group.

Data collection consists of two stages: baseline data and curriculum and sleep (MySleep 2016). In the baseline data stage, we created two questionnaires by REDCap (Research Electronic Data Capture) for students and parents respectively. REDCap is a secure, web-based application designed to support data mining for research studies that provides 1) an intuitive interface for validated data entry, 2) audit trails for tracking data manipulation and export procedures, 3) automated export procedures for seamless data downloads to common statistical packages, and 4) procedures for importing data from external sources (Harris et al 2009). All questions included in the questionnaires are from a professional website. In this stage, we also used the Learning website (Learning.com) to test students' 21-century learning skills. In the curriculum and sleep data collection stage, we employed Philips Actiwatch Spectrum, MySleep platform, and Acer Iconia One 8 Tablet. The Actiwatch model uses actigraphy principles to record sleep schedule variability, quantity, and quality statistics. In addition, it also has a highly sensitive accelerometer and a colored light sensor to monitor activity data and light exposure data (Actiwatch Spectrum). In this stage, students wear the Actiwatch for five days to collect sleep and activity data.

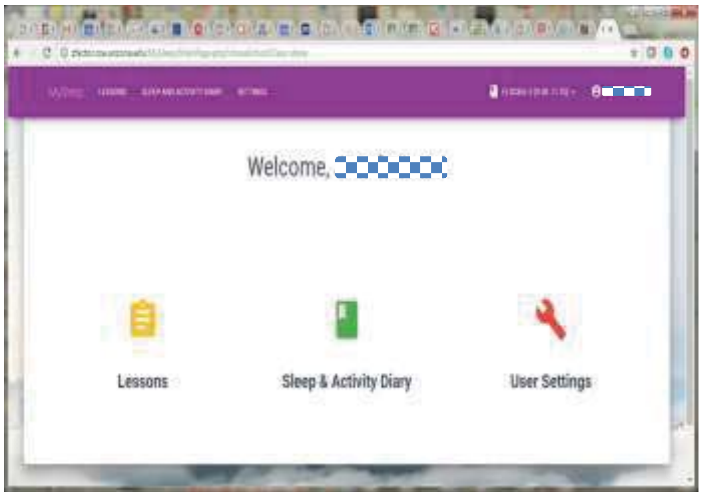

Figure 1: The user interface page for the MySleep platform that shows training lessons, sleep and activity diary, and user settings for page reconfiguration.

Figure 2: The uploaded actigraphy data from actiwatch for one week. The user followed instructions to wear actiwatch for one week. We used USB cables to retrieve the data from actiwatches.

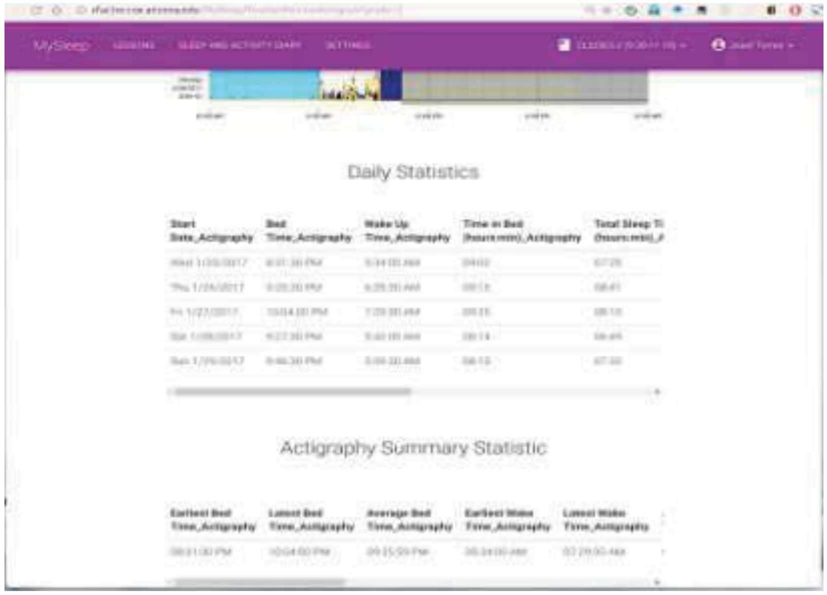

Figure 3: The daily statistics calculated using actigraphy data from actiwatch for one week (Top) and summarized statistics (Bottom).

During the first week of the curriculum, each student receives a tablet and an Actiwatch. Then after one week, students' Actiwatch data are uploaded to MySleep. Students can review and analyze their sleep data. Figure 2 displays a week's actigraphy for one subject. The actigraphy shows the time series activity (black line), yellow light (yellow line), blue light (dark blue line), and sleep duration (blue shadow). Figure 3 demonstrates a daily statistics, and a summary statistic. The daily statistics table includes students sleep data, such as bed time, wake up time, time in bed, etc. The summary table is a statistic table. It includes the earliest, latest, and average time. It also include the average sleep quality, the average number of awakens, and the average awaken durations. Students can review their actigraphy data, and compare them with their sleep diary and activity diary. They will use these data to analysis their sleep quality, and do their final course project. Teacher can check students sleep data, and help them to understand the meanings of their data. Parents can be notified about their children's sleep quality as well.

3 MYSLEEP AS A PROGNOSIS HEALTH INFORMATION SYSTEM

MySleep is also a Prognostic Health Information System (PHS) as described by Figure 4. It includes hardware sensors and a server. The hardware sensors may support ECG measurements, EEG measurements, and activity tracking (e.g. actigraphy by Actiwatch). The server includes five modules as demonstrated in Figure 4. The database is our core to store all subjects' data in a structural way. We use the questionnaire module to record subject information and habits, and then record the information to the database. The biomedical signal processing module processes the raw biomedical signals, and then store the processed data to the database. The data analysis module has three machine learning algorithms: Hidden semi-Markov Model, Decision Tree, and Bayesian Network for analysis of the various results (Dong & He 2007; Jerez-Aragonés et al 2003; Lucas & Abu-Hanna 2004).

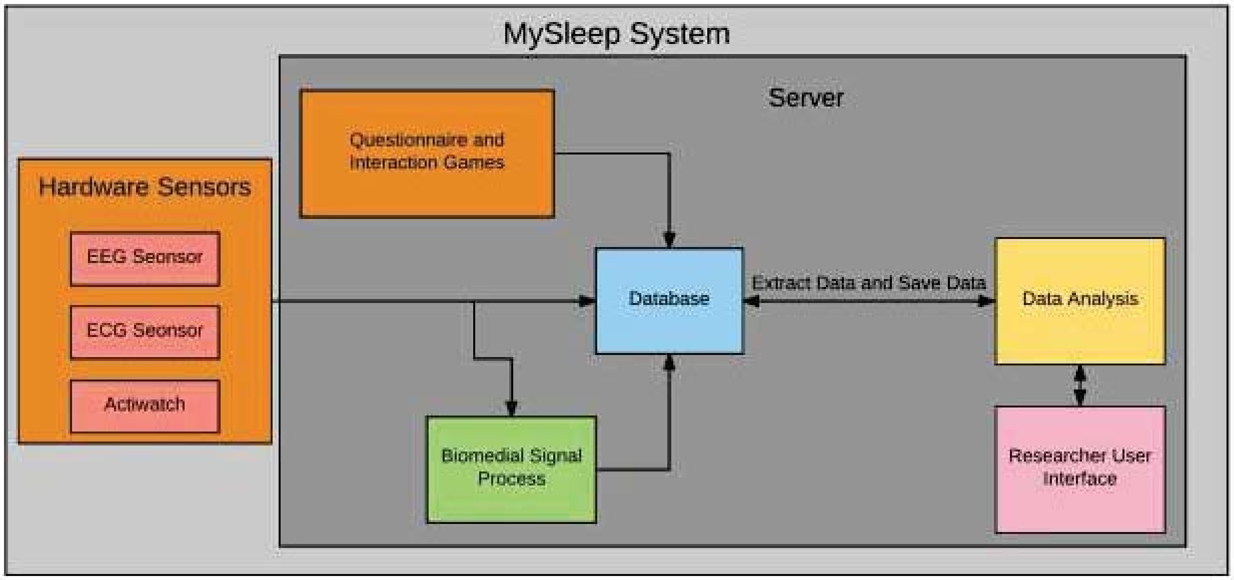

Figure 4: MySleep as a Prognosis Health Information System that can take in data from wearable sensors to measure activities, ECG waveform, and EEG waveform to further understand sleep quality.

4 BODY CHANGE PREDICTION USING MYSLEEP PLATFORM

Sleep is necessary for the human body, just like food and air. During our sleep, we maintain our physical and mental health for another day. Sleep is especially important for children and adolescents as growth related hormones are released during sleep to build muscle mass and repair cells and tissues. Lack of sleep will affect children's cognitive abilities and emotional state. If it continues, it will eventually put children at risk of developing chronic illness (Sleep-on-body). According to Harvard Medical School, lack of sleep also leads to weight gain and ultimately is tied to high risk of obesity (Sleep-on-body). This is because lack of sleep reduces leptin and increases ghrelin. Leptin alerts the brain when we have enough food, while ghrelin stimulates appetite. What makes it worse is that sleep deficiency also promotes the generation of higher levels of insulin after meals, which ultimately increases the risk of type II diabetes. Higher blood pressure and higher heart rate are the key side effects introduced by lack of sleep on the cardiovascular system. As is well known, the immune system produces cytokines and infection-fighting antibodies and cells. In addition, cytokines also helps sleep which in turn provides energy for defence against infectious diseases. Therefore, sleep deficiency also increases the probability of contracting infectious diseases.

In the current MySleep platform, we explained sleep impact on the central nervous system, immune system, digestive system, and cardiovascular system. Through training and experience, most children realized that lack of sleep can impair their ability to concentrate and learn in class. Through a reaction game, they also had a first-hand measurements of reaction time vs. sleep hours. Using cold virus as an example, we demonstrated how sleep hours can affect the immune system. At the end of training, most children also tied emotion changes with lack of sleep. MySleep also included a simulation scheme for the average sleep hours with body changes. For example, we used a simulation to provide the psychomotor vigilance task performance, blood sugar glucose level, heart rate and probability to catch cold using the average sleep hours as inputs. Figure 5 demonstrates the results of one simulation for psychomotor vigilance task performance in terms of reaction time. These results are produced based on adult/teenager patient data (Venker et. al. 2007; Peters et. al. 2009; Mahler et. al. 2012; Prather et. al. 2012).

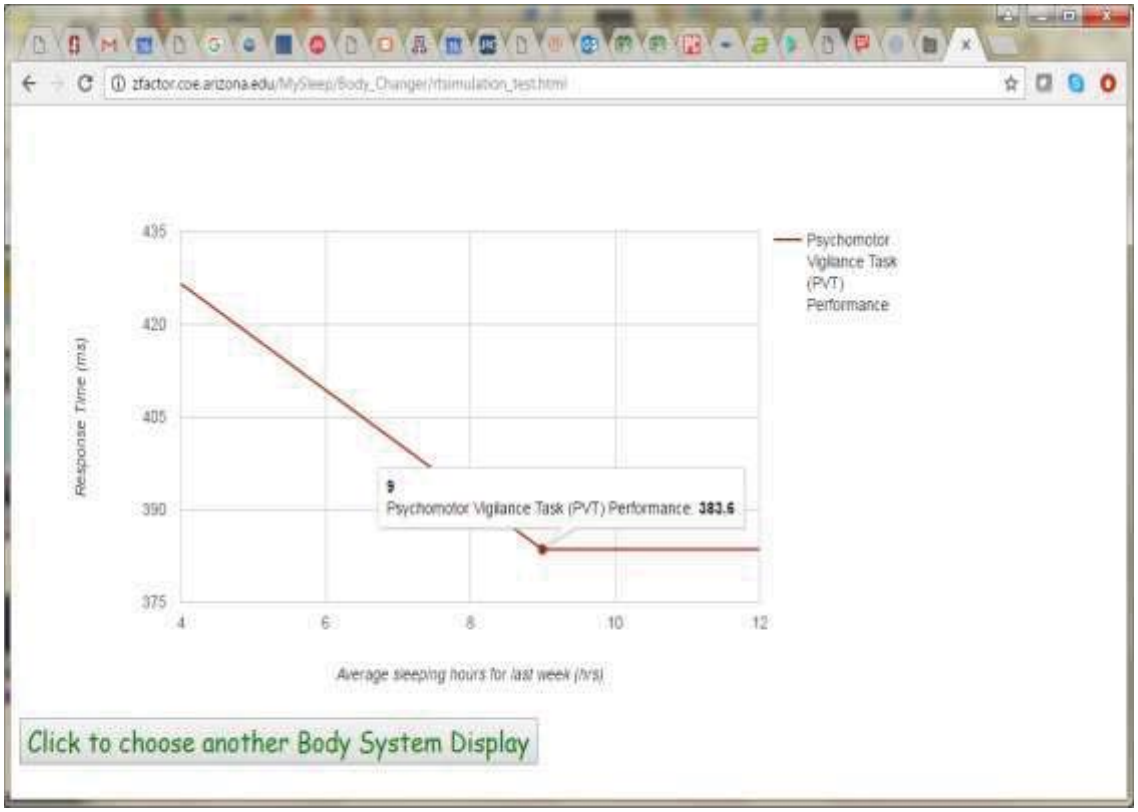

Figure 5: Psychomotor vigilance task performance for average sleep hours as 9 hours.

In order to personalize the prediction for each child, we used Local Spine Regression (LSR) to assess similarity. For example, one child user can input his/her age, weight, education level, average sleep hours as the user profile. (Note that some of these parameters have been incorporated into the database for MySleep.) Based on similarity assessment, a child user cohort is retrieved from the database given parameters that best described the child user. Thus, the future body changes or responses due to lack of sleep of a group of children with similar conditions can be aggregated. Thus, the retrieved information can be used to predict the future of this child user (Wang et. al. 2012). We would like to point out that LSR will be part of the package. And additional entries from medical caregivers and doctors will be used to refine and improve the accuracy of the LSR results.

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