A Mobile Brain Sensing System for Recommending Third Places

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Abstract  
Newly available EEG headsets allow us to sense mental states which could be useful in understanding how our brains are affected by the surrounding environments. In this paper, we present a novel recommendation approach that is based on mental states analysis. Mobile EEG headsets are used to detect mental states at different places to understand how they stimulate our brain signals. By analyzing EEG data, we could classify places according to the mental state signature, then we could build a map to guide and recommend therapeutical third places to people that lessen brain fatigue and mental rejuvenation.

Author Keywords  

ACM Classification Keywords  
C.3 [Special-purpose and Application-based Systems]: Real-time and embedded systems, H.5.m [Information Interfaces and Presentation (e.g., HCI)]: Miscellaneous, I.2.9 [Robotics]: Sensors, J.3 [Life and Medical Sciences]: Neuroscience, J.4 [Social and Behavioral Sciences].

General Terms  
Experimentation, Design, Human Factors.
Introduction

When people need to think, study, or meditate, they often go to quiet and tranquil places. For most individuals, these places are found in outdoor environments. Those places can help reduce stress and therefore remedy the directed attention fatigue (DAF) caused by the busy lifestyle. Several studies have found that Natural stimuli, such as green spaces and beaches [6], coffee shops [8], retail shops [2] and health clubs can lessen stress and hence, relief mental fatigue. Recently, studies have classified such places into “Third places” where people can relax and enjoy their time. Our work attempts to utilize the recent mobile technologies to find and recommend third places for quiet contemplation or entertaining places to change thoughts and focus.

The recent availability of mobile, affordable and dry electroencephalography headsets (EEG) make it feasible to take these devices to settings other than labs. Over the past decade, researchers have focused on using in-lab EEG headsets for brain-computer interface (BCI) such as gaming and assistive technology. However, the current mobile EEG headsets have changed BCI research direction to outdoor application. Off-the-shelf EEG headsets can detect brainwaves in outdoor environments accurately and hence, building powerful BCI applications. Our work studies brainwaves to help understand how people perceive different environments. Based on the analysis of EEG, and environmental noise data at different places, we are able to tag and classify places according to the level of relaxation sensed and to guide people to places that can help in managing stress and restoring their attention.

Third Places and their restorative potentials

American Sociologist Ray Oldenburg (1989) argues in The Great Good Place book [8] the importance of “Third places”, which are places that are neither home nor work. In third places, individuals can relax and enjoy each other’s company. Oldenburg pointed that places such as coffee shops, bookstores and many others can be great places to enjoy your time. Third place is a home away from home in which the place is pleasant and relaxing and people can feel comfortable there. “Though a radically different kind of setting from the home, the third place is remarkably similar to a good home in the psychological comfort and support that it extends” [8].

Recent researchers have linked third places to the potential of restorative benefits and attention restoration theory (ART) [6]. ART suggests that a person’s ability to direct attention in thought becomes fatigued with use. Directed attention fatigue (DAF) is a condition that reduces the overall mental effectiveness and focusing and planning difficulties [3].

Ubiquitous technologies can reveal the respondent’s whole body and senses in generating knowledge and communicating a place. A research done by [1] tries to understand the people-place relationship using the EEG technology. In this paper, we define a place as an outdoor space that can be visited by people.

Materials and Methods

The recent availability of low-cost wireless electroencephalography (EEG) headsets [4, 7] and programmable mobile phones with powerful capabilities have given researchers the ability to detect brainwaves in outdoor places. The Neurosky wireless EEG headset was used in our research. The headset is equipped with a single-channel EEG sensor and an electrode that rests on the forehead on the FP1 position according to the international 10-20 system and a second electrode that contacts the ear [7]. Neurosky headsets can detect raw EEG signals, different frequency bands Delta, Theta, Alpha, Beta and Gamma, and two mental states (attention and meditation). The attention level indicates the intensity of a user’s level of mental "focus" or
"attention". The meditation level indicates the level of a user's mental "calmness" or "relaxation".

In addition, we developed Android application for mobile phones to connect to the wireless EEG headset over Bluetooth and record different EEG data in outdoor environments. The mobile phone application also collects environmental noise levels using the mobile environmental noise monitoring system, NoiseSpy [5] and global positioning system (GPS) data. Noise helps in detecting some abnormal environmental distractions which might affect user perception in relation to a place.

**Experimental Setup**

Ten subjects have participated in our experiment; between the ages of 17 to 35 (mean age of 21.7) with three males and seven females. The volunteers were sent to three places to understand how these distinct places affect our minds and therefore the restorative power of these places. These are: coffee shop, supermarket and garden which are within a short walking distance from each other. The experiment route starts from the coffee shop, supermarket and finally the garden. In each place, the subject was instructed to stay for five minutes and then to move to the next place. The participants moved through the same sequence of places individually and were followed and observed by a researcher. After completing the experiment, all participants were asked to answer a questionnaire about their demographics, health, tag their mental state at each place explicitly and other questions to rate the device’s comfort level.

**Analysis**

In order to carry out the analysis step we had to pre-process the data by filtering out the higher levels of environmental noise, as high levels of noise in the surrounding environment (i.e. the environment surrounding the place) can impact mental states. In another step, we have performed an initial statistical analysis step to show the significant differences in the meditation levels of the three places, a technique known as one-way repeated measure ANOVA test was adopted [9]. In this work, the method was used to investigate the changes in the mean values of the subjects in the 3 different places.

**Results and Discussion**

Our questionnaire showed that all of the subjects did not suffer from any health issues prior to the experiments and all of them have described their mood as "normal". Such information is useful to understand any distinct stress patterns that may occur in the data due to these reasons. Figure 1 depicts meditation levels extracted from the EEG sensor of the ten subjects. The graph shows that high level of meditation was sensed at café and garden, whereas the supermarket demonstrates a lower level of meditation. In addition, the one-way repeated measure ANOVA test compared the meditation levels at three different places (café, supermarket, and garden). The means and standard deviations are presented in Table 1. The test proves to be statistically significant which suggest that the effect for places, since Wilk’s Lambda $\Lambda$ is lower than the $P$ value: $\Lambda = .002 < P$.

Were the $P=0.05$ threshold is an arbitrary one that became commonly used in medical and psychological research. Higher Wilks' Lambda values suggest from zero to one; a $P$ value that is very small indicates that the observed effect is very unlikely to have arisen purely by chance. This suggests that there was a
noticeable change in the meditation levels in the three places. The one-way repeated measure ANOVA test is used to observe the differences in meditation levels among the three places. However, we have also employed ANOVA test to determine which place differs the most from the others.

By comparing each place with the others, we noticed that the supermarket and garden are having the highest significant difference among the other places with $\sigma = .001 (<.05)$. People felt more relaxed in the café and garden and our results showed that there was no significant differences between those places ($\sigma = .855 > .05$). These results strongly suggest that people feel relaxed in response to place stimuli. In soothing third places people can restore their attention and lessen stress levels. In the future, we are planning to integrate our results into a location-based mobile system, and evaluate the ability of our system to classify and categorize places in real time. In doing so, we will be able to influence brainwaves by guiding people to relaxing environments.

![Figure 1. Meditation levels of 10 subjects at different places](image)

<table>
<thead>
<tr>
<th>Places</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Café</td>
<td>56.9777</td>
<td>5.86631</td>
<td>10</td>
</tr>
<tr>
<td>Supermarket</td>
<td>48.7153</td>
<td>6.60941</td>
<td>10</td>
</tr>
<tr>
<td>Garden</td>
<td>60.5617</td>
<td>5.93503</td>
<td>10</td>
</tr>
</tbody>
</table>

**Table 1. Meditation level means and standard deviations**

**Conclusion**

Our preliminary experiments and results showed a noticeable pattern in EEG signals in relation to different places. These differences allow us to understand how people perceive urban environments and hence, build a recommendation map of third places that relaxes them and remedies the directed attention fatigue caused by their stressful lifestyle.

**References**


