Validation of the SWAY app's effects using Electroencephalography

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ABSTRACT

Mental wellbeing is a state where each individual releases their own potential, to cope with normal stress of life, and to work productively. In this paper, we investigated the psychological and neural effects of using Sway application, which assist users to maintain a healthy mental wellbeing. Our investigation was conducted in two different settings: (1) waiting at a bus stop, and (2) stationary working at a desk. In each setting, we compared between two conditions: with and without using the Sway app. Our results show that Sway app helps participants to be more relax and have lowered mental workload in both settings.

Author Keywords

Sway, EEG, relaxation, beta band power, mental workload.

INTRODUCTION

According to WHO[1], about 800,000 commit suicide every year, with one main contribution is mental disorder. Additionally, around 20% of the world's children have mental disorders, which will follow during their lifetime. Because of this, mental wellbeing and how to improve it has gained a lot of attention, in both academic and industry. Mental wellbeing can be defined as a state where each individual releases their own potential, to cope with normal stress of life, and to work productively, consequently make contribution to the society. Because of this, there are many guidelines and methods to help people archive a better mental health, specifically to be more relax and less stress in their daily life, such as from National Health Service (UK), Mental Health Foundation, or Canadian Mental Health Association (Canada). An alternative trending approach is to encourage people to interact with a specialized application on their smartphone, designed to help users become less stressful and achieve a strong relaxation states. Sway application is specifically design to accomplish this. The added effects of applications, such as Sway (see Figure 1), compared to a normal condition without using it, is unknown. It is necessary to validate their claimed effects to help public users have the appropriate tool for this problem. We aim to investigate this problem with the Sway app in this paper.

Figure 1. Sway user interface

Traditionally interactive programs are evaluated by investigating performance (i.e. [12]), or users' behaviors. However, with programs designed for using with ease and pleasure, an evaluation method measuring users' affective or inner states is more suitable. Usually this is done by questionnaires answered by participants during the experiment. However, they occur after the event when important issues may be forgotten. Additionally participants may not be aware of their states or might simply guess. Neural signals, measured from the brain can better reflect a users' current state and provide an evaluation metric.

There are different methods to detect neural signals such as fMRI, MEG, fNIRS and EEG. A brief summary of those techniques are discussed in [13]. In addition, EEG devices are portable (compared to fMRI, MEG) and have high temporal resolution (compared to fNIRS). EEG signals have been also shown to capture the affective state (such as

[1] http://www.who.int/features/factfiles/mental_health/mental_health_facts/en

relaxation [8], arousal [7], and task engagement [4]). One purpose of our application, Sway, is to help user relax in working related settings, both inside and outside the workplace. Here, we aim to measuring relaxation, and beta waves using EEG to validate its effectiveness.

Using EEG signals to estimate relaxation states of user has been investigated and made its way into a commercial product [9]. In addition, it has been shown that while relaxed, or mediated, the signals in human brain is dominated with lower alpha frequencies (8-10Hz). It was also shown that alpha band signals have high amplitudes during: relaxed states, closing of the eyes, and reflecting states [3].

In addition, it has been reported that people in state of increasing activity produced the higher EEG frequency, which is in the beta band (13-30Hz) [11]. They are low amplitude waves which are evident during periods when the person is alert, working, active, busy, stressful, and in active concentration [3].

EXPERIMENT 1: BUS STOPSCENARIO

Apparatus

Ten participants (5 males and 5 females) between the ages of 26 and 37 volunteered for the study. Participants came in their natural states (not necessarily stressed). Before taking part in the study, participants read the information sheet explaining about the study, were given answers to all their questions, and signed the consent form. Participants were paid about 10 USD for their participation.

The study was conducted at a bus stop using a within design setting. Participant performed two tasks in a counter balanced order: (1) normal waiting at the bus stop, and (2) using the Sway app while waiting (see Figure 1). For both condition, participants wore the Emotiv EEG headset, try to limit their body and facial movements, and to refrain from talking during the tasks. Before beginning each task, participants were given enough time to practice the task, until they confirmed that they are ready to start.

Participants were introduced to the Sway app before going to the experiment site, until they confirmed that they are comfortable with using the application. Participants kept the phone on the body at their preferred place. The phone picked up their subtle movements using built in gyroscopes. Sway app used these movements to play calming sounds and the visual feedback.

SIGNAL PROCESSING

We used an Emotiv EPOC wireless headset for measuring EEG signals. This headset can capture EEG signals at 14 channels and has 2 reference channels (DRL and CMS). Its signals quality have been validated by previous studies (e.g. detecting and classifying Event Related Potentials [13], and evaluating visualization effectiveness [2]). This headset is portable, easy to setup, and most users can wear it comfortably for at least an hour [6].

EEG signals were sampled at 2 KHz internally then down-sampled to 128 Hz output. We inserted markers into the marker channel, which is in parallel with EEG signal channels. These were: start recording and stop recording, events for each condition. We then adapted the "sliding window technique" which is commonly used to process EEG signals (e.g. [10] and [1]). The recorded EEG signals were segmented into 4-second epochs with 2-second overlap between them. The DC offset was removed by subtracting the averaged value from the reference signals.

To remove artifacts from muscle movements, we adapted a decontamination process [5] to decontaminate Emotiv's EEG signals. There are two steps: (1) Three data point spikes detection with amplitudes greater than 100 uV (e.g. caused by tapping or bumping the sensors); and (2) Notch, low and high pass filters to remove unwanted artifacts (e.g. from muscle movements). After processing the signals, we removed participant 1 from the analysing due to the outlier effects.

Frequency bands β, α, and θ, are then computed as the combined power in the ranges of 13–22 Hz, 8–12 Hz and 5–7 Hz frequency bands.

Relaxation was calculated as in Brainball [8]:

Relaxation Index = alpha / beta

Beta power was indicated by the PSD of beta band:

Beta power index = beta

We used AF3, AF4, F3, and F4 to calculate Relaxation and Beta power as they are in the same region (the frontal lobe) as used in BrainBall.

RESULT

Table 1 summarizes the results, which are the averaged relaxation and beta power during each task. They are also illustrated in Figure 2 (relaxation) and Figure 3 (beta power, which is related to alert, working, active, busy, stressful, and in active concentration).

Condition	Relaxation	Beta power
Normal waiting	0.87	8.00E+06
Sway app	0.92	6.64E+06

Table 1. Averaged relaxation and beta power for the 2 tasks

First, we found that participants in Sway condition had higher level of Relaxation (Normal condition: M = 0.87 SD = 0.18; Sway condition: M = 0.92, SD = 0.16 – see Figure 2). However, pair-wise comparison between the two conditions could not find significant differences between them ($t_9 = -0.851$, $p = 0.417$).

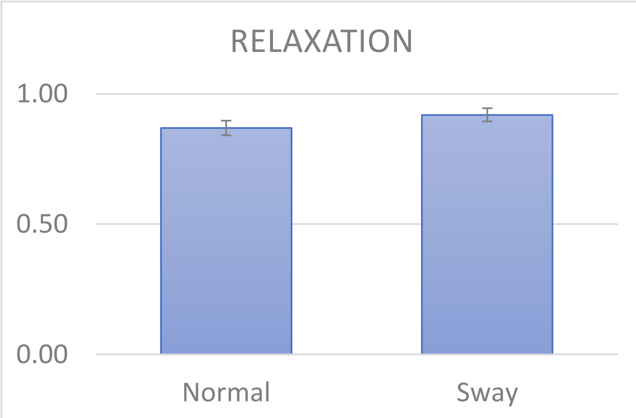

Figure 2. Averaged relaxation values for the two conditions with standard errors

Second, we also observed that participants in Sway condition (M = 6.64E+06 SD = 1.81E+06) had lower Beta power than in Normal condition (M = 8.00E+06 SD = 6.64E+06) – see Figure 3, indicating that Sway had helped them to elicit less amount of workload. However, pair-wise comparison between the two conditions could not find significant differences between the two conditions (t_9 = 1.857, p = 0.096).

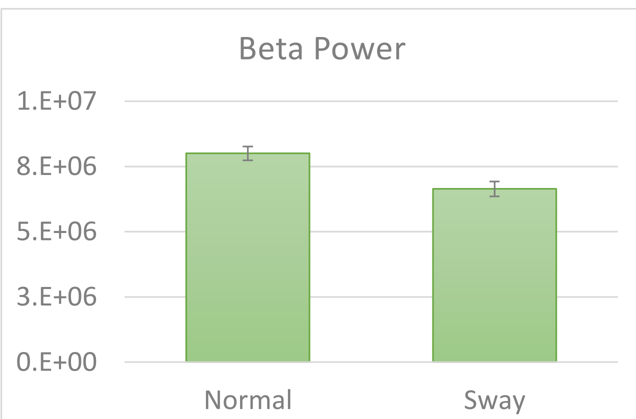

Figure 3. Averaged beta power values for the two tasks with standard errors. The beta power is related to various state of minds including alert, working, active, busy, stressful, and in active concentration. It has been observed in activities that require high demands of neural resources [11].

Discussion

Although we could not find significant differences between the two conditions, in terms of Relaxation and Beta Power, we found that it was almost significant for the Beta Power. One possible explanation for this is we only experimented on 10 participants. In specific, 7 participants had produced much lowered beta power in the Sway condition, compared to Normal. Increasing this number would amplify the difference and have a stronger power, consequently may lead to a significant difference.

EXPERIMENT 2 – WORKSTATION SCENARIO

To validate Sway app further, we conducted another experiment with participants in an office working environment. We aim to understand the effect of a creative use of the Sway app, by putting the phone into the pocket, or holding against body, while gently turning the office chair slowly and continuously to make a mindful movement in a regular office setting.

Apparatus

Eleven participants (10 females and 1 males, between 28 and 45 years old) volunteered for the tasks. Similar to the previous experiment, participants came in their natural states (not necessarily stressed). However, we removed one participant (participant #11 because of the outliner effect). Before taking part in the study, participants read the information sheet explaining about the study, were given answers to all their questions, and signed the consent form. Participants volunteered for the study in exchange for free version of an application with a similar purpose as the Sway app.

Figure 4. Experimental setup of experiment 2. Participants were instructed to perform their normal work while wearing the Emotiv EEG headset.

The study was conducted in a regular office environment where participants sat comfortably on a chair and in front of a table with a given laptop. They were asked to perform the normal office tasks such as reading news, replying emails, etc. Here, participants performed their normal working state first for 10 minutes, then continued with the Sway app, as described above. In this condition, participants kept the phone with the Sway app opened at a preferred place (e.g. in their pocket) or on their body and made mindful movements.

Participants wore the Emotiv EEG headset for the whole period of the experiment. They were instructed to limit their body and facial movements, and to refrain from talking during the tasks (see Figure 4). Before beginning each task, participants were given enough time to practice the task, until they confirmed that they are ready to start. Participants did not participant in the previous experiment.

Results

We used the same equations described above to calculate Relaxation:

Relaxation Index = alpha / beta

and Beta power:

Beta power index = beta

Table 2 summarizes the results, which are the averaged relaxation and beta power during each task. They are also illustrated in Figure 5 and Figure 6.

	RELAXATION		Beta Power	
	C1	C2	C1	C2
Mean	**0.84**	**1.07**	**6.55E5**	**6.53E5**
SD	0.12	0.31	1.2E5	1.3E5
SE	0.04	0.10	0.3E5	0.4E5

Table 2. Averaged relaxation and beta power for the 2 tasks (C1: normal working, C2: Sway app)

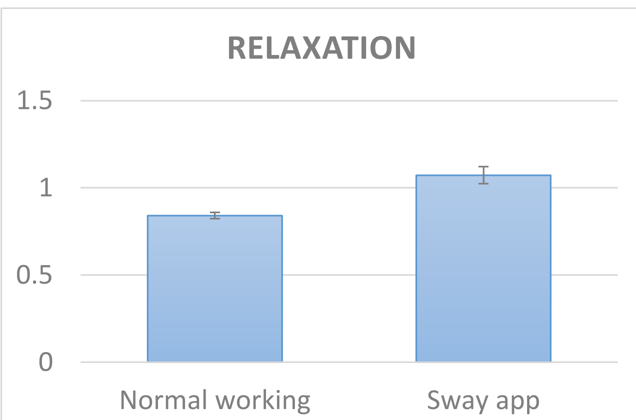

Figure 5. Averaged relaxation values for the two conditions with standard errors

First, we found that participants in Sway condition had higher level of Relaxation (Normal condition: M = 0.84 SD = 0.12; Sway condition: M = 1.07, SD = 0.31 – see Figure 5). Additionally, pair-wise comparison between the two conditions show significant differences between them (t_9 = 3.308, $p < 0.01$).

Second, we also observed that participants in Sway condition (M = 6.53E+06 SD = 1.3E+06) had lower Beta power than in Normal condition (M = 6.55E+06 SD = 1.2E+06) – see Figure 3, indicating that Sway had helped them to elicit less amount of workload. However, pair-wise comparison between the two conditions could not find significant differences between the two conditions (t_9 = 0.042, p = 0.968).

Discussion

Our results showed using Sway app helped participants to perform their task in a more relaxed way, as indicated a significant higher amount of Relaxation in the condition that they used Sway app. This result validates the Sway app's claim that it helps users achieve a better wellbeing state, by having a more relaxation state of mind.

In addition, our results indicate that the two conditions (normal working and using Sway app) had similar and non-significant differences of workload, as indicated by the amount of Beta power. This maybe because participants were instructed to work freely as they wanted for 10 minutes, consequently put in a less stressful state compared to their normal working condition.

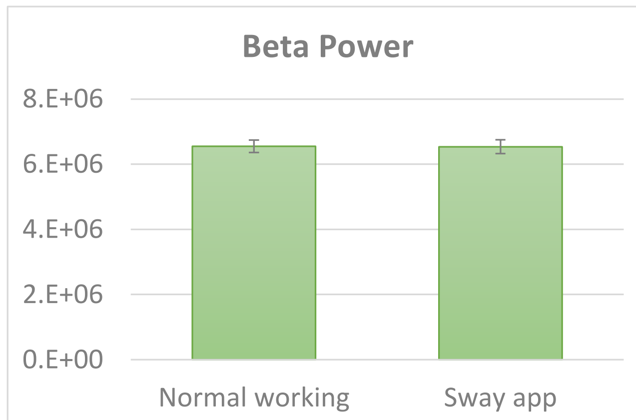

Figure 6. Averaged beta power values for the two tasks with standard errors. The beta power is related to various state of minds including alert, working, active, busy, stressful, and in active concentration. It has been observed in activities that require high demands of neural resources [11].

CONCLUSIONS

In this study, we conducted two experiments to validate the effects of Sway app, in two different settings of waiting at a bus stop and stationary working at a desk. The results of both studies confirmed that Sway app helps users to be more relax and have lowered mental workload, which is in-line with the app's claim. Our results indicate that this app is one of the appropriate methods to help users achieve an improved mental wellbeing.

REFERENCES

[1]. Anderson, C.W. and Z. Sijerčić. Classification of EEG signals from four subjects during five mental tasks. Proceedings of the Conference on Engineering Applications in Neural Networks. 1996. Springer.

[2]. Anderson, E.W., K.C. Potter, L.E. Matzen, J.F. Shepherd, G.A. Preston, and C.T. Silva, A user study of visualization effectiveness using EEG and cognitive load, in

EuroVis. 2011, Eurographics Association: Bergen, Norway. p. 791-800.

[3]. Baker, S.N., Oscillatory interactions between sensorimotor cortex and the periphery. Curr Opin Neurobiol, 2007. 17(6): p. 649-55.

[4]. Berka, C., D.J. Levendowski, M.N. Lumicao, A. Yau, G. Davis, V.T. Zivkovic, R.E. Olmstead, P.D. Tremoulet, and P.L. Craven, EEG correlates of task engagement and mental workload in vigilance, learning, and memory tasks. Aviation, Space, and Environmental Medicine, 2007. 78(5).

[5]. Berka, C., D.J. Levendowski, R.E. Olmstead, M.V. Popovic, M. Cvetinovic, M.M. Petrovic, G. Davis, M.N. Lumicao, and P. Westbrook, Real-time analysis of EEG indices of alertness, cognition, and memory with a wireless EEG headset. International Journal of Human-Computer Interaction, 2004. 17(2): p. 151-170.

[6]. Ekandem, J.I., T.A. Davis, I. Alvarez, M.T. James, and J.E. Gilbert, Evaluating the ergonomics of BCI devices for research and experimentation. Ergonomics, 2012. 55(5): p. 592-598.

[7]. Hagemann, D., J. Hewig, C. Walter, A. Schankin, D. Danner, and E. Naumann, Positive evidence for Eysenck's arousal hypothesis: A combined EEG and MRI study with multiple measurement occasions. Journal of Personality and Individual Differences, 2009: p. 5-5.

[8]. Hjelm, S.I. Research + design: the making of Brainball. Interactions. 2003. ACM.

[9]. Hjelm, S.I. and C. Browall, Brainball - using brain activity for cool competition. NordiCHI, 2000.

[10]. Lee, J.C. and D.S. Tan, Using a low-cost electroencephalograph for task classification in HCI research, in ACM Symposium on User Interface Software and Technology. 2006. p. 81-90.

[11]. Ray, W. and H. Cole, EEG alpha activity reflects attentional demands, and beta activity reflects emotional and cognitive processes. Science, 1985. 228(4700): p. 750-752.

[12]. Ryu, D.-S., W.-K. Chung, and H.-G. Cho, PHOTOLAND: a new image layout system using spatio-temporal information in digital photos, in Proceedings of the 2010 ACM Symposium on Applied Computing. 2010, ACM: Sierre, Switzerland. p. 1884-1891.

[13]. Vi, C. and S. Subramanian, Detecting error-related negativity for interaction design, in ACM CHI Conference on Human Factors in Computing Systems. 2012, ACM: Austin, Texas, USA. p. 493-502.