Multimodal imaging integrating structural and functional information

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Nuero-Imaging learning through novel neuro feedback capabilities

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ABSTRACT

This study aims to create a neurofeedback system and observe whether wearing this system assists participants in consciously changing their state of mind. Brainwaves are produced by synchronized electrical pulses from masses of neurons communicating with each other. Through the use of a Neurosky Electroencephalogram (EEG) biosensor, we can detect the brainwaves that result from neuron activity. Attention and meditation levels are two significant examples of brain activity that are reflected by the human body. Our neurofeedback system can monitor attention and meditation levels that humans are normally unable to sense. The Arduino-medium-developed program records brainwaves as attention and meditation values (eSense meter value). In addition, we constructed a vibration system that provided real-time notification to notify participants when their state of relaxation or concentration changed. With appropriate training, users of the neurofeedback system can develop strategies to control their state of mind successfully. [4]

INTRODUCTION

The brain is made up of approximately 100 billion neurons. There are numerous electrical activities in the brain that lead to the synthesis of brainwaves. The brainwaves are produced by synchronized electrical pulses from an abundance of neurons when communicating with one another. An EEG biosensor can perceive the brainwaves emanated from neurons. The bands given by the EEG biosensor provide insight into our mental and emotional states of mind at any given time. Brainwaves are divided into different frequency ranges to describe their functions. Two specific types of brainwaves are alpha and beta waves. Alpha waves range from 8 to 12 Hz and signify relaxation, reflection, and mediation. Beta waves range from about 14 to 30 Hz and are typically associated with thinking, focus, decision making, and attention. [1][2][4].

Current applications of the EEG biosensor can be found in the diagnosis of epilepsy, which causes abnormalities in EEG biosensor readings. Biosensors are also used to diagnose sleep disorders, depth of anesthesia, comas, encephalopathies, and brain death. In addition to its application in human medical science, EEG is also used for observing human emotional states in daily life. Mental strains can

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negatively impact daily tasks and responsibilities. Being able to switch from a state of relaxation to a state of concentration can positively impact their ability to reach a peak potential in completing daily tasks. For our study, we attempt to create a neurofeedback system and see whether wearing the feedback system can help people to improve their state of mind. The use of our neurofeedback system aids in achieving this goal. Since EEG bands and raw data are associated with different states of mental activity, they work well for our research and therefore, our experiment. [2][3]

In order to record the values of concentration and relaxation levels, this study requires the use of a 1 channel EEG headset known as the Neurosky biosensor, which is non-invasive, dry, and low cost. It can perceive the brainwaves and quantify them into attention and meditation values. The Neurosky biosensor allows us to program it with our system via Arduino. Additionally, we create a vibration system which is fastened to the subject's arm to remind them to adjust their state of mind if their current state is not optimal for relaxation or concentration. [3]

In this paper, we used a vibration system to send a real-time notification to a subject's arm. This notification would signal a need to adjust their state of mind from either relaxation or concentration. Further, we tried to compare the difference between people wearing the vibration system or without the vibration system to see whether it helped subjects improve their ability to control their state of mind through a neurofeedback system. Our future goal is to eventually use the neurofeedback system to help people train and improve their ability to have more control over their state of mind. [3]

CONCEPT & METHOD

To detect the EEG signals, we chose Neurosky as our biosensor. The Neurosky EEG biosensor is non-invasive, dry and low-cost equipment as shown in Fig. 1. Also, this equipment can perceive the brainwaves classified to frequencies in Hertz, including delta, theta, alpha, beta and gamma, and measures the attention and meditation level in the system. The Neurosky headset was programmed via Bluetooth to communicate to a vibration system controlled by a microprocessor and attached to the users' arm. When the headset collects the brainwave data, the system calculates the user's concentration value and expresses it as a number ranging from 0 to 100. With those concentration values, the vibration system shown in Fig. 2 would vibrate when specific conditions were met according to our programming. [3]

Fig. 1 Neurosky headset

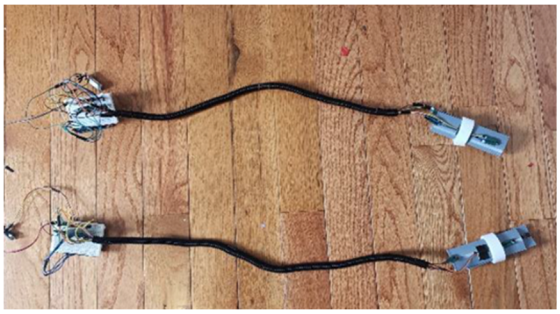


Fig. 2 The vibration systems

In our research, we used the Arduino Uno R3 microcontroller board. The microcontroller board allowed us to process our programming with both the Neurosky headset and vibration system we made. Concentration data served as input for the system which then interpreted the data as attention or meditation values. These values were then assessed, and if they fell or raised above a determined level then the vibration system attached to the subject was activated. Fig. 3 is the Schematic of our whole system showing how it works, and Fig. 4 is our Relaxation/Concentration Feedback System. [4]

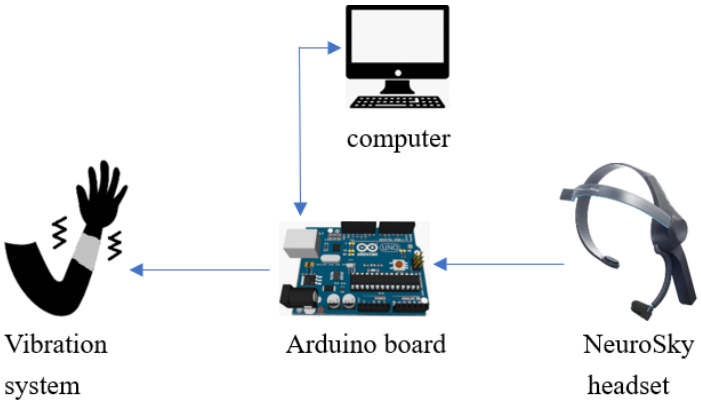


Fig. 3 Schematic of our whole system

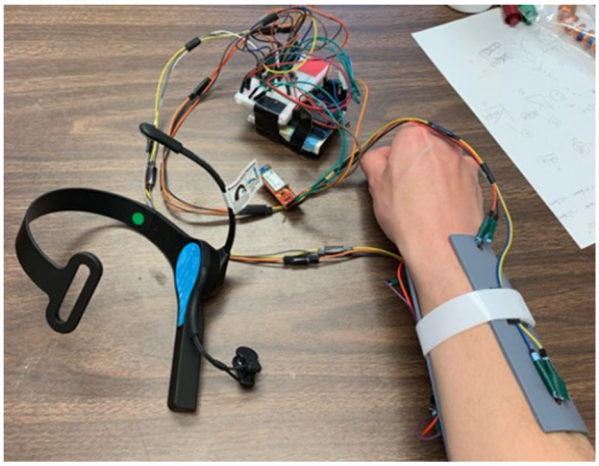


Fig.4 Relaxation/Concentration Feedback System

When the system is set to concentration mode, it vibrates if it detects that the user's attention levels are too low according to a threshold specified by us. The vibration system on the tester's arm reminds the tester to increase their focus. In the relaxation mode, if the person's attention levels are too high, referring to the threshold we specified, the system would vibrate to tell the user to relax. The system was tested by having the subjects use the system without the feedback system as they tried to focus or meditate and then perform the same actions with the vibration system giving them feedback. [3]

When using the vibration system, at first, the user's results are worse than when they do not have a feedback system. They find it harder to concentrate or meditate due to the vibrations distracting them. However, as they continued to use the vibration system, the results quickly improved, as the users learned to react to the vibration system. Eventually, concentration levels were significantly higher when the user would try to focus, and significantly lower when they would try to meditate than when it was without a feedback system. The data was better and more consistent. [3]

EXPERIMENT

1. ***EEG task setting***

This research was approved by the UMBC IRB protocol EEG2. The experiment was divided into two parts, relaxation and concentration. When the headset collects the brainwave data, the system can calculate the user's attention level and express it as a number ranging from 0 to 100. On this scale, a value between 40 to 60 is considered "neutral" and is similar in notion to "baselines" that are established in conventional EEG measurement techniques. A value from 60 to 80 is considered

"slightly elevated" and be interpreted as levels being possibly higher than normal. A value between 20 to 40 indicates "reduced" levels of the eSense. For testing in relaxation, we set our standard number as 35 which represented people were relaxing when their attention value was below that threshold. Conversely, a value above 35 meant people were not in a state of relaxation. In the concentration test, we set our standard value to 65. An attention value above 65 meant that the subject was concentrating. If the attention value was below the threshold we specified, people were no longer concentrating. We tested participants who were notified when their value crossed the threshold by a vibration system attached to their arm against participants who had no notification system. If the attention value of subjects wearing our vibration system rose above 35 during the relaxation test or the attention value dropped below 65 in the concentration test, the feedback system vibrated to remind the testers to calm down or focus as appropriate. [6]

2. *Task and procedure*

We selected three participants and each person tested three times in both the relaxation and concentration tests. They performed these tests both with and without the feedback system. During EEG acquisition, concentration and relaxation tasks were kept separate. Upon completion, participants started their next scheduled test.

In relaxation tasks, participants were asked to sit quietly for one minute with their eyes closed. Their attention levels were collected with and without the feedback system. For the duration of the concentration task, participants were instructed to watch television news programming on a computer screen for one minute. After collecting their attention level while wearing the feedback system, subjects then repeated the same task without the feedback system. [5]

RESULTS

Fig. 5 First tester in relaxation with or without feedback system

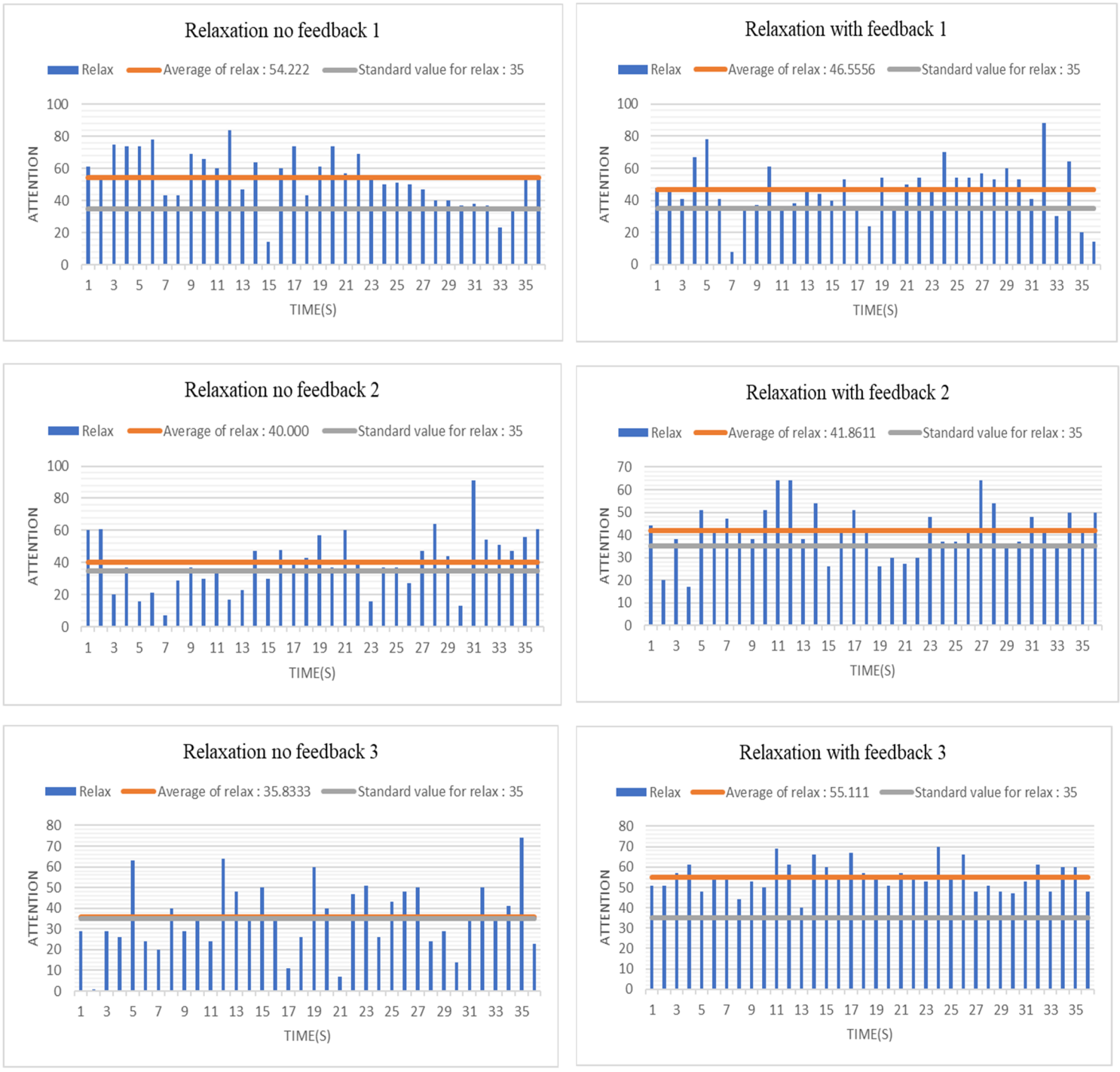
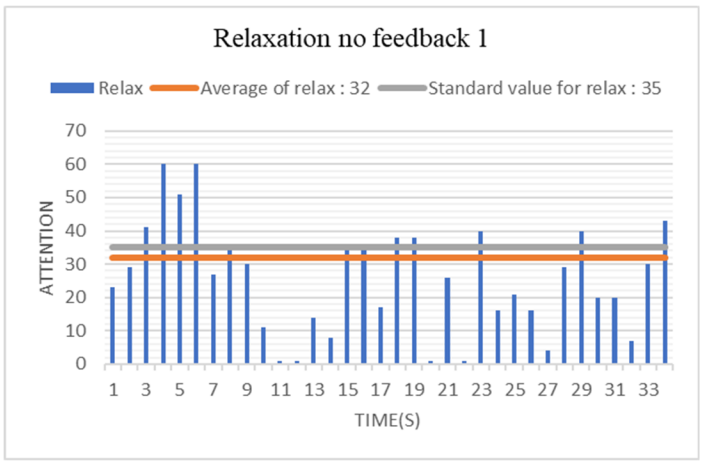
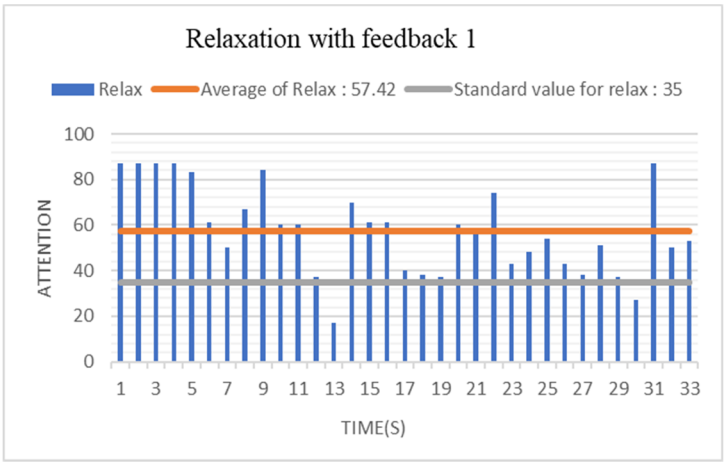
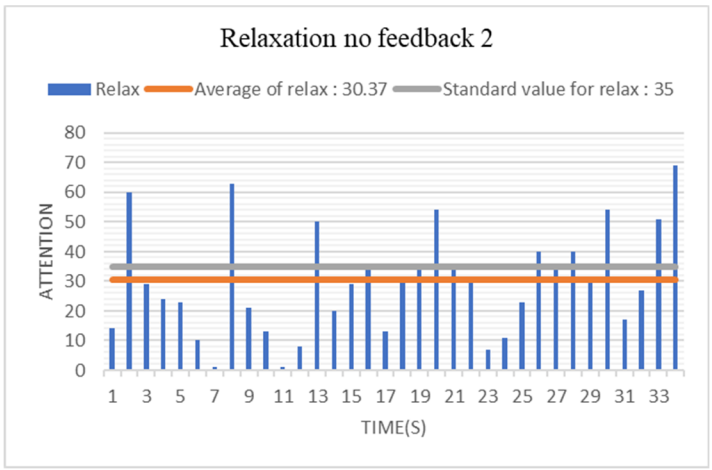
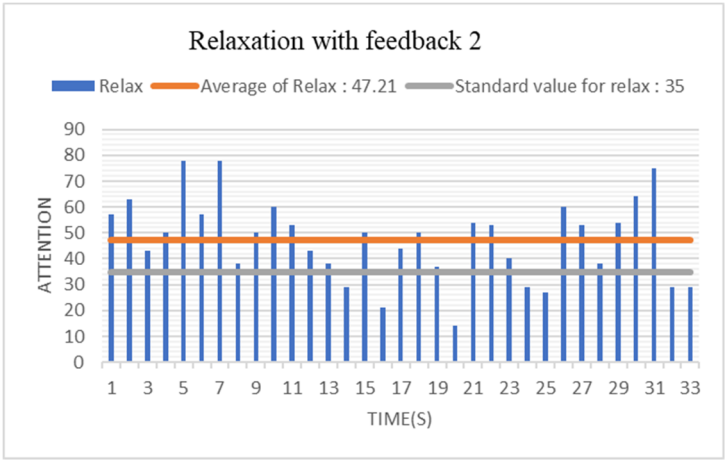


Fig. 6 Second tester in relaxation with or without feedback system









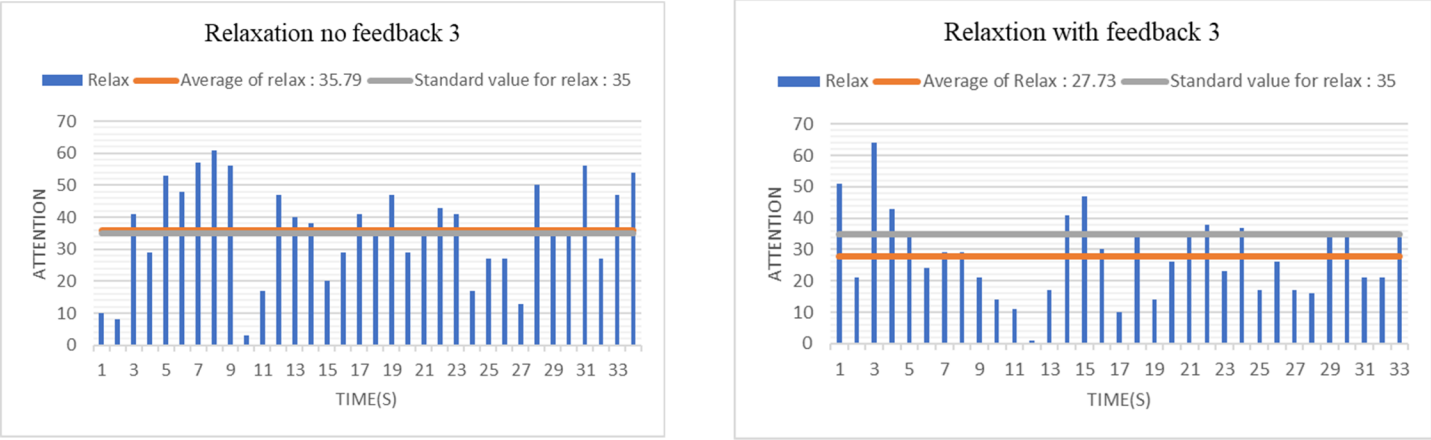
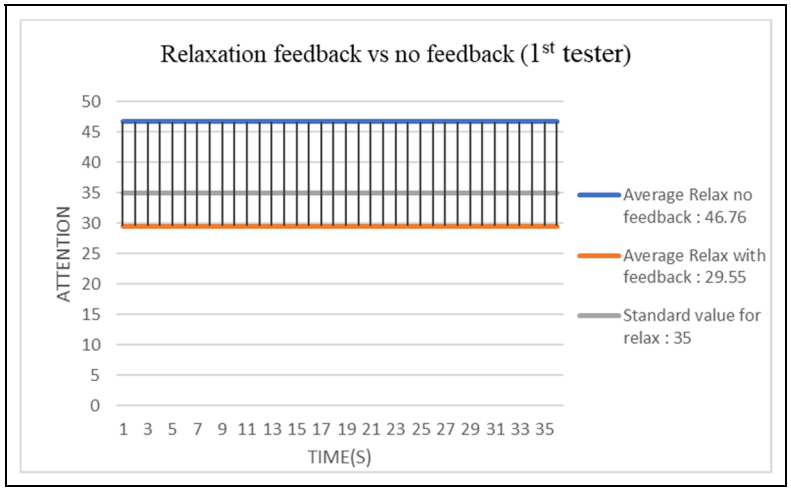
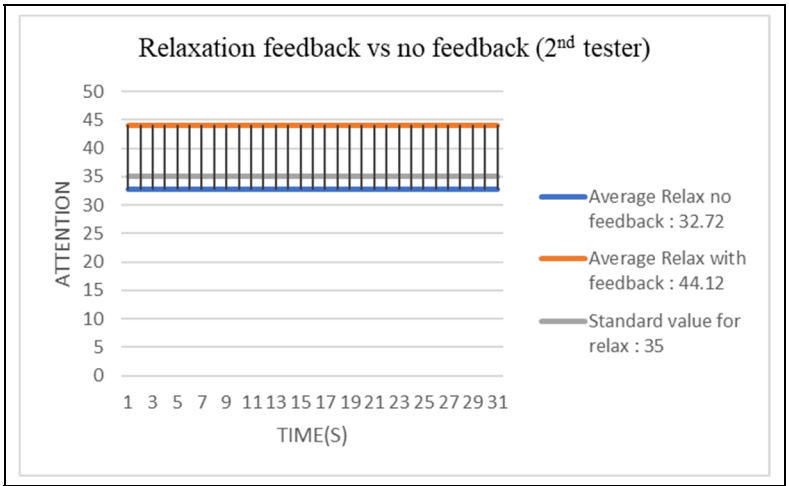


Fig. 7 Third tester in relaxation with or without feedback system

After we collected data for each person three times in relaxation tests, we averaged data from each person with or without the vibrator to see whether people with feedback from a vibrator will remind themselves to adjust. Fig. 8 displays an average for the three testers in our relaxation experiment.





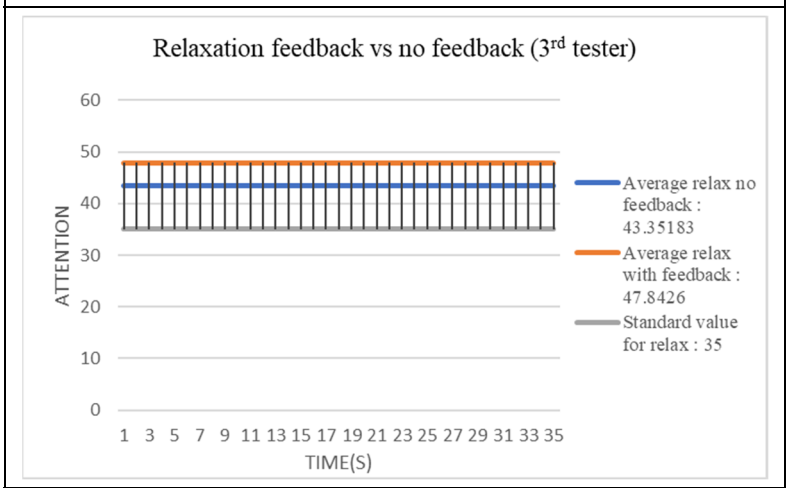


Fig. 8 Averaged diagram for each three testers

After finishing the relaxation task, we tested concentration, and participants were asked to watch the news on a computer screen for one minute.

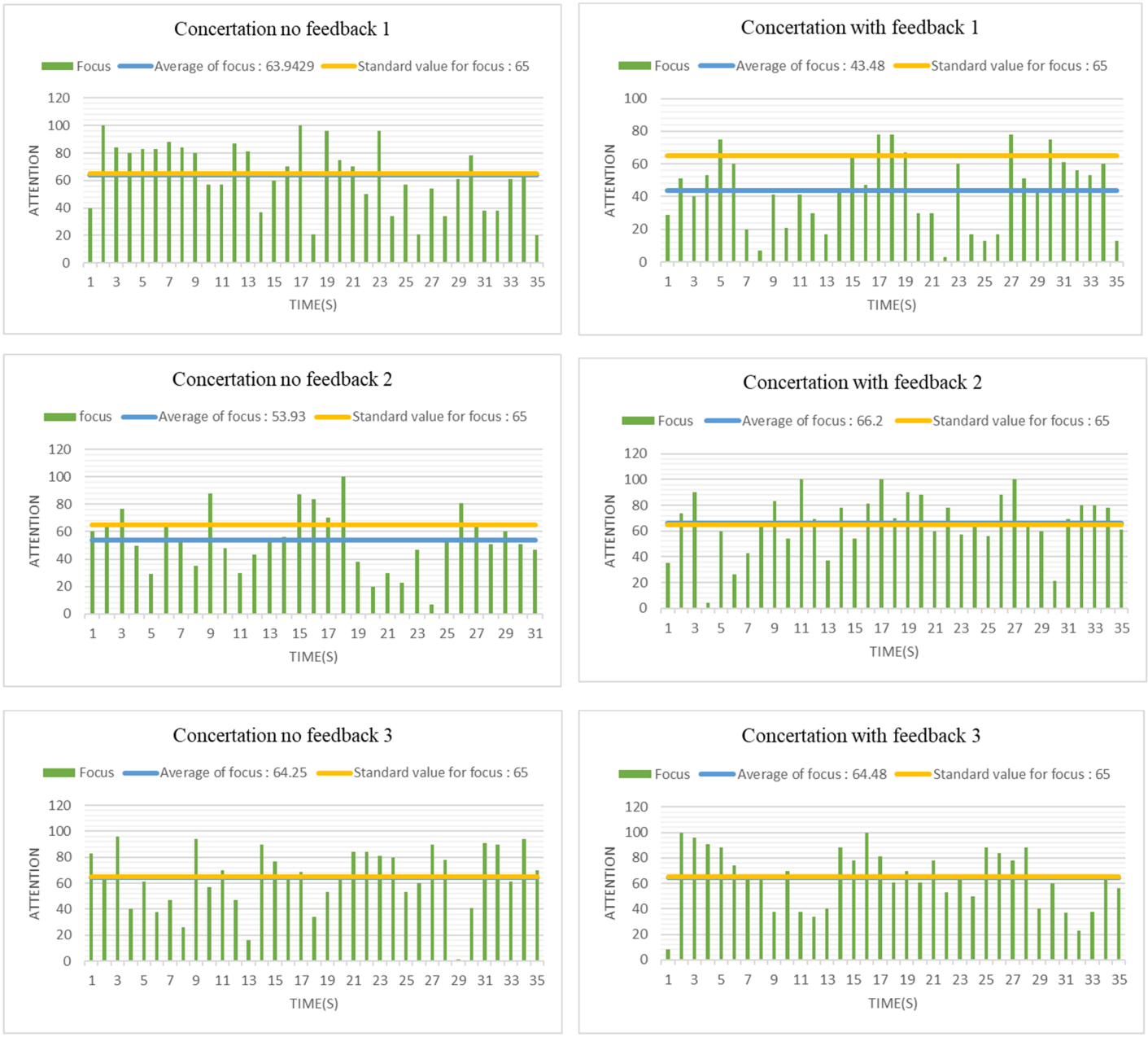


Fig. 9 First tester in concertation with or without feedback system

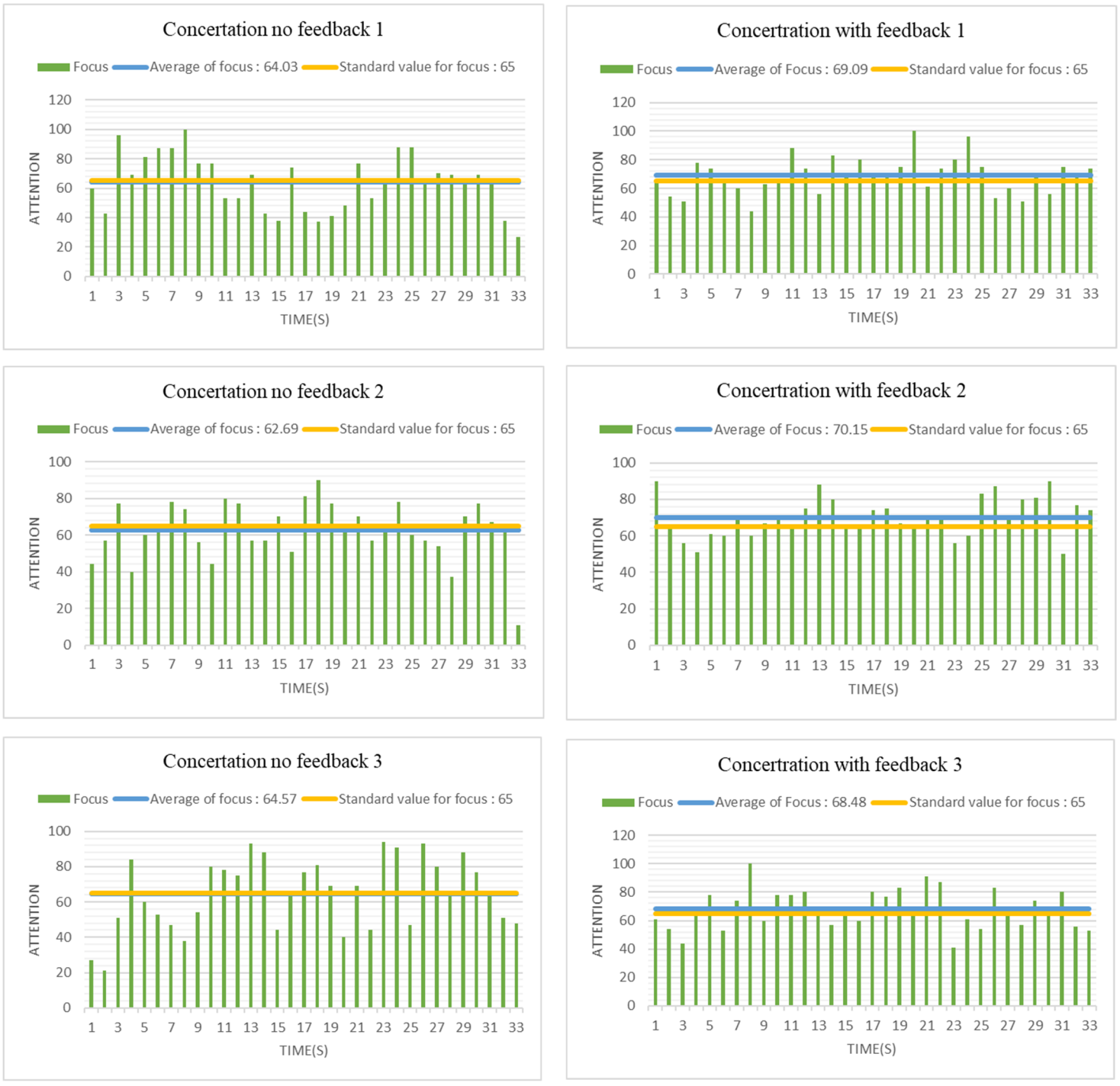
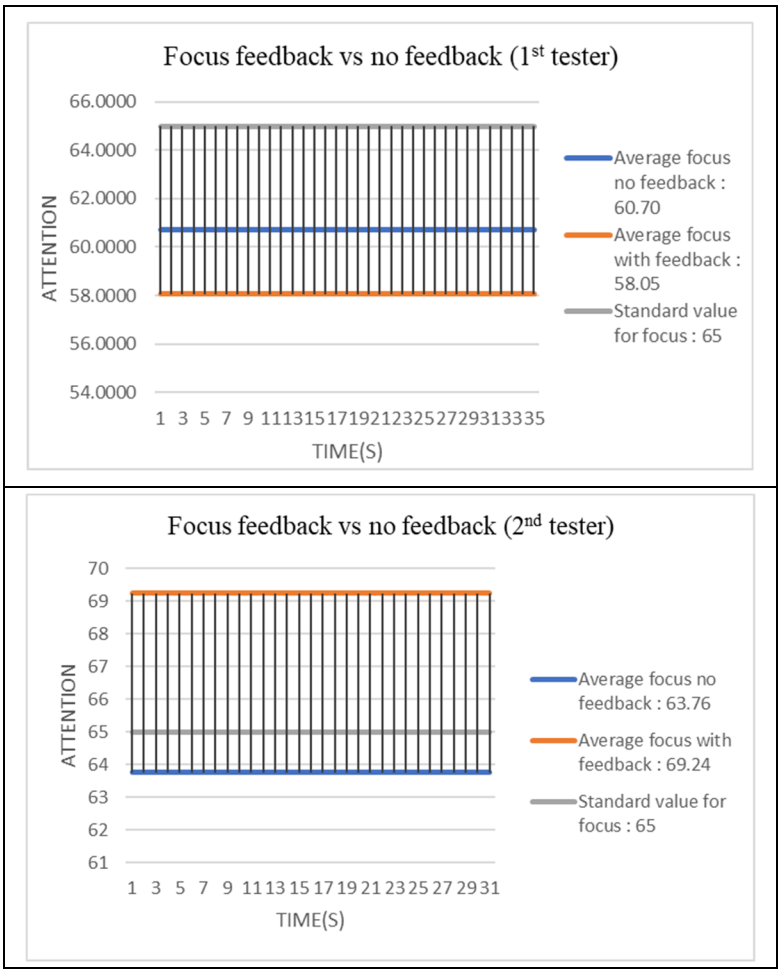


Fig. 10 Second tester in concertation with or without feedback system

Fig. 11: Third tester in concertation with or without feedback system

After we collected attention data for each person three times, we averaged each person with or without vibrator to see whether people with the feedback system will remind themselves to adjust. Fig.12 displays the average of three testers in our concentration experiment.



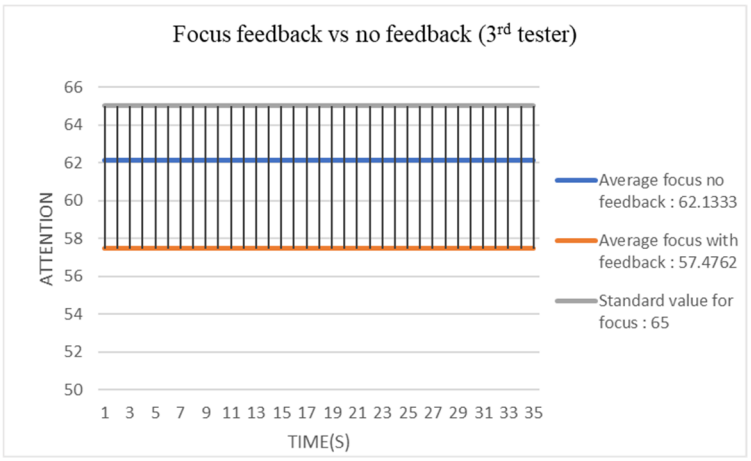


Fig. 12: Averaged diagram for each three testers

DISCUSSION

An efficient measure of brain function would be helpful to researchers or clinicians they serve. The EEG reflects real-time electrical activity of the brain and allows people to observe human emotional states in daily life. We selected three participants for testing. Using the Neurosky biosensor and our feedback system, we examined whether a neurofeedback system could help a user improve their ability to control their state of mind. After we collected all three testers' data, we found the total average data for the relaxation and focus experiments.

TABLE. I Average data for three testers in relaxation part

Relaxation		
	Relax with feedback	Relax without feedback
1st tester	29.55	46.76
2nd tester	44.12	37.72
3rd tester	47.8426	43.3518
Average	40.5	42.61

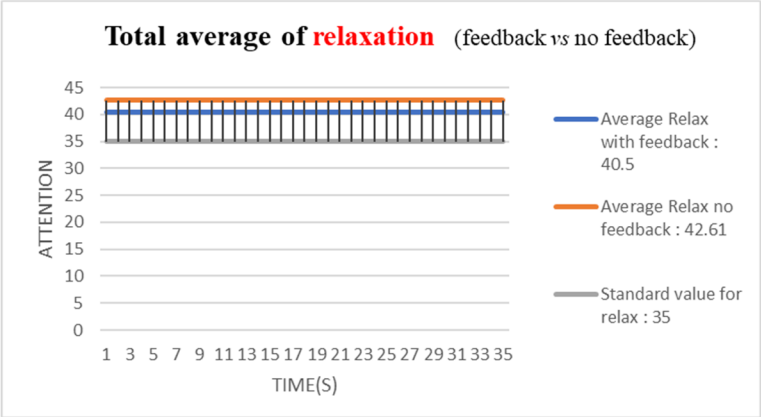


Fig. 13 Total averaged diagram for relaxation

As can be seen in Table Ⅰ and figure 13, people with the feedback system perform better in the relaxation task than people without the feedback system. The first tester' s data in relaxation with the feedback system is very close to what we expected. Our feedback system was presumably successful in helping them relax. However, the other two testers' data in relaxation with the feedback system are worse than without the feedback system. Casting doubt on that conclusion.

One of possible reason for the disparity in results is the feedback system distracted those two participants from returning to their task. It is also possible that these two subjects are not usually in a relaxed state making it more difficult for a notification system to calm them.

TABLE. Ⅱ Average data for three testers in concertation part

Concertation		
	Focus with feedback	Focus without feedback
1st tester	58.05	60.7
2nd tester	69.24	63.76
3rd tester	57.4762	62.13
Average	61.58	62.19

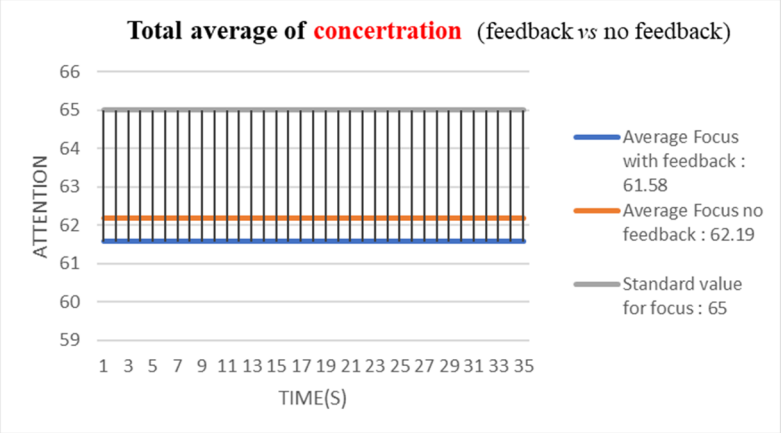


Fig. 14 Total averaged diagram for concertation

As can be seen in table Ⅱ and figure 14, the variation between concentration values for participants with or without feedback is not substantial in our concertation experiment. The first and third participants' results were not in line with what we expected. Both participants had a more difficult time returning to a state of concentration with the vibration system attached to their arm. In future work, we believe more trials may able to shed further light on these results. A possible cause of these results is that the feedback system was foreign to participants and served as more of a distraction than a reminder. Additionally, repeated vibrations may have affected participants' moods and made it more difficult for them to reenter a state of concentration. According to our data, the second tester can control his state of mind with the feedback system, so his data matched our hypothesis very well.

There are still many issues left to be improved in our research. First, in regards to the participants, the small sample size is not enough to draw any conclusions regarding the general population. More participants for a larger sample size would not only provide a more complete data set, but any conclusions drawn from this data would be more convincing. Second, the study was composed of an insufficient number of experiment exercises. Participants were not used to wearing the biosensor and feedback system during tasks. More exercises would allow participants more time to grow accustomed to the sensor and feedback system. The basis for this can be seen in our data where participants' results quickly improved as the users learned to react to the vibration system. In both the cases of meditation and concentration, users produced improved results from baseline when they became accustomed to the systems. Finally, an environment without any external interference is necessary during the experiment. If there is a loud noise or someone passing by the research environment participants could be distracted and create inaccurate data.

We identified that our system can help people control their state of mind. With enough training, participants can easily adjust their state of mind between relaxation and concentration. The concertation experiment revealed interesting differences. If the participant tried to write notes when they watched the news on the screen, they became distracted and the feedback system reminded the tester to focus. In contrast, a tester who did not take notes focused better on the experiment. Therefore, we eliminated note taking from the focus experiment to facilitate participants maintaining their state of mind.

In the future, we plan to use the Epoch emotive headset in conjunction with the Neurosky to track the subject's relaxation and concentration values while giving us the raw EEG band data. By analyzing the specific EEG band data, we can compare each case more thoroughly and completely. By comparing the different brainwaves, we can find patterns that may improve people's efficiency and ability to control their state of mind.

CONCLUSION

The brain is mainly made up of neurons. These neurons communicate with each other by sending electrical signals. We used a biosensor to detect these electrical signals or brainwaves. Using a neurofeedback system, we constructed, researchers provided participants with real-time feedback about their mental state. Our results show that our system helped participants improve their state of mind in the relaxation task, but they struggled during the concertation task. We believe with a larger sample size and preparatory training in the future, users of the system will develop strategies to control their state of mind successfully. The feedback system proved distracting for participants, so future trials should include a training phase to accustom participants to the feedback system. This will counteract the surprising nature of the feedback system and produce more accurate results for analysis. Our hope is that this feedback system could one day play a role in daily life by facilitating deeper levels of relaxation and higher levels of concentration with proper training.

REFERENCES

[1] Introductory guide to EEG & BCI for Entertainment, [online] Available at: http://neurosky.com/wp-content/uploads/2016/06/Intro-Guide-EEG-BCI.pdf

[2] What are brainwaves, [online] Available at: https://brainworksneurotherapy.com/what-are-brainwaves

[3] Jean-Paul Badjo, Po-Wei Tu, Dr. Fow-Sen Choa. Relaxation/Concentration Feedback System (unpublish data), 2019

[4] Büşra Ülker, Mehmet Barış Tabakcıoğlu, Hüseyin Çizmeci1, Doruk Ayberkin. Relations of Attention and Meditation Level with Learning in Engineering Education, 2017

[5] Jeffrey M. Rogers, Stuart J. Johnstone, Anna Aminov, James Donnelly, Peter H. Wilson. Test-retest reliability of a single-channel, wireless EEG system, 2016

[6] Neurosky, ESense (tm) Meters, [online]. Available at: http://developer.neurosky.com/docs/doku.php?id=esenses_tm#attention_esense