

BCI Mandala-based intervention tool to increase mean attention levels in subjects

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Abstract - Brain-computer interfaces are increasingly being employed to study psychological processes. In this project, we attempted to create a psychological intervention tool based on the same concept, using a Mandala. A Mandala is a design with recurring patterns in concentric layers. It's a useful tool to increase focus and attention, as observed in a few studies. In this project, a Mandala-based intervention tool was created and its effect on the attention levels of subjects was tested. The Mandala consisted of concentric layers of LEDs mounted across six layers. An EEG device was used to measure the attention data. The attention levels of the subject controlled the lighting up of the subsequent layers of the mandala. Subjects had to focus on the Mandala and light up as many layers as possible in a limited amount of time. The attention readouts per second were continuously measured and analyzed based on the different types of attention tasks that the subjects performed during the intervention. It was observed that the mean attention level on a scale of hundred rose serially across trials in the participants. The Mandala acted both as a visual readout of brainwave data, as well as a simultaneous intervention tool. The Mandala can subsequently be taken to a setting with individuals with attention problems.

Key Words: Mandala, Attention, Brain-computer interface, Intervention, EEG

1. INTRODUCTION

Recent scientific advances in the discipline of Brain-computer interfaces (henceforth referred to as BCI) have paved the way for its application in diverse fields ranging from stroke rehabilitation to robots which play musical instruments. For instance, though locomotion is largely controlled by the spinal neural networks, researchers opine that locomotor rehabilitation programs can be improved by employing BCIs (Cheron, et al., 2012), which can be highly useful for people like stroke victims and those with cerebral palsy. Leeb, et al. in 2015 proposed a Telepresence Robot for people with severe motor disabilities employing a confluence of BCI and Internet of Things. While several studies have shown that BCI related games and activities can be helpful for specially-abled individuals, a BCI tool constructed to serve as a readout of attention and facilitate neurofeedback has not been presented so far. This study focuses on creating a cost-effective Mandala-based attentional tool, which gives real-time readouts, helping the participant understand their level of attention at a given instant of time. A confluence of Engineering construction

and Cognitive Psychology, the study aims to create a method of helping typically-developed as well as individuals with special needs to improve their mean attention levels.

Attention can be defined as an internal cognitive process by which one actively selects environmental information (i.e. sensation) or actively processes information from internal sources (i.e., visceral cues or other thought processes) (Dictionary of Cognitive Psychology). Attention allows cognitive processes to take in selected aspects of the sensory world in an efficient and accurate manner (Fernandez-Duque & Johnson, 2002; Palmer, 1999). In general terms, attention can be defined as an ability to focus and maintain interest in a given task or idea, including managing distractions. There is no single definition for the psychological process, as it depends on the conditions and circumstances during which it is employed.

In recent years, several researchers have contributed to the application of brain-computer interface in enhancing the attention level of various categories of subjects. For instance, in a study conducted on children with Attention-deficit hyperactivity disorder (ADHD), which is a common childhood psychological disorder characterised by inattention and restlessness, Lim et al., in the year 2012 devised an experiment to improve attentional capacities of children with ADHD by setting up an 8 week long training program for them. They created games on brain computer interface to help improve attention. The subjects were to control an avatar in the game using the signals from the EEG. The behavioural & attentional improvements of these children was monitored by the ADHD-RS by parents during the start of the sessions, in between and at the end of the sessions.

A group from Korea including Kim et al., talks about the effect of games and mandala on the attention of school children. The authors took three groups of children: mandala group, games group and a control group. The children were in total given 12 sessions across four weeks. Their attentional abilities were measured before and after the sessions using a standardized tool called the FAIR test for concentration and attention. It was found that the games and the mandala group was effective in improving attention among children. In totality, BCI tools can be effective technological aids to improve attention.

This experiment was designed to study the effect of a Mandala-based intervention on the attention levels of subjects. A Mandala is a symmetric design with concentric

layers, each of them having repetitive patterns and motifs. Traditionally, a Mandala has been used in Asian cultures as a tool to focus and improve attention. The same rationale was employed in this study, with the addition of a modern BCI component. The Mandala was printed on a 4x4 feet board. The board consists of 206 LEDs that adorn the Mandala design in a concentric pattern. They are divided into 6 layers, each with different coloured LEDs. The Mandala design and the LED placement are shown below.

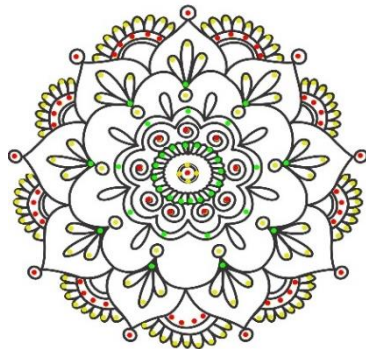


Fig-1.1: Study Mandala design

The experiment was designed in two phases. The first phase measured attention readouts of subjects which was used to set thresholds for the second phase. The second phase involved a subject performing a cognitive task, followed by the intervention tool and ultimately repeating the first task. The details of the experiment phases are explained further. Since the intervention tool is reward-based, i.e., the higher the attention levels of the subject, the more number of layers light up - this model can be extrapolated to facilitate elongation of attention span in children with ADHD and Autism.

2. SYSTEM ARCHITECTURE

2.1 Block Diagram

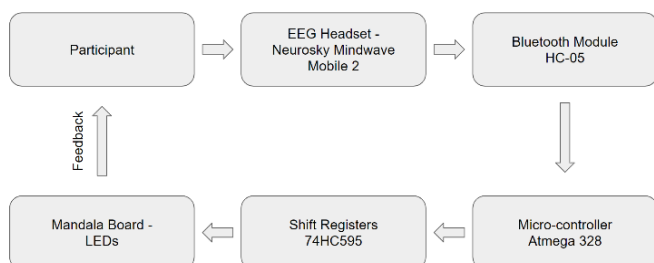


Fig - 2.1: Block diagram of tool

2.2 Hardware

2.2.1 Neurosky Mindwave Mobile 2

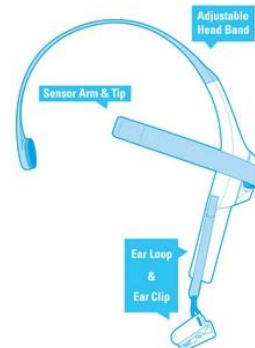


Fig-2.2.1: Neurosky Mindwave Mobile 2 device

Neurosky Mindwave is a single electrode EEG headset that can be used to obtain brain-wave data. It consists of a dry electrode in contrast to many other EEG devices which would require the application of a conductive gel between the sensors and the head. It is portable and easy to use. The Neurosky uses Bluetooth to transmit raw sensor data to any other Bluetooth enabled device. It also consists of in-built electrical noise filtering algorithms and embedded signal processing solutions.

2.2.2 Development Boards: Atmega 328 (Arduino Uno)

Atmega 328 is a single micro-chip microcontroller created by Atmel and it consists of a modified Harvard architecture 8-bit RISC processor core. It consists of 32-bit flash memory, 1 KB EEPROM, 2 KB SRAM, 23 general-purpose I/O lines, 32 general-purpose registers, 3 timers/counters with internal/external interrupts, serial programmable USART and a 2-wire serial interface that is byte-oriented. It also has a programmable watchdog timer with an internal oscillator. It comes with 'read-while-write' capabilities. The device operates between 1.8 to 5.5 volts.

2.2.3 Communication: Bluetooth Module HC-05

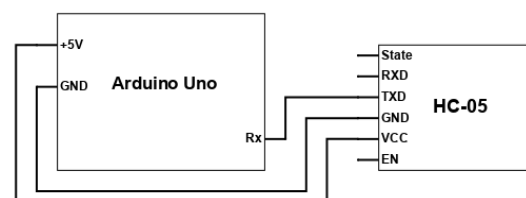


Fig-2.2.3: HC-05 circuit diagram

HC-05 is a very useful Bluetooth module that enables full-duplex wireless communication between either two microcontrollers or between a microcontroller and any other device like a phone, laptop or in this case, the EEG headset. The Bluetooth module can be interfaced with any microcontroller as it uses a USART communication protocol

at different, configurable baud rates. The command mode can be used to change the configuration of the module. It operates in two modes: Data mode and AT command mode. Data mode is used for sending and receiving data from other Bluetooth devices while the AT command mode is used to change the default settings of the module. It uses the 'Serial Port Protocol' (SPP) which enables easy pairing with microcontrollers.

2.2.4 Shift Register: 74HC595

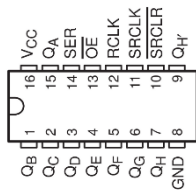


Fig-2.2.3: 74HC595 pin diagram

It is an 8-bit, serial-in, parallel-out with 3 state output latches. It works through synchronous serial communication. Shift registers are generally used to increase the number of I/O pins on the microcontroller. The 595 has two registers each with 8 bits of data, namely the shift register and the latch register. The shift register receives data from the data pin and the data is copied and stored in the latch register. Each storage bit is connected to one of the output pins Q0-Q7 which reflects the value stored in the latch register.

3. WORKING

The setup works on a neuro-feedback mechanism. The biosensor is employed to get the brainwave data from the subjects. The device used for this purpose is the Neurosky Mindwave 2. It has several built-in algorithms that enable users to obtain data in the form of attention, meditation, blink detection, brainwave bands (ex. delta, theta, alpha, and beta) and also raw data. The data is transmitted to the Atmega-328 microcontroller through the Bluetooth module HC-05. The Bluetooth module is interfaced with the microcontroller and uses USART to communicate with it with a baud rate of 57600. The attention and meditation data that are received from the biosensor are on a scale of 0-100 in steps of 1. The data is transmitted once every second.

Controlling 206 LEDs independently using only Arduino Uno is not possible as it has only 13 digital and 6 analog outputs. Therefore, we used 26 shift registers (74HC595) in series to effectively increase the number of digital outputs to 208 while using only 3 pins from the Arduino. 74HC595 works on a Serial in - Parallel out protocol. The data pin (pin 14) receives the data from the microcontroller serially and outputs the Logic values on its output pins (Q0-Q7). The data is transmitted to the next shift register through Q7' on

pin 9. The registers outputs are individually addressable via the software code thus we are able to control individual LEDs.



Fig-3.1: Printed Mandala Board with LED placements



Fig-3.2: Attention visualization using the BCI Mandala setup

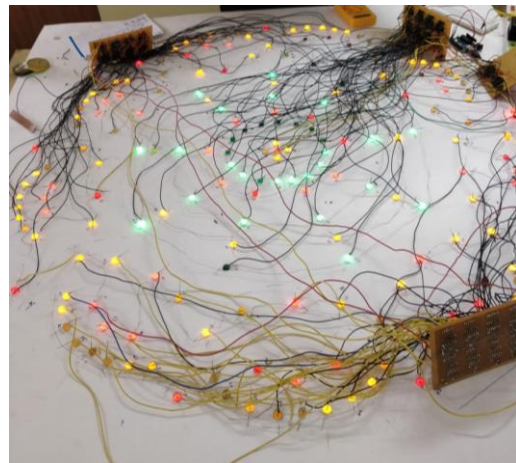


Fig-3.3: Back of the Mandala with circuit implementation

There are two phases to the project.

- i. Determining the attention/meditation thresholds for lighting up the different layers of the mandala through experimentation with participants.
- ii. Using the mandala board as a neuro-feedback based intervention tool to improve the attention levels of the participants.

4. EXPERIMENT AND ANALYSIS

4.1 Phase 1

The experiment was conducted on school going children of Grade 8. This was to determine the baseline attention levels of the students while performing different activities and to use the data in order to determine thresholds for lighting up the layers of the mandala.

Aim: To determine the baseline levels of attention in school going kids, grade 8 (n = 5)

Procedure:

- a. The participant was made to wear the biosensor headband in a quiet room.
- b. The participant was instructed to do three tasks with each task being performed for two minutes.
 - i. Task 1: The participant was instructed to not focus their attention on any object.
 - ii. Task 2: The participant was instructed to read from a book.
 - iii. Task 3: The participant was instructed to focus on a single point.
- c. The attention data was recorded for two minutes during each task and the recorded values with poor signal quality (due to artifacts) were discarded.
- d. The recorded values were then graphed using Box and Whisker plots to study their characteristics.

Graphs and Tabulation:

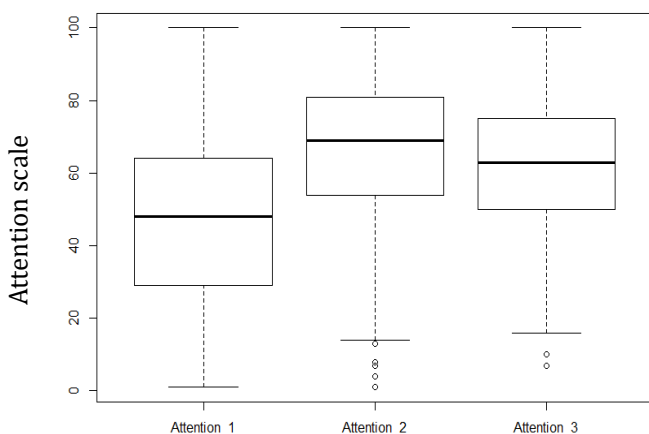


Fig-4.1.1: Mean attention levels of subjects across 3 attention based tasks – no focus, reading and point focus from left to right. Higher attention levels are observed while reading.

Result – The obtained values were used to set thresholds

for different layers of the Mandala to be used in the second phase of experiments.

4.2 Phase 2

This experiment was conducted to study the effects of using the mandala as a neuro-feedback tool to study attention levels in participants. The attention range obtained from phase 1 were used to set thresholds for lighting up the layers of the mandala. The experiment helps in determining the feasibility of using the mandala board as an intervention tool to help increase the mean attention levels in subjects.

Aim: To determine the feasibility of using the mandala board as an intervention tool to increase mean attention levels in subjects.

Procedure:

Pre-Intervention: The subject was asked to perform a cognitive task for 2 minutes and their attention levels were recorded.

Intervention: The subject was instructed to focus on the mandala board for two minutes and try to light up the entire board. This requires an immense amount of concentration and focus. The attention levels were recorded.

Post-Intervention: The subject was asked to perform the same cognitive task again for 2 minutes and attention levels were recorded.

Graphs and Tabulation:

Pre-intervention task performance

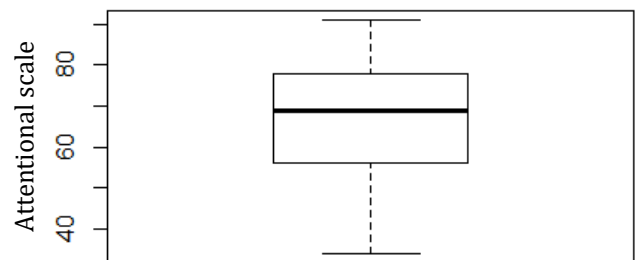


Fig-4.2.1: Attention levels of the subject while performing the cognitive task before Intervention. Median attention level is at 69.

Intervention task performance

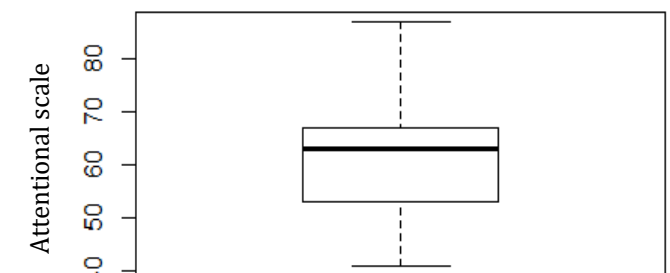


Fig-4.2.2: Attention levels of the subject during the intervention using the mandala. Median attention level is at 63.

Post-Intervention task performance

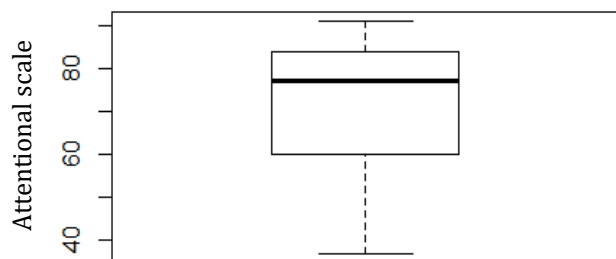


Fig-4.2.3: Attention levels of the subject while performing the cognitive task after the intervention. Median attention level rises to 77.

Table - 1: Statistical comparison of attention data through the experiment.

	Pre-intervention	Intervention	Post-intervention
Min.	34	41	37
Median	69	63	77
Mean	66.59	61.32	71.12
Max.	91	87	91

Observations

The tables and plots clearly indicate that the mean attention level of the subject during a cognitive task increased after the intervention was supplied from 66.59 to 71.12 which is a 6.8% increase. Similarly, the median levels increased from 69 to 77 which is a 11.6% increase.

5. CONCLUSIONS

The LED Mandala is a novel tool which can find application in many fields. Yoga and meditation centers can use it as an aid for meditation. It can also be used as a physical scale for the display of attention/meditation levels while studying the effects of different stimuli on the mind. It can be used as a tool to decrease anxiety and stress levels in workplaces. Another application would be in special education centers where children with special needs can make use of the Mandala to improve their attentional abilities.

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