USABILITY TESTING ON MOTIONMOUSE: A PROTOTYPE TO CONTROL ANDROID TABLET USING EMOTIV EPOC+

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ABSTRACT

Portable brain-computer interfaces (BCI) headsets that available today in the market provides users with unique ability and experience to interact with their mobile phones and tablets. Researchers try to use BCI outside the labs by implementing and developing applications for BCI mostly on Android platform, which are of different types and purposes, such as communication purposes, controlling external devices and for entertainment such as games. But typically, those BCI related applications are somewhat limited in terms of their scope of control, i.e. the users can only interact with one application at a time and cannot switch to other application without touching the device screen. This paper addresses the development of a MotionMouse, a prototype that provides users with an alternative to fully interact and control an Android tablet by controlling not just one, but many different application types. The evaluation of the prototype was based on ISO 9241-11:2018 standards with a result that demonstrate the ability of controlling and generating touch events on the device using Emotiv EPOC+ with effectiveness of 63.82% (accuracy of the correct target) and efficiency of 3.22 clicks per minute. In addition, the participants also found that it was easy to perform the tasks with few showed excitements during the experiment.

Keywords*: *Human-computer interaction, Android, Mobile interaction, Usability test, Brain-computer interface

1.0 INTRODUCTION

Since 1973, when Jacques Vidal proposed a system that can translate electroencephalography (EEG) signals to a computer signals [1, 2] the name of brain-computer interface (BCI) has emerged as a system that provides users with the ability to control and interact with their surroundings using their brain waves [1, 3]. The EEG signals have usually been processed by computers, but with today's technology the processing power of portable devices is improving every day and it can replace the computers for processing the EEG signals [4]. The researchers try to take advantage of the portable devices due to their small sizes and the long battery life as compared to PC and managed to start using BCI outside the labs [5]. In addition, due to the availability of portable BCI headsets in the market, makes it easier to develop and create applications for Android devices [6].

Most of the recent applications that had been developed for Android devices are independent applications; like a notepad, which can be controlled using BCI and the user can write a message in that application using Emotiv EPOC [4], or a car racing game which allows the user to control the car speed using NeuroSky Mindwave headset [7] or to control a wheelchair using an Android mobile to redirect the signal from headset to Arduino device that controls the wheelchair [8].

The current limitation that was found from these works is the BCI users can only interact with one application at a time, and cannot access, interact nor control the device operating system and were limited to use the presented application on the screen of the device only and cannot shift or switch the application without the necessity of touching the device screen [6]. A prototype called MotionMouse was developed to solve those limitations based on the proposed model in [6] as a proof-of-concept of that model which focuses on providing the users with a control application to be the first application to receives the user brain signal and that application should be able to control the main functions of Android system like touch [6]. Based on that the user will have the freedom to select the desired application on the Android device of communication, entertainment or control types [6].

There are two goals of this study. The first goal is to provide a practical implementation by developing a prototype based on the model in [6] which can help developers and researchers to implement that model in different methods and using different headsets. The second goal is to assess and evaluate the usability of MotionMouse prototype by utilizing Emotiv EPOC+ as an alternative for the users to interact with their Android devices. This paper presents and describes the development of a prototype application called MotionMouse that allows the BCI users to control an Android device and to choose the desired applications to control (launch and play), instead of just use one application and needing to still touch the screen to run another application. In this study, the users have the ability to perform the previous touch interaction without touching the screen and have access to most of the Android operating system functions and applications.

The structure of this paper is as follows. The next section describes the background and related work to this study. The subsequent section explains the methods of the study, the description of the participants, prototype development, experiment procedure and ends that section with the evaluation of the prototype. This is followed by the results of the experiment. This paper ends with the conclusion and future works.

2.0 BACKGROUND AND RELATED WORK

The brain is the main command system of the body [9] and it is filled with neurons. Every time we think, feel, move, or remember something, our neurons in our brains communicate with each other by sending small electric pulses. Although the paths the signals take are isolated, some of the electric signal outflows that path, where the researchers and scientists can detect those signals [10]. A brain computer interface is a computer-based system that monitors brain signals, analyses those signals and translates them to a computer signals that are connected to an output device to carry out the desired action [11].

Brain-Computer Interface (BCI) or Brain-Machine Interface (BMI) or sometimes known as Mind-Machine Interface (MMI), all refer to the same system which is monitoring human brain signals using sensors and translate it into computer signals, enabling them to directly control machines like wheelchair or a computer, either to assist them to communicate or to interact with their environments [1, 3]. In 1929, Hans Berger has made a significant breakthrough in the development of electroencephalography (EEG) to enable the non-invasive monitoring of brain activities from the human brain [2]. The first trial to monitor brain signals on a neurophysiological basis was reported in 1968, and the first report of voluntary control of human brain pulses was published by Kamiya in 1969 [2]. The term brain computer interface was first introduced by Jacques Vidal in 1973 when he presented a system that has the ability to convert brain signals to a computer command [1, 2].

Non-invasive BCI is widely used for research purposes and in clinical trials. The signals that come from the user's brain can be used in many ways based on what action or task the user performs to produce that signal. For example, there is a technique called motor imagery (MI) which the user is required to imagine the movement of either right or left hand. By doing so, a locally confined response can be noticed in the EEG signal and that signal could be used to move a mouse cursor or a wheelchair [12].

One of the main goals of BCI is to provide communications ability to severely disabled people [3] by using the brain waves to control external devices without using the spinal or the peripheral motor system, or for Yes and No communication, or even writing a letter [13]. There are two main methods for using BCI in a medical context either as assistive BCIs to enable disabled patients to communicate or control remote devices or as rehabilitative to help patients with neural recovery [2].

Researchers tried to use BCI technology in real life outside of the strict environment of the lab and to enable patients to use that system in their daily life. This was possible with the current wearable headset in the market along with the advantage of portable devices like the small size, the long battery life and the embedded powerful CPU in those portable devices [5]. Due to that, the development of BCI applications had shifted from computers toward Android devices. For instance, a communication application which provides users with the ability to write a message by looking at the Android device screen for communication proposes [4]. This application uses p300 which utilizes Visual Evoked Potential (VEP) technique that depends on visual stimulation where the user focuses on the target on the screen while the screen is flashing, and the user’s brain generates signals in response to that visual stimulation [6]. Another example is for entertainment that is by controlling a racing car speed in a game by concentrate and relaxing [7], or to control a wheelchair remotely using Android device [8].

All those applications provide users with unique experience with have their unique features like high accuracy or new type of interaction, but all of them had one limitation in common, which is the scope of control, i.e. the users were limited to use the presented application on the screen of the device only and cannot shift or switch the application without the necessity of touching the device screen [6]. The interaction model in [6] suggest that providing the users with a control application that controls and interact with the operating system of the device would be the best solution to that limitation and it will give the user to freedom of choice over the desired application in the device rather than limit the users with one application [6].

One of the most popular low-cost EEG portable headsets is Emotiv EPOC which had been used in many types of research [14, 15, 16]. It has 14 EEG sensors distributed across the scalp to record and monitor brain activity following the international system 10-20. That number of sensors makes the EPOC a popular choice for researchers which allow them to conduct many different types of studies researches [4, 14, 15, 16]. The Emotiv SDK is also considered as one of the many things that made the headset so popular which allows the developers to implement the headset into their applications and projects easily using the Emotiv SDK or to conduct researches [6].

Previous studies using the ISO 9241-11:2018 standards [17, 18], in order to use BCI headsets as assistive input device for mobile devices, usability evaluation is necessary by using ISO 9241-11standards which covers Effectiveness, Efficiency and User-Satisfaction [17], the effectiveness of that study was by calculating the accuracy of the task compilation, efficiency was calculated by the time spent to complete the task and the user-satisfaction was determined by using the 5-point Likert scale questionnaire [17]. Satisfying those elements is necessary for this study to achieve the goal of evaluating the usability of the prototype and check whether Emotiv EPOC+ is suitable for controlling Android devices.

3.0 METHODS

This section presents the overall methods that had been used in this study, from participants and prototype development to the evaluation of this study.

3.1 Participants

The participants of this experiment were five postgraduate students from the Faculty of Computing of Universiti Teknologi Malaysia (mean age of 28 ± 1.4 years old, all male). The selection of participants was based on their technical background about recent technologies and availability. All participants have been introduced and trained to use brain computer interface with a computer almost three months before the development of the prototype to get familiar with the BCI as a concept and the ways of using it.

3.2 Prototype Development

A prototype is created based on the proposed model in [6] the target platform of the prototype is Android. Therefore, the Android Studio 2.3.3 is used to develop the prototype, with the target device runs Android 6.0 operating system, hence compiler SDK API 23 was used to compile and debug the application. Debugging and testing were done directly on the target device which is Samsung Galaxy Tab A 8 SM-P355 using USB debugging mode. The device also runs rooted operating system to grant the prototype the required permissions to inject events, which in this case, the touch event to the system, and gives the user the control over the operating system.

In this study, Emotiv EPOC+ had been used for signal acquisition from the user's brain scalp, it has14 EEG sensors which are F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF3 and AF4 [1, 15]. AF3 and AF4 sensors were used to validate that the headset is connected and placed correctly on the user's head, so it can detect the winks and blink which is one of the easiest and most common implementations of the portable headsets using there standard SDK and reported in many studies [15, 16, 17] Fig.1 shows the sensor locations of the headset, similar to what has been discussed in [15], which the signals from those sensors were translated as clicking by implementing the standard free Emotiv SDK community 3.3.4 in the prototype to detect the winking of the eyes. As for moving the mouse cursor, the Gyroscope data of the EPOC+ was used to simulate the mouse movement by tracking the users head movement similar to [16], which was conducted on the Windows platform.

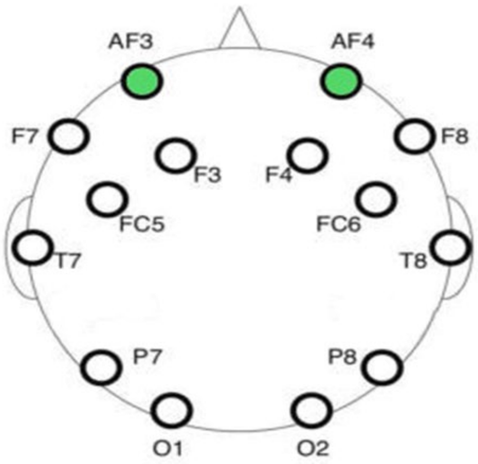

Fig 1. Emotiv EPOC+ Sensors Location [1, 15].

3.2.1 Prototype System Architecture

Ultimately, the prototype must acquire the signals from the headset to the Android device using Bluetooth. Two signals were used from the headset to simulate movement and touch in the device. The first signal used in the application is the gyroscope that is to simulate movement. The gyroscope will drive a visual mouse cursor in the device screen to the desired location based on the user head movement.

The second signal used in the application is acquired from the headset EEG sensors to detect eyes blinking to specifically detect wink to be used in the application to simulate touching and clicking the mouse cursor location. To do so, sensors in location AF3, AF4 of the headset located in the user's forehead had been used to detect eyes winking. Fig 2 illustrates the prototype system architecture based on the proposed model in [6].

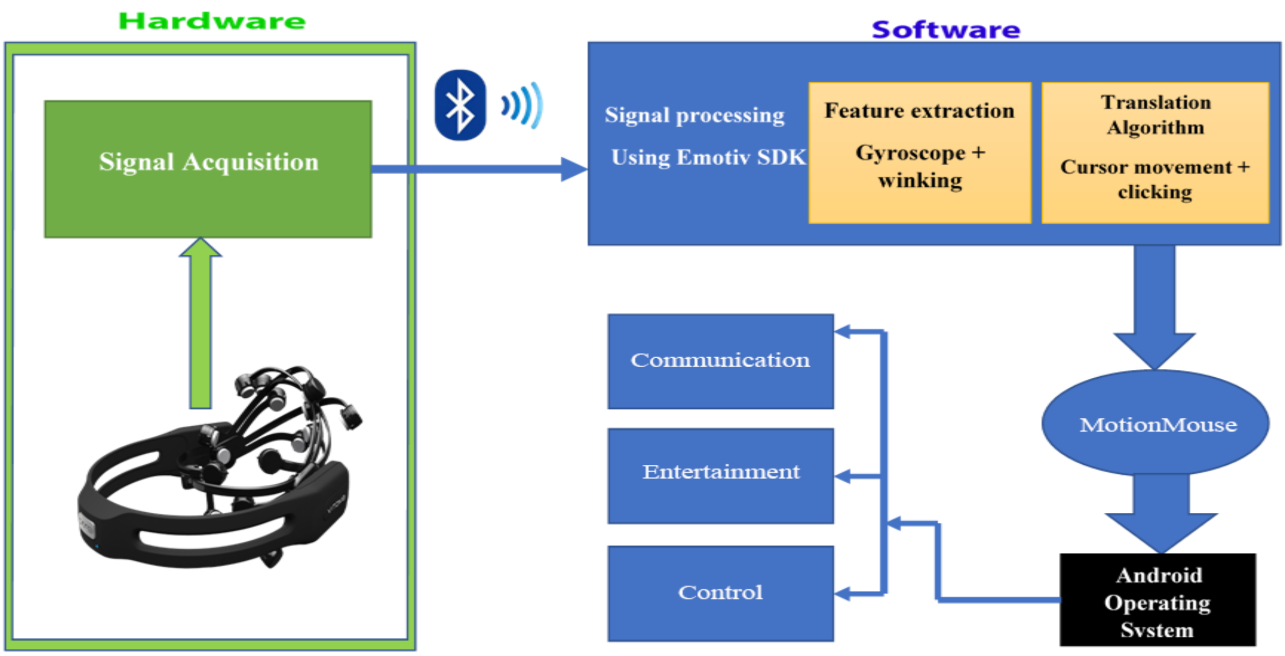

Fig 2. Prototype System Architecture Diagram.

3.2.2 Prototype Classes Structure

The prototype consists of three distinguished Java classes. Each class has different functionality and purpose. The first class is the Main Activity class. This class is responsible for connecting the application to the headset using Bluetooth and fetches the required signals from the headset and direct those signals to the other classes as well as drawing the interface of the application on the Android screen.

The second class is the Mouse Accessibility Service class and it is responsible for drawing the mouse cursor on the device screen and move the courser on the screen based on the gyroscope data that comes from the headset through the first class. The third and last class of the project is the Injector class. This class is responsible for injecting touch event into the cursor location to simulate screen touching based on the winking signals that come from the first class and then goes to the second class to locate the cursor coordination. Based on those data, the Injector class will take root permissions from the Android system to inject the touch event at the cursor location. Fig 3 illustrates the prototype classes interaction.

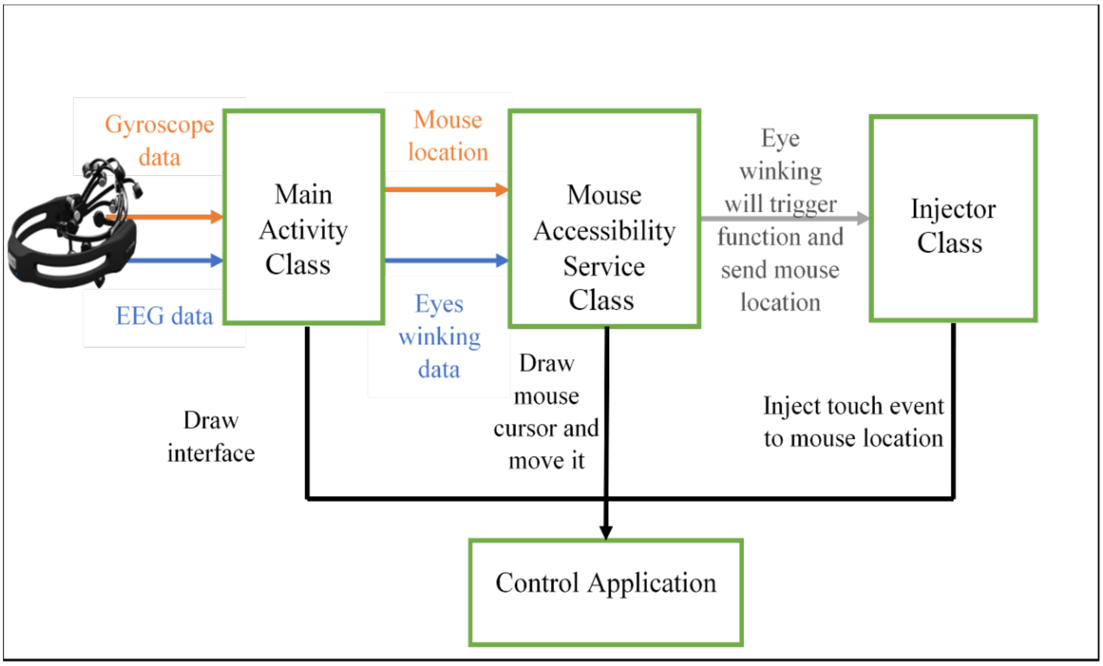

Fig 3. MotionMouse classes interaction.

3.2.3 Prototype Interface and the Assistive Application

The Main Activity class draws the interface and it consists of two buttons; Start and Stop, and two text boxes. The start button triggers the second class to draw the mouse cursor in the screen and start receiving and sending the gyroscope data from the headset to the second class to move the mouse cursor. The stop button will hide the mouse cursor by stopping the second class from working. The two text boxes show the status of the X and Y that comes from the headset gyroscope. Those numbers changed based on the gyroscope movement and based on that change the second class will determine either to add a pixel or to deduct a pixel of the mouse cursor location on the screen.

The prototype alone was not enough to achieve the interaction without touching the screen. The mouse cursor only works inside the application interface. Typically, the user must touch the home button on the device to go to the home screen in order to be able to use the mouse cursor. To give the user the ability to go to the home screen without touching the device, an assistive application called “simple control (navigation bar)” was installed in the Android device. The application provides the user with navigation buttons floating on the device screen, as an alternative to the hard buttons that are available on the device frame. Fig 4 shows the interface with the assistive navigation bar in the dark rectangle on the left and the hard buttons in the white rectangle at the bottom.

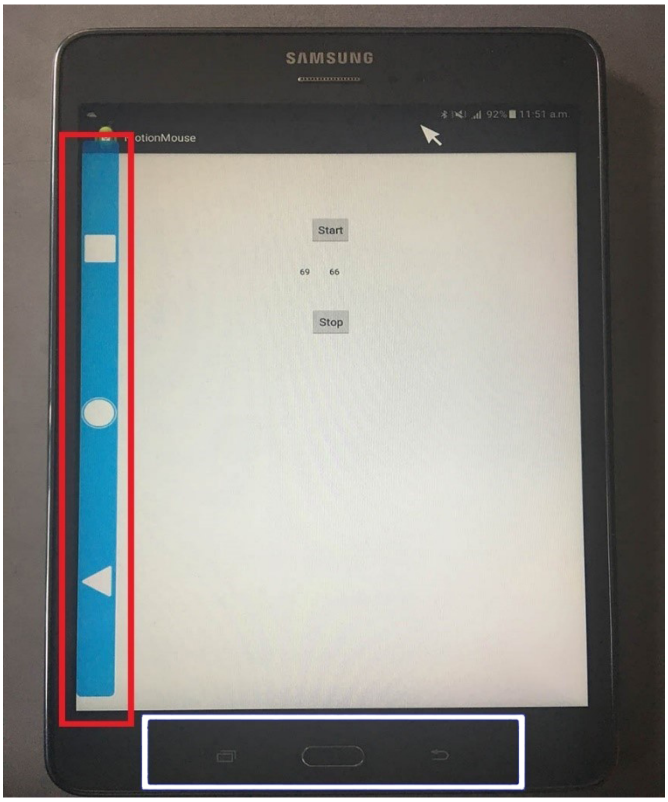

Fig 4. The prototype interface with the assistive bar.

3.2.4 Experiment Sessions

At the beginning of every session, the Emotiv EPOC+ was given to the participant to place it comfortably over his/her head. The headset was then connected to the computer and then check the placement of the sensor on the user scalp to be sure that the sensors can read the user's brain signals. The headset was then connected to the Android device using Bluetooth before launching the prototype and start the application.

Once the application is ready and the mouse cursor is present on the screen, the participant was instructed to do the following:

Using your head movement, aim then wink…

1. The navigation bar to go to the home screen
2. The notepad icon on the home screen
   - O Inside the notepad application (it will make the keyboard shown in the screen).
   - O The letter H followed by the letter I.
3. The middle button in the navigation bar to go to the home screen.
4. The bubble shoot game icon.
   - O Start the game and select level 1.
   - O Finish the level 1 of the game.
5. The middle button in the navigation bar to go to the home screen.
6. The LED app icon.
   - O Connect the Android device to the Arduino.
   - O The ON button followed by the Off button.

3.3 Experimental Procedure

The goal of this study is to assess and evaluate the usability of the MotionMouse, which utilize Emotiv EPOC+ as an alternative way to interact with Android devices. The particular headset which was used in this study is Emotiv EPOC+, which has all the necessary sensors to achieve the study goals. The headset consists of 14 EEG sensors and is capable of detecting the users' eye winking. The headset is also equipped with a gyroscope sensor that monitors the user head movements. Emotiv EPOC+ can be considered as a hybrid BCI headset due to the existing gyroscope sensor embedded in the headset.

The experiment is divided into multiple tasks that the participants must perform using the prototype to achieve the main goal of this experiment. The tasks were; (1) switching tasks of a different application, (2) preparing tasks and (3) executing task.

- Task 1: The switching task is to use the assistive navigation bar to switch between different applications without touching the device screen by driving the cursor using head movement to the navigation bar and wink to select the middle button to go to the home screen.

- Task 2: The preparing task is to launch the pre-installed applications on the target device to provide the users with communication, entertainment and control applications and prepare those applications for use. Like in the case of the communication application, the user has to open the notepad application and click on the app to show the keyboard, or in the entertainment application the user has to launch the game and select the level, and in control application, the user has to launch the application and pair it with the Arduino device by driving the cursor using head movement to the target and wink to select the targeted button.

- Task 3: The executing task is to use those applications after launching and preparing the application for use.

To support the abovementioned tasks, the following application types were prepared.

- Communication. In this experiment, a notepad application is used. The participants have to launch a pre-installed application in the device to provide them with the communication ability. In this task, the user has to switch from the control application (the prototype) to the home screen to launch a notepad application and tap in the text area in the application to view the Android keyboard on the screen. After the keyboard pops up on the screen, the user has to try to type "hi" by moving the prototype mouse cursor over the Android keyboard to the letter "H" and wink to select it. They have to do the same thing in order to click the letter "I".

- Entertainment. In this task, the user has to switch from the notepad that was opened in the previous step to the home screen to open a simple game that installed in the device called "Bubbles Shooter". The idea of the game is to shoot the ball to other balls that match the color. After the game is opened, the user has to start and select the first level. Users have to play and finish the first level of the game by shooting the colored balls on the screen using the prototype mouse cursor to aim and wink to shoot the ball.

- Control. The target device is equipped with Bluetooth 4.0 that enables the device to communicate to multiple Bluetooth devices, i.e. the headset and the Arduino, at the same time. In this task, the user has to switch from the "Bubble Shooter" game that was opened in the previous step to the home screen of the device using the navigation bar, then open a control application called "LED" that already installed in the target device. Next, the user has to prepare or set up, the application to be used by pairing the application with the Arduino device, which equipped with Bluetooth chip HC-06 and a small led light. After the preparing is done, the main interface of the control application will appear, which consists of two buttons "ON" and "OFF". The user has to click the "ON" button first to light the LED on the Arduino and turn it off after that by clicking the "OFF" button.

3.4 Evaluation

In order to check whether the prototype is usable to be an alternative way to interact with Android devices and to be used as an assistive control application, a usability assessment is conducted to validate and evaluate the usability of the MotionMouse that utilize the model [6] using the ISO 9241-11:2018 standards [17, 18], which consist of three measured parameters, which are:

(i) effectiveness; by calculating the accuracy of the prototype. In this study, the effectiveness was measured in terms of performance – as objectively assessed through accuracy (percentage correct clicks), as per performed by previous studies [17, 19, 20]. The usability test standards were used to calculate the accuracy of the prototype, as effectiveness defined by ISO 9241-11:2018 as "accuracy and completeness with which users achieve specified goals" [18]. This study defines the correct clicks as the successfully clicked target that the participants instructed to click, and any clicks outside the targeted area would be considered as an incorrect click.

(ii) efficiency; by calculating time durations of the tasks and calculating clicks per minute to measure the required time to finish the given tasks using the prototype [17, 19], In addition, this study follows the usability test standards, which were used to calculate task time duration, as efficiency was defined by ISO 9241-11:2018 as "resources used in relation to the results achieved", while resources can include time, human effort, costs and materials [18]. At the end number of clicks that been performed during the experiment for both correct and incorrect clicks will be divided on time durations to calculate the prototype throughput (how many clicks the prototype can produce per minute), this method has been used in [19] to calculate number of characters per minute including the incorrect.

(iii) satisfaction via a set of post-questionnaires. Previous studies used post-questionnaire and direct questions to evaluate BCI applications like in [17, 21, 22]. The questions were designed as to address the metrics as per outlined by the ISO 9241-11:2018 standards [18] and in other works such as [21, 22]. The idea of the experiment is to let the participants move a mouse cursor in an Android device with their head movement and perform clicking by winking an eye.

Observation was also used during the experiment for qualitative data purposes. To achieve this, all sessions of the experiment had been recorded from two different angles. One was from a camera behind the participant to monitor the Arduino response to the command, and the other is screen recording from within the Android device using "Du recorder" application to help identify how many correct and incorrect clicks the user performed during the experiment.

4.0 RESULTS

4.1 Effectiveness

Based on Table 1, the total correct clicks that the users performed during the experiment is 97 clicks. The difference in the correct click between users is due to the game in the entertainment application. The game is quite tricky and can be finished in a different way, which was why some participants managed to finish the game with 8 clicks and others with 9 clicks. The total incorrect clicks are 55, and the sum of both correct and incorrect clicks is 152.

The calculation to obtain the accuracy was based on [20], i.e. the number of correct selections is divided by the total selections. The overall accuracy of the prototype is 63.82%. While the accuracy for each application, which was calculated in the same way, is shown in Table 2. In addition, to know how well (or not) each participant performed for every application, a total number of clicks per application are also recorded in Table 3.

Table 1. Correct and Incorrect Clicks per Application

		User 1	User 2	User 3	User 4	User 5	Total	Average
Communication	**Correct**	5	5	5	5	5	25	5
	Incorrect	6	7	4	7	4	28	5.6
Entertainment	**Correct**	8	9	8	9	8	42	8.4
	Incorrect	2	1	1	0	3	7	1.4
Control	**Correct**	6	6	6	6	6	30	6
	Incorrect	7	4	3	2	4	20	4
Total Clicks per User		34	32	27	29	30	152	30.4

Table 2. Accuracy per Application

	Communication	**Entertainment**	**Control**
Accuracy	47.17%	85.71%	60.00%

Table 3. Number of Clicks per Application

	User 1	**User 2**	**User 3**	**User 4**	**User 5**	**Average**	**Standard Deviation**
Communication	11	12	9	12	9	10.6	1.36
Entertainment	10	10	9	9	11	9.8	0.75
Control	13	10	9	8	10	10	1.67

The above results show the overall accuracy of the prototype is 63.82% over the whole operating system, which leaves an average error rate of 36.18%, which is considered acceptable, as some researches indicate that the average error rate in BCI starts from 5% up to 60% [21]. But if we looked at the accuracy based on applications that the participants used in the experiment, the entertainment application (bubble shooter) gets the highest accuracy percentage with the lowest error rate, and the communication application (notepad) get the lowest accuracy percentage with highest error rate. This is despite the fact that the prototype was developed to be generic, i.e. not to interact with just one application, and has the same movement and the same way of generating touch (clicks) in all types of applications. Yet, it has different accuracy rate between different applications. Furthermore, the standard deviation in Table 3 indicates that all participants did not struggle a lot to hit the target in the game.

That big difference in accuracy level between those applications was suspected to be due to the different sizes of the graphical user interface (GUI) target areas, both size of the buttons and target locations, the bigger the size of the button the better accuracy. Fig 5 shows the interface of the game bubble shoot and the notepad application, which the area inside the red rectangle is touchable.

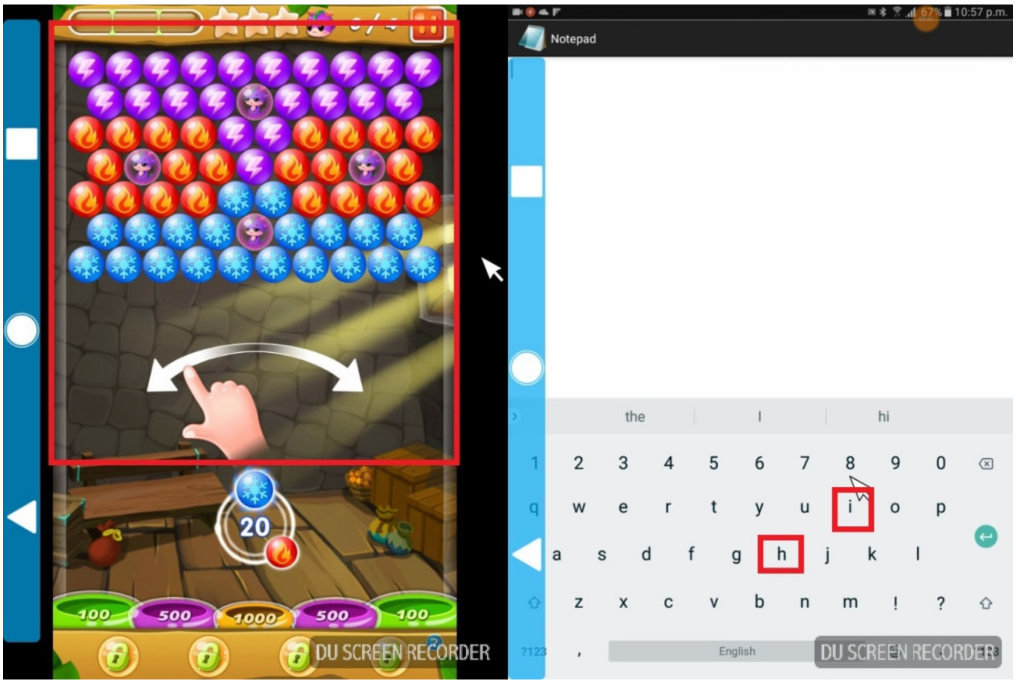

Fig 5. The touchable area in Bubble Shoot game and the Notepad application.

4.2 Efficiency

Completion time has been calculated for every application type as shown in Table 4. To obtain the efficiency of the prototype, the average selection (clicks) from Table 3 is divided with the average time in minutes from Table 4.

Table 4. Time Duration in Seconds

	User 1	User 2	User 3	User 4	User 5	Average	Minutes
Communication	53	157	120	224	88	128.4	2.14
Entertainment	174	108	222	316	118	187.6	3.13
Control	257	309	134	285	265	250	4.17
Total	484	574	476	825	471	566	9.43

The throughput of the prototype is calculated by dividing the average clicks 30.4 with the average time in minutes 9.43, which indicates that the prototype managed to perform 3.22 selection per minute that is considered as acceptable, based on other BCI usage like p300 speller applications that uses VEP technique usually provides from 3 to 8 selections per minute [23]. Therefore, the prototype managed to meet the minimum number of selections per minute.

The current challenge that could affect the efficiency is the root permissions, that is required to inject the touch event, i.e. for every click the user performs the prototype, it must access the Android operating system runtime and take root permission, which that increases the time required to perform clicks. In addition, it could also be affected by the weak detection of the headset the user eye winking. The efficiency of the prototype, however, can be improved in the future by enhancing the prototype code.

4.3 Satisfaction

In this study, a survey has been distributed to the five participants of the main experiment to get their feedback in order to evaluate the usability satisfaction of the prototype. The survey questionnaire was developed based on the prototype functions and the experiment tasks using the Likert scale.

The questionnaire consists of six questions. The first two questions are about prototype functionalities, and the third question was about how the user feels while using the BCI for controlling the Android platform. These questions consist of five points scale which is used to help the participants to express how much they agree or disagree with the given questions about the applications they used during the experiment. The fourth question was about the applications they used in the experiment. Fig.6 shows the participants' response to these questions.

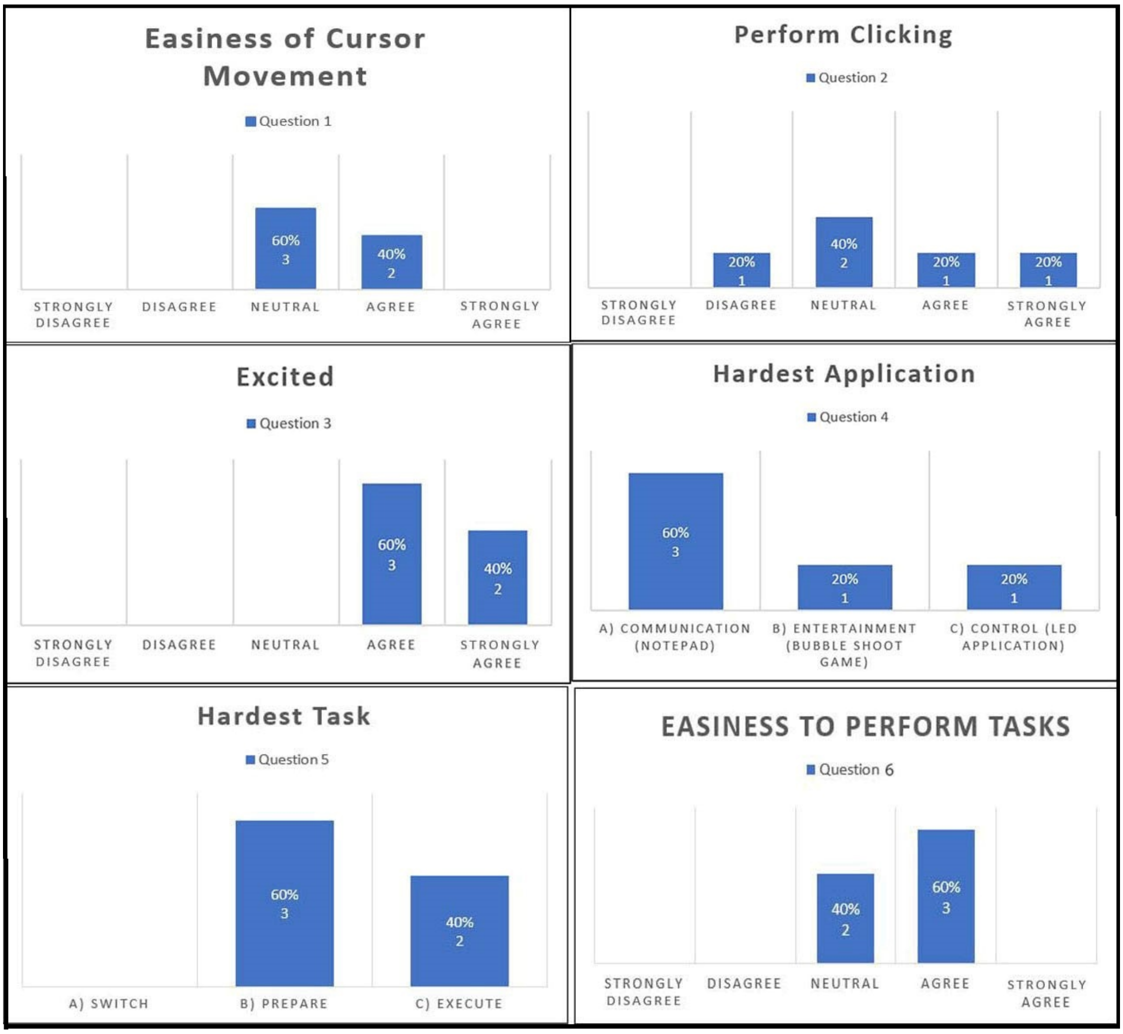

Fig 6. Questionnaire Results.

The first question is about the easiness of moving the mouse cursor using the head movement. Fig.6 shows the percentage of the neutral response is the highest with 60% and 40% for the agree response. The participants did not reject the idea of controlling the mouse with their head's movement, but they think the prototype still needs some improvements. In general, the easiness of the mouse movement is acceptable.

Question 2 is about one of the prototype functionalities, which is winking to perform click or selection in the Android device. The above Fig 6 shows 20% agreed and another 20% strongly agreed with the ease of clicking by winking. Fourty for neutral, which they do not think it was easy nor hard to perform the selection. 20% disagree with the statement above as they think it was very hard to do the selection. This could be affected by the headset (BCI) itself, which sometimes does not recognize nor detect the wink due to the signal quality because of the dry and semi-dry EEG sensors have low-quality signals compared to the traditional wet EEG [24]. However, the overall easiness of performing selection using wink is acceptable.

Questions about user feelings had been frequently reported before in many ways in previous research papers like in [22]. In this study, the participants have been asked if they felt excited while using the prototype and controlling the operating system with the BCI. The figure above shows sixty percent agree and fourty percent strongly agree with the statement, so all participants felt excited during the experiment. All participants have a solid background about technology, which uses a new technology to interact with mobile was for sure interesting and full of excitement for any person with a strong technical background. Further study should be done with participants of different backgrounds.

Another question is about the hardest application the users used during the experiment and it is a direct question with three possible answers. The above figure shows that the majority by sixty percent picked (A) the notepad application, 20% for (B) bubble shooter game and another 20% for the control application. The participants explained the reasons for their answers are due to the differences of GUI of an application to another, and it is hard sometimes to focus the mouse cursor on the target, especially if the target is small. These reasonings are in fact consists with the accuracy results in Table 3 that indicate that the notepad application (communication) has the lowest accuracy rate with 47.17%, as compared to the other application, like entertainment and control.

The fifth question with three possible answers was about the hardest task. The above figure shows that the majority, with 60% picked B (prepare) as the hardest task from the three tasks, the second hardest task was C (execute) by 40%. The participants justify their picks by explaining the problems they faced while winking (sometimes the winking does not respond yet selection was performed). Those answers are in fact reflecting Table 5, which is the sum of the task duration, with the highest task average time for preparing tasks is 259.2 seconds. Next to it comes the execution tasks with 201.8 seconds on average. The longer it takes the participants to complete the task, the more frustrated they get.

Table 5. Tasks Time Duration in Seconds

	User 1	**User 2**	**User 3**	**User 4**	**User 5**	**Average Time**	**Standard Deviation**
Switch	39	21	183	241	41	105	89.54
Prepare	319	297	168	304	208	259.2	59.92
Execute	126	256	125	280	222	201.8	64.97

The last question was about the easiness of using the prototype to control the Android operating system and to perform the giving tasks using Emotiv EPOC+. The analysis of the fig.6 has shown that three respondents agreed that it was easy for them to perform the tasks and control the system using the prototype, and two responses were natural. Thus, generally, we can conclude that the overall usage of the prototype is easy.

5.0 CONCLUSION

Brain Computer Interface (BCI) portable headsets with Bluetooth connectivity and support for Android provides a new and unique interactive way to use mobile devices. Currently, most of the applications that use BCI are limited in terms of the scope, i.e. the BCI can only interact with those dedicated applications one at a time, and the users do not have the liberty to access to another type of applications that did not been developed to interact with BCI.

The main goal of this study is to give users the ability to switch between different applications rather than focusing on one type of applications with high accuracy. This prototype achieved the main goals of the study which is enabling the users to control multiple applications and have control over the touch function of the operating system with decent effectiveness and efficiency rate; 63.82% accuracy, and the ability to perform 3.22 clicks per minute, respectively.

The users managed to open and control multiple applications and access some of the Android device functionalities. The results of the post-questionnaire indicate that the smallest GUI applications are the hardest for the users to interact with. The users enjoyed the experiment and using BCI to interact with the Tablet was full of excitement.

This study can be considered as a small step towards brain mobile interface. Further study and experiment need to be done before we can see a full Brain Mobile Interface BMI for mobile devices that come as an assistive interaction device instead of a pen and other assistive devices.

6.0 FUTURE WORK

This study opens the path for future works using BCI to interact with mobile devices. For instance, to find a way to increase accuracy and enhance the performance of the prototype. Others include, use different brain computer interfaces, explore other ways to emulate mouse movement and to generate touch, access other android interaction functions, other than touch like swap left and right or long touch, add sensors indicator to the prototype to make it easy to place the headset over the user scalp and test the usability with older participants or with patients who have difficulty to interact with mobile devices in normal way.

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