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Smart Room System for Paralysis Patients with Mindwave EEG Sensor Control

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Abstract— **Persons with disabilities experience physical, intellectual, mental, or sensory difficulties. One type of disability is paralysis. Paralysis is a condition where there is interference with the nerves that control body movement, causing the limbs to be unable to move. Paralyzed people will find it difficult to move without the help of others. Therefore, research was carried out by creating an intelligent room system to help persons with disabilities manage their own rooms so that they do not always have to be accompanied by a nurse. Paralyzed people can turn lights or fans on and off, and send help messages to their carers via the Telegram bot. This study used the NeuroSky Mindwave EEG headset which detects the user's brain signals with outputs in the form of attention level, relaxation level (meditation), and blink strength level. The resulting signal is processed via a PC and sent via NodeMCU to give commands in the form of turning lights and fans on or off, as well as sending messages to nurses. From this research a system was produced that could turn on the lights based on the value of Attention ⩾ 70, turn on the fan based on the Meditation value ⩾ 74, then the value of BlinkStrength ⩾ 81 which was counted 2 times to turn off the lights, 3 times to turn off the fan, 4 times to turn off the lights and fan, and more than 4 times sending help messages.**

Keywords— **Paralysis; smart room; NeuroSky Mindwave; attention; meditation; BlinkStrength.**

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I. INTRODUCTION

Persons with disabilities in Law Number 8 of 2016 are any person who experiences physical, intellectual, mental, and/or sensory limitations for a long period of time which can hinder interaction, communication, and daily activities [1]–[3]. One of the obstacles experienced by persons with disabilities is impaired mobility. Based on data from the Disability Study issued by the Ministry of National Development Planning of the Republic of Indonesia, impaired mobility ranks second highest among other types of disabilities with a percentage of 38.3% [1]. One example of persons with disabilities who are included in the mobility disorder section is sufferers of paralysis[3]. Paralysis is the inability to move the muscles in the human body. Paralysis can be temporary or permanent. In general, the cause of a person experiencing paralysis is due to stroke, spinal cord injury, and multiple sclerosis [4]–[8].

Many researchers have developed assistive technology in the form of machines or computers for people with disabilities, such as the use of human-centered design (HCD) using gesture patterns and speech recognition by Shehab et al [9], the use of assistive technology to communicate using leap motion sensors by Rusydi, et al [10]. Another example is the application of biosignal technology (biosignal) to build communication between humans and computers or machines. There are several types of biosignals, including Electrooculograph (EOG) to detect eye movements [11], Electromyograph (EMG) to detect muscle movements [3], [12], Electrocardiograph (ECG) to detect heartbeats [13] and Electroencephalograph (EEG) by detecting brain signals [14]–[20].

One of the applications of EEG is in establishing communication between the human brain and a computer through Brain-Computer Interface (BCI) technology. BCI generates a signal that originates in the brain and translates it into a command on the computer [15], [21], [22]. The application of BCI has been carried out in various applications, such as in games [23], rehabilitation [6], [24], [25], implementation of smart homes [26], object recognition [14], detection of emotions in persons with disabilities [27], intelligent robotic exoskeleton [2], robotic hand [21], robotic arm [20], wheelchair [8], [17], control relay module[18], cursor control [19], virtual keyboard [7], [22] and others. The EEG signal is obtained from the voltage variation resulting from the flow of ions across the brain's nerve cell membrane by placing electrodes on the scalp [28].

One of the tools used to detect brain signals is the *NeuroSky* Mindwave headset. This tool consists of 3 electrodes attached to the forehead and in the form of ear clips that are clipped to the ears [26]. The *NeuroSky* Mindwave headset produces 3 variables consisting of attention which is shown from the user's focus level, meditation which comes from the user's level of relaxation and awareness, and Blink Strength which is obtained from the strength of the blink of an eye [29].

There have been several studies using the *NeuroSky* Mindwave headset. Among them are [15] and [26]. Research [15] discusses the speed control of the Festo Robotino mobile robot using the *NeuroSky* Mindwave EEG Headset based on the Brain-Computer Interface. In this study, a mindwave EEG sensor was used to control the speed of the Festo Robotino mobile robot. The value used in this study is the Attention value. Before the Attention value reaches 40, the robot will remain silent, and when the Attention value is more than 40, the robot will move forward. Furthermore, research [26] discusses brainwave-controlled systems for smart homes. In this study, the *NeuroSky* Mindwave Headset was used with the Arduino UNO microcontroller to turn on and turn off home appliances. Home appliances accessed in this study were PCs, monitors, WiFi routers, and kettles. The sensor reading values used are Attention 50 and BlinkStrength 90. The difference between these two studies and the research that the author is going to do lies in the implementation of the object and the microcontroller used. In this study, the sensor will be implemented in lights, fans, and the Telegram application via the NodeMCU ESP8266 microcontroller.

Then there are also several previous studies related to controlling electrical equipment, including [30] and [31]. Research [32] discusses controlling household appliances using a Bluetooth-based Arduino Uno. In this study, the control of electrical equipment was carried out using a smartphone to control lights in 6 rooms and 1 fan. Then 2 sensors are also used, namely the PIR sensor to detect the intensity of light in the room and the LDR sensor to detect movement in the room. Furthermore, research [31] discusses electronic equipment control systems via Bluetooth media using voice recognition. The control of electrical equipment in this study is by using Arduino Uno as a microcontroller and voice recognition found on an Android smartphone so that by using voice input, users can turn on and turn off house lights. The difference between the two studies and the research that the author will conduct lies in the sensors. In this study, only one sensor is used to control electrical equipment, namely the Mindwave EEG sensor.

From several previous studies related to Mindwave and control of electrical equipment, the authors will create a smart room system to help paralyzed patients manage their own homes so they don't need to be accompanied by a nurse. This smart room will later be controlled by a Mindwave EEG sensor from *NeuroSky* by utilizing the output values in the form of Attention (level of focus), Meditation (level of relaxation), and Blink Strength (strength of eye blink). So that people who suffer from paralysis will be able to turn on and off the lights, turn on and turn off the fans, and send help messages via Telegram bots to nurses who need help. The microcontroller used in this study is NodeMCU ESP8266 which is equipped with a WiFi module so that it can send messages via Telegram bots.

This paper consists of several sections including an introduction which contains background, problems, studies based on previous research, and the solutions offered. the second part describes the methodology that describes the system design and system process flow. The third section describes the results and discussion and closes with conclusions.

II. Material and Method

This part explains about the materials and methods for develop the system. There are system design, system works, and process of the system.

A. System Design

The general design of the system contains an overview of the system design to be made. The general design of this system can be seen in Fig. 1.

Fig. 1 illustrates the prototype form of the smart room system. Only one sensor is used, namely the NeuroSky Mindwave Headset which is connected to the laptop via a USB adapter. After that, serial communication is carried out on the laptop via the laptop's COM port from the USB Adapter to NodeMCU so that sensor data can be sent to NodeMCU. After that, NodeMCU will be programmed via the Arduino IDE to set relays and telegram bots based on the Mindwave sensor output. For more details, the component connections used in this system are shown in Fig. 2.

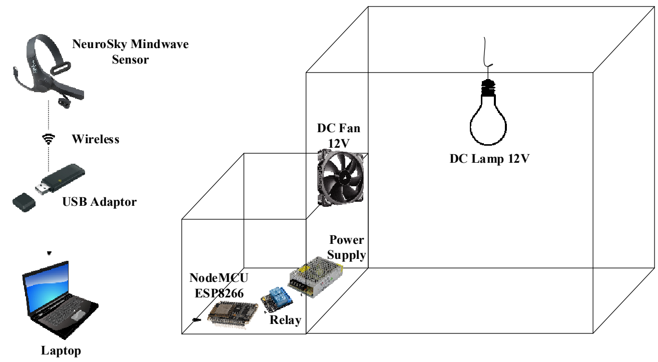

Fig. 1 General Design of The System

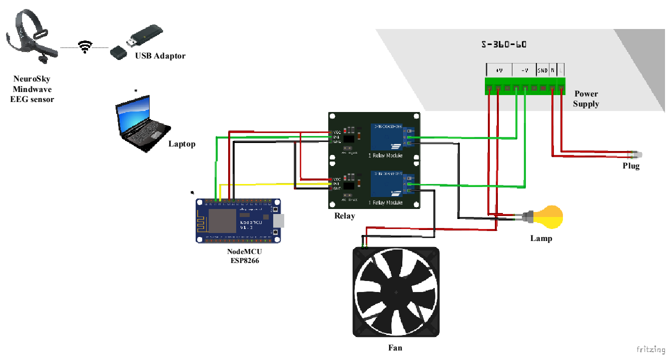

Fig. 2 Schematic Circuit System

The work of each device in the image above is as follows:

1. The NeuroSky Mindwave headset which functions as an EEG sensor that will read the user's brain waves equipped with a USB adapter.

2. USB Adapter, used to connect the mindwave sensor to the laptop and to the NodeMCU ESP8266.
3. Laptop for NeuroSky Mindwave adapter USB connector to NodeMCU ESP8266.
4. NodeMCU ESP8266 as a microcontroller which includes a WiFi module to run the system and connect the system to the Telegram application.
5. Relay to disconnect and connect current to lamp and fans.
6. 12V lamp as the output of the system.
7. DC 12V fan as the output of the system.
8. Power supply to change the current voltage so as not to exceed the maximum limit of the device.

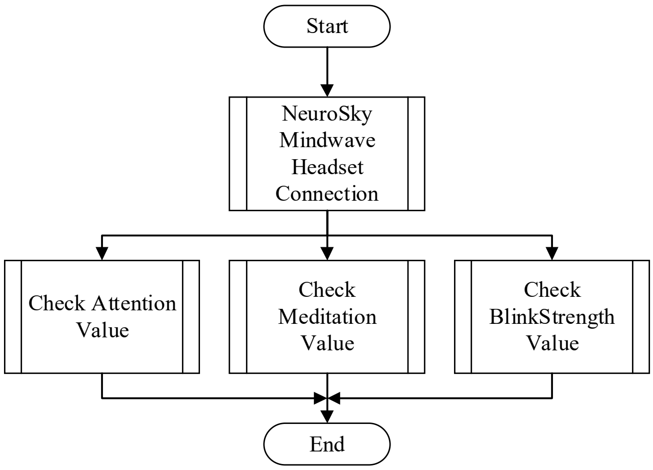

Fig. 3 Process Design Flowchart

B. Algorithm

Process design is carried out by determining the functional specifications and flow of the system starting from input, process, and output. The process design of this research can be seen in the flowchart of Fig. 3.

The system starts by running the sub-program to connect the NeuroSky Mindwave headset to the laptop and NodeMCU, then if it is connected then the sub-program to check the Attention value, check the Meditation value, and check the BlinkStrength value will be executed simultaneously. The NeuroSky headset connection sub-program can be seen in the following flowchart in Fig 4.

To connect the NeuroSky Mindwave Headset to a laptop and the NodeMCU ESP8266, the NeuroSky Mindwave Headset is first connected to the laptop using the USB adapter available from the NeuroSky Mindwave headset. If not connected then repeat the previous process. If connected, the laptop is also connected serially via the COM port to NodeMCU. If not connected then repeat the previous process. If connected then proceed to the next process. The Attention value checks sub program is used to turn on the lamp based on the Attention value reading, which can be seen in the following flowchart in Fig. 5.

To turn on the lamp, the user must increase focus to reach an Attention value ≥ 70. If the Attention value has been reached, the lamp will turn on. If not, then the program is finished.

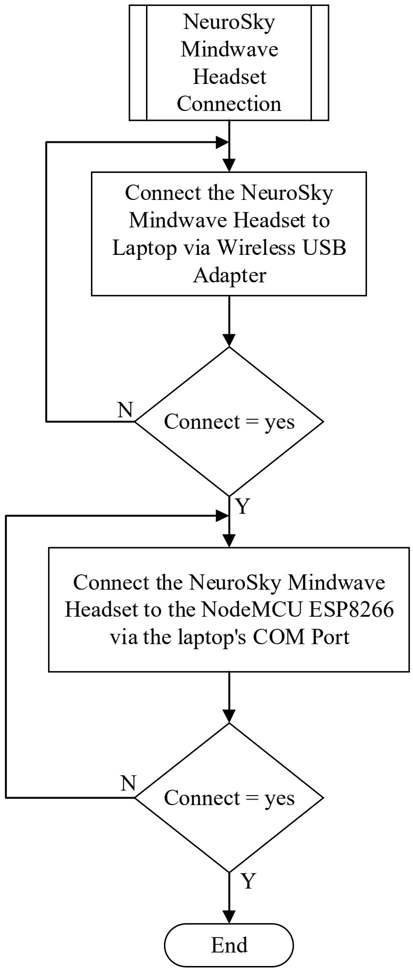

Fig. 4 Flowchart for connecting the NeuroSky Mindwave Headset

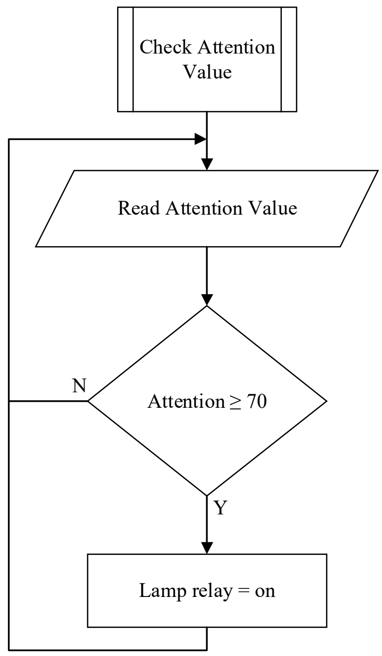

Fig. 5 Flowchart for Turning On The Lamp

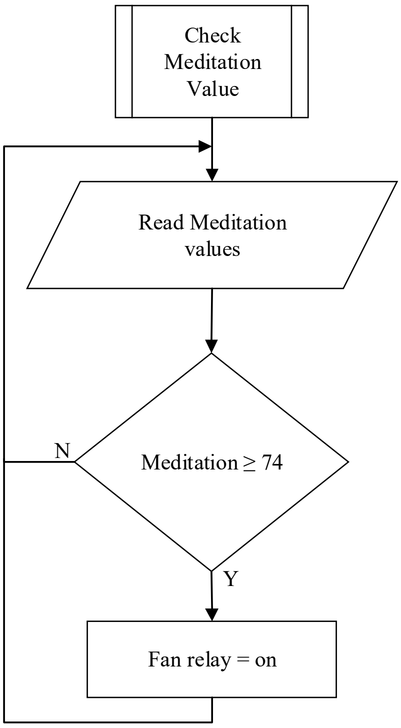

Fig. 6 Flowchart for Turning On The Fan

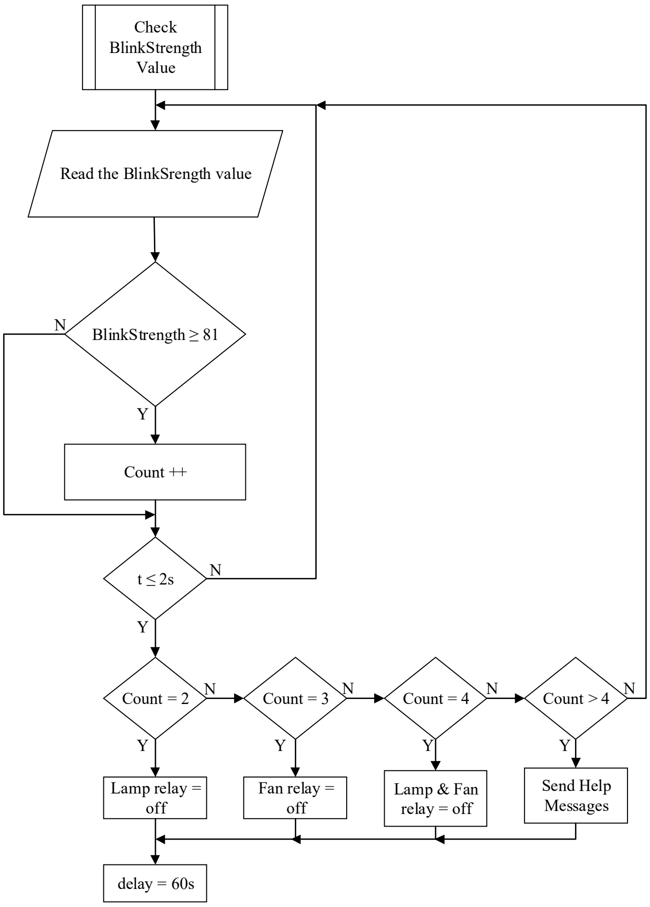

Fig. 7 Flowchart for turning off the lamp, turning off the fan, turning off both, and sending help messages.

The Meditation value checks sub program is used to turn on the fan based on the reading of the Meditation value, which can be seen in the flowchart of Fig. 6. To turn on the fan, you must increase your mind and mental relaxation to reach a Meditation value of ≥ 74. If the Meditation value has been reached, the fan will turn on. If not, the program is finished. The BlinkStrength value checking subprogram is used to turn off the lamp, turn off the fan, turn off both, and send help messages based on the count of reading the BlinkStrength values, which can be seen in the flowchart of Fig. 7.

To turn off the lamp, turn off the fan, turn off both, and send a help message, the Count value is initialized as a counter and t as the time to count the Count in seconds. Then the user will blink hard to reach the BlinkStrength value ≥ 81. If the BlinkStrength value has been reached, the Count will start counting. If the Count is counted as 2 then the lamp will turn off, if the Count is counted as 3 then the fan will turn off, if the Count is counted as 4 then the lamp and fan will turn off, and if the Count is counted more than 4 times then a help message will be sent. Then to calculate the total Count, you will be given 2 seconds. The goal is given only 2 seconds, namely to minimize accidental blinking but is detected strongly. If the time has reached 2 seconds, the Count and t will be reset back to 0. Then to read back the Attention and Meditation values to turn on the lamp and fan, a delay of 60 seconds is given so that the lamp and fan don't turn on immediately when the Attention and Meditation values reached after the lamp and fan turn off.

III. Result and Discussion

In this part, discuss about the result and discussion from the implementation of system design and algoritm.

A. Hardware Implementation

The hardware that will be implemented in this system consists of components as shown in Fig. 2. Fig. 8 shows the hardware implementation consisting of the NodeMCU ESP8266, Relay, and Power Supply which are located in a small box beside the miniature room. 12V DC fan and 12V lamp located in a miniature room. The NeuroSky Mindwave headset is worn by the user. USB Adapter, laptop, and cable to NodeMCU are connected serially via the laptop's COM port.

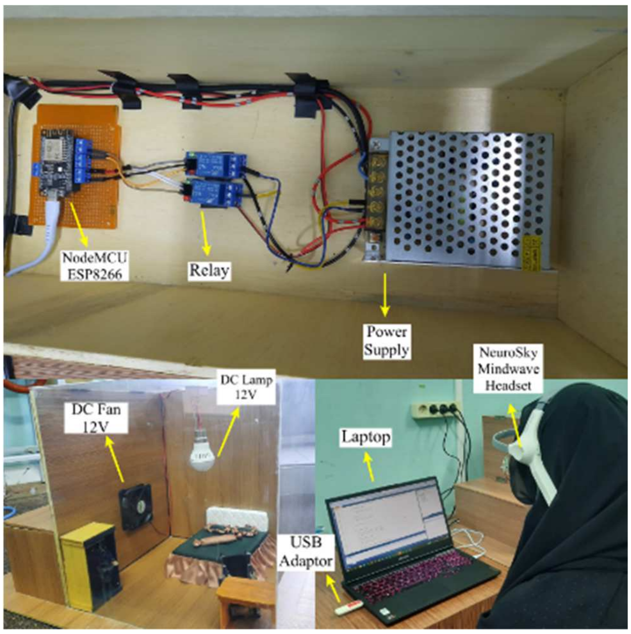

Fig. 8 Hardware Implementation

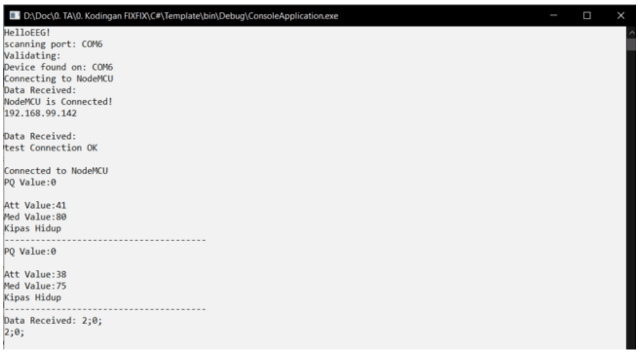

Fig. 9 Console display when a C# program is running

B. Software Implementation

There is two software used in this study, namely the C# program which uses Microsoft Visual Studio software, and the .ino program which uses Arduino IDE software.

The software implementation in the C# program is a program to connect the USB adapter with the NodeMCU ESP8266 serially via the laptop COM port so that the signal data obtained from the Mindwave sensor is sent to the NodeMCU ESP8266 to be processed according to system goals. The COM port used by the Mindwave USB adapter is COM6 and the COM port used by the NodeMCU ESP8266 is COM8. The C# program also determines the value of Attention, Meditation, and BlinkStrength used. This C# program is also used to run the entire system by pressing start on the Microsoft Visual Studio toolbar. When the program is run, a console will appear showing the output of the program that has been made. The following display can be seen in Fig. 9.

Software implementation in the .ino program is a program to activate and deactivate relays to lamp and fan, a program to send help messages via Telegram bot through readings from the Mindwave EEG sensor. As well as making a count program based on reading the BlinkStrength value. This count will start when the BlinkStrength reading value ≥ 81.

If count = 2 then the lamp will turn off, if count = 3 then the fan will turn off, if count = 3 then the lamp and fan will turn off, and if count >= 5 then the help message is written "Patients Need Help !!!" will be sent via Telegram bot.

To calculate the total count, you will be given 2 seconds of time. The goal is given only 2 seconds, namely to minimize accidental blinking but is detected strongly. When it is more than 2 seconds, the count will be reset back to 0. Then after the lamp or fan turns off, a 60 second delay will be given for the program to read the Attention and Meditation values again so that it can turn on the lamp and fan again.

C. System Testing and Analysis

No more than 3 levels of headings should be used. All headings must be in 10pt font. Every word in a heading must be capitalized except for short minor words as listed in Section III-B.

1) NeuroSky Mindwave Headset Testing

Testing of the NeuroSky Mindwave headset is carried out by looking at the output generated through software provided by NeuroSky called App Central. a 1-minute experiment was conducted on 3 respondents to see how the output generated from the Mindwave sensor when the respondent focus, relax, not focus, and not relax.

This test was conducted to see the effectiveness of the user in maintaining a level of focus, relaxation, not focus, and not relax. The following results from the experiment can be seen in Fig. 10 – 13. Fig. 10 shows when respondents were asked to increase their focus, respondents 1 and 3 were able to improve their focus well so that the resulting Attention value was high. Meanwhile, respondent 2 was unable to improve his focus properly so the resulting Attention value was low. The expected Attention value when the respondent focuses is above 80. Based on the graphic results in Fig. 10, it can be concluded that not all respondents can achieve a high Attention value, so it takes an even longer time to achieve it.

Fig. 11 shows when respondents were asked to increase relaxation, the Meditation scores produced by the three respondents were in the middle, neither high nor low. Just as before, the Meditation value of respondent 2 is lower than that of respondents 1 and 3. The expected Meditation value when the respondent is relaxed is above 80. Based on the graphic results in Fig. 11, it can be concluded that not all respondents can achieve high Meditation values, so they need a longer time to achieve it.

When the respondent is asked not to focus, the Attention value produced by the three respondents is in the middle, the expected result when the respondent is not focused is that the Attention value is below 20. Based on the graphic results in Fig. 12, it can be concluded that not all respondents can reduce the Attention value to a low level, so it will take an even longer time to lower it.

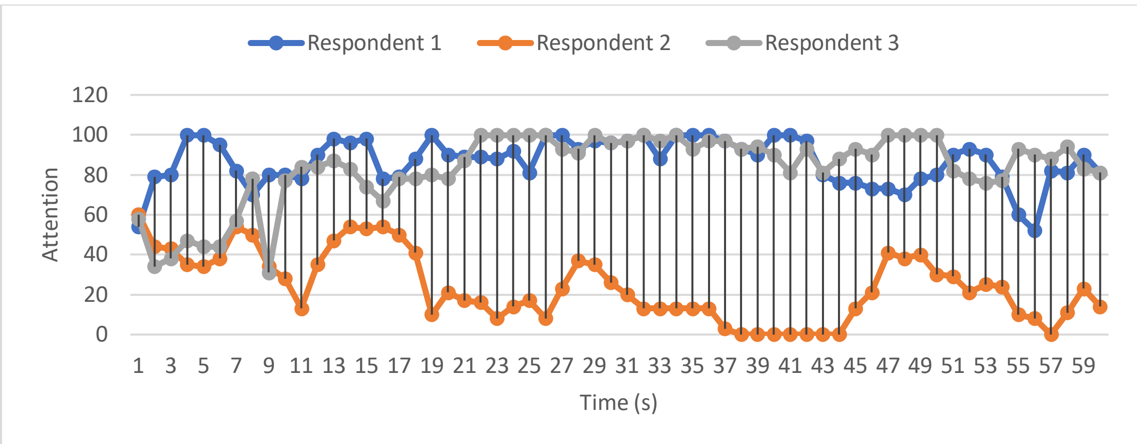

Fig. 10 Graph When Respondents Focus

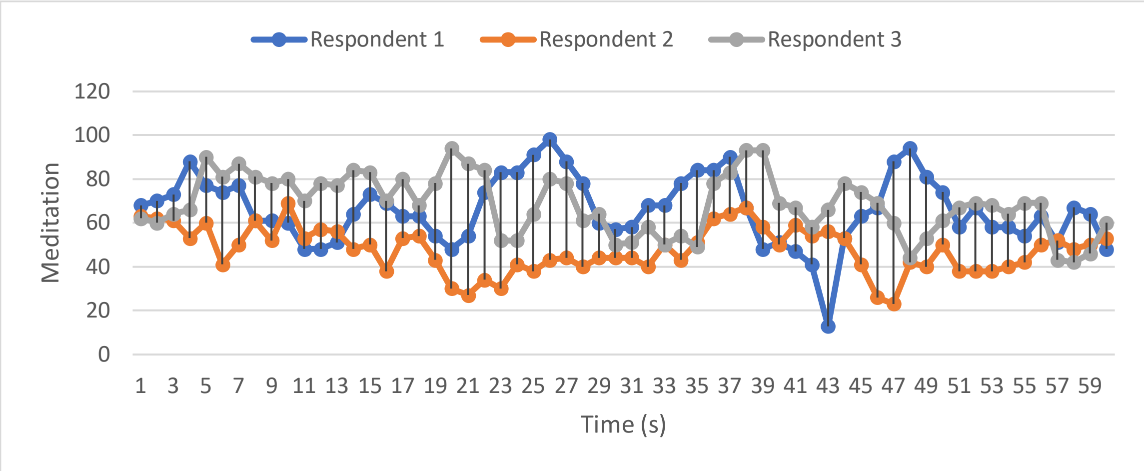

Fig. 11 Graph When Respondents Relax

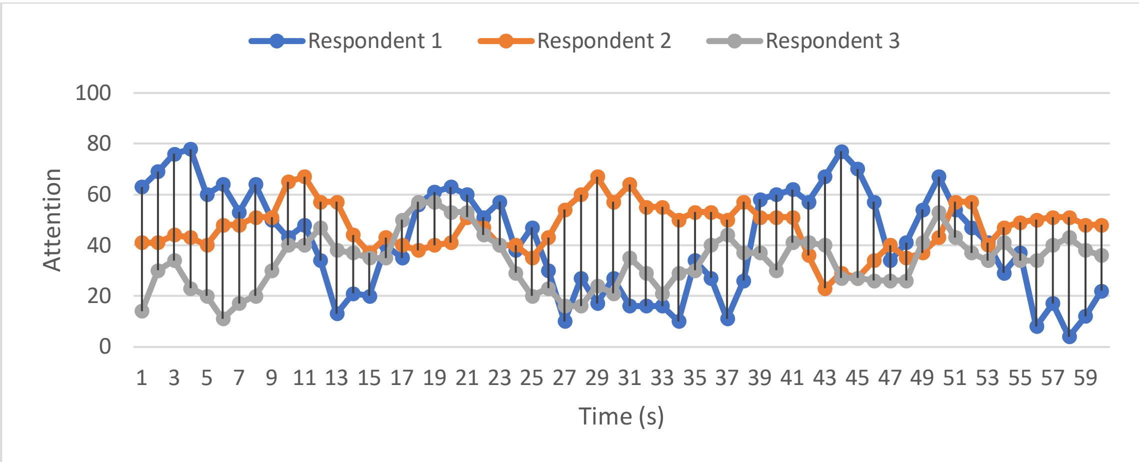

Fig. 12 Graph When Respondents Are Not Focus

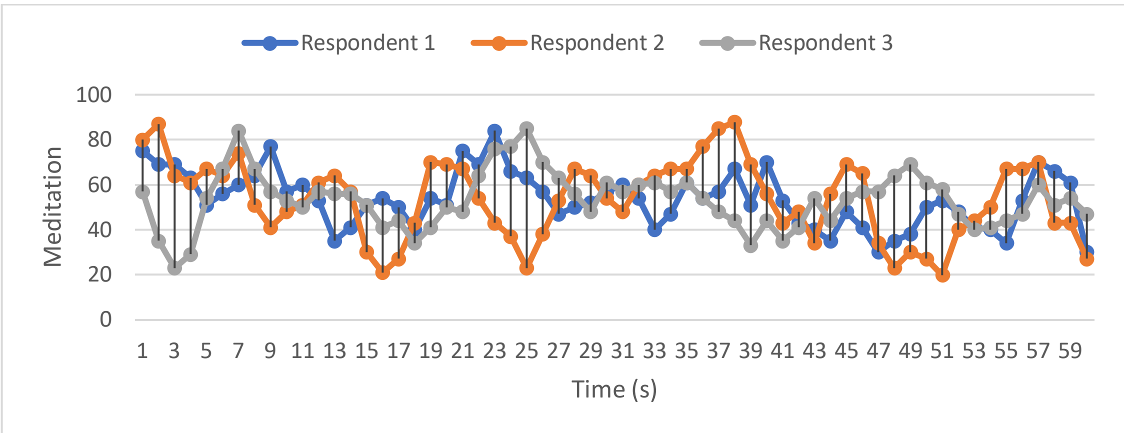

Fig. 13 Graph When Respondents Are Not Relax

Fig. 13 shows when the respondent is asked not to relax, the Meditation value produced by the three respondents is in the middle, the expected result when the respondent is not relaxed is that the Meditation value is below 20. So it can be concluded that all respondents cannot reduce the Meditation value to a low level, so it takes even longer time to lower it.

From the four experimental results above, it can be concluded that not everyone can adjust their level of focus and level of relaxation properly. it takes even longer to achieve the Attention and Meditation values by increasing and decreasing focus and relaxation. So it is necessary to test the minimum value of attention and meditation used in the system.

2) Attention Value Testing

The Attention and Meditation tests were conducted on 30 respondents who were asked to increase their focus and then increase their relaxation. The 30 respondents who were asked to do this test were people who did not experience paralysis (normal). Then the BlinkStrength test is carried out with

TABLE I
COMPARISON OF AVERAGE ATTENTION AND MEDITATION WHEN FOCUSED

Average	Attention	Meditation
Max	93.6	87.8
Min	22.8	19.03
Longest	67.1	54
Range 0 – 25 (s)	5.4	5.8
Range 25 – 50 (s)	20.4	32.2
Range 50 – 75 (s)	45.2	49.6
Range 75 – 100 (s)	34.3	17.9

several different types of blinks to see the difference in the values produced by the sensor.The result of Attention value depends on the user's focus level. the higher the user focus, the higher the value generated will be too. Vice versa. This Attention value has a range from 0 – 100. This test is done within 2 minutes.

From the results of testing the value of Attention to 30 respondents, it can be taken the average value of the Respondent's Attention, the maximum value of Attention achieved by the respondent, the minimum value of the Respondent's Attention, and the Attention value with the longest span of time when tested within 2 minutes. Then there is also an accumulation of time in seconds for the Attention range values, namely from 0 – 25, 25 – 50, 50 – 75, and 75 – 100. Likewise with the Meditation value as a comparison. From these results, a comparison can be made between the values of Attention and Meditation when the respondent increases focus as shown in table I below.

From table I it can be seen that the average value of Attention is higher than the average value of Meditation. However, the difference in value is not that great. This is because Meditation is also related to focus [8]. Then from the results of this test, it is also determined how many Attention values are needed to turn on the lamp. Which is taken from the lowest value of the highest Attention produced when the respondent is focused, which is 70. Therefore the Attention value needed to be able to turn on the lamp is ≥ 70.

3) Meditation Value Testing

The result of Meditation value depends on the user's level of mind and mental relaxation. The higher the user's relaxation, the resulting graph will be higher too. Vice versa. This Meditation value also has a range of values from 0 – 100. This test is also carried out in 2 minutes. Respondents were asked to increase their mental relaxation by positioning their bodies in a comfortable position and holding their breath. Several respondents meditate by listening to natural sounds such as running water, the sound of rain, and so on.

Like the previous Attention value test. From the results of testing the Meditation value on 30 respondents, a comparison can be made between the Meditation and Attention values when the respondent increases focus as shown in table II below.

From table II it can be seen that the average value of Meditation is higher than the average value of Attention. However, the difference in value is also not that far away, as was the case with the previous Attention value test. This is because Meditation has something to do with a focus.

TABLE II
COMPARISON OF AVERAGE MEDITATION AND ATTENTION WHEN RELAXED

Average	Meditation	Attention
Max	92	88
Min	28.5	17.2
Longest	62.9	49.5
Range 0 – 25 (s)	4.3	12.5
Range 25 – 50 (s)	26.2	36.3
Range 50 – 75 (s)	53.7	46.2
Range 75 – 100 (s)	29.8	19.1

TABLE III
BLINKSTRENGTH VALUE TEST RESULTS

Respondents	Unconscious Wink	Aware Wink	Strong Wink
1	61	100	170
	82	70	152
	65	94	209
	42	114	103
	52	58	213
	57	103	185
	61	79	121
	77	104	65
	46	90	221
	105	88	92
	82	81	111
	74	104	127
	59	97	93
	37	112	157
	73	73	69
2	31	143	127
	42	188	91
	74	80	74
	24	74	100
	38	86	76
	49	85	80
	50	83	148
	35	90	63
	36	88	87
	48	79	88
	88	70	89
	75	72	58
	33	86	77
	47	108	102
	41	106	122
3	97	162	204
	80	166	170
	86	159	201
	92	155	188
	55	163	192
	80	148	189
	74	139	188
	32	135	190
	35	133	176
	40	155	185
	105	158	184
	46	137	160
	52	142	158
	47	144	161
	48	146	160
Avg	**59**	**112**	**137**
Min	**24**	**58**	**58**
Max	**105**	**188**	**221**
Standard Deviation	**21.4**	**33.9**	**49.6**

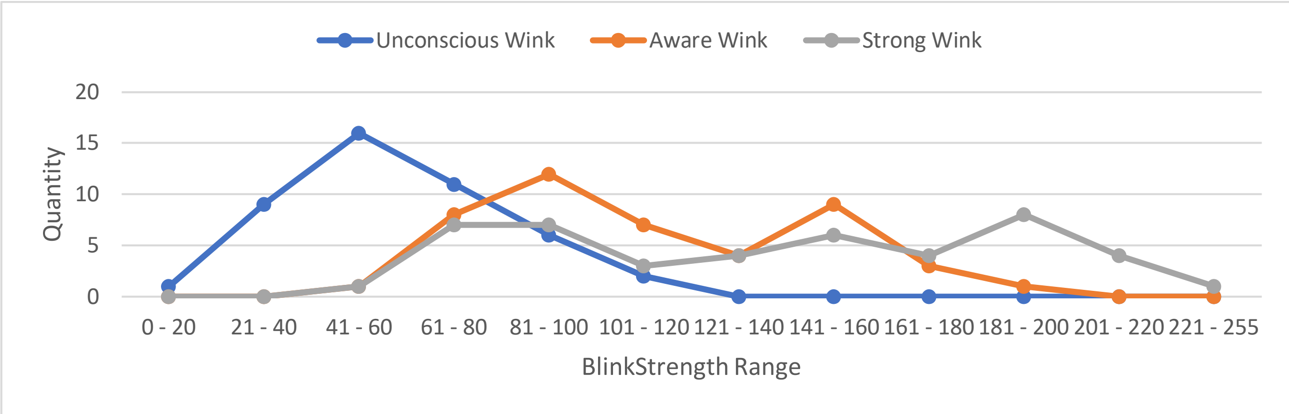

Fig. 14 Graph Blinkstrength value in per-condition range

From the results of this test, it is also determined how many Meditation values are needed to turn on the fan. The same as the previous Attention value test, taken from the lowest value of the highest Meditation produced when the respondent is relaxed, which is 74. Therefore the Meditation value needed to be able to turn on the fan is ≥ 74.

4) BlinkStrength Value Testing

Testing the BlinkStrength value was carried out on 3 respondents by comparing the results of the strength of eye blinks when blinking is involuntary or unconscious, then blinking intentionally or consciously, and blinking forcefully when the eyes are rounded or looking up.

The 3 respondents who were asked to do this test were also people who did not experience paralysis (normal). BlinkStrength values range from 0 – 255. The stronger the blink, the higher the resulting BlinkStength value. 15 eye blink samples were taken per condition. The test results can be seen in table III below.

From the test results in table III, it can be seen the average value, maximum value, and minimum value of BlinkStrength for each condition. At the time of unconscious blinking the value is lower than conscious blinking.

TABLE IV
BLINKSTRENGTH VALUE IN PER-CONDITION RANGE

Range	Unconscious Wink	Aware Wink	Standard Deviation
0 - 20	1	0	0
21 - 40	9	0	0
41 - 60	16	1	1
61 - 80	11	8	7
81 - 100	6	12	7
101 - 120	2	7	3
121 - 140	0	4	4
141 - 160	0	9	6
161 - 180	0	3	4
181 - 200	0	1	8
201 - 220	0	0	4
221 - 255	0	0	1

Then the value of strong blinking is higher than conscious blinking, but the value is not much different. Of the three respondents, some respondents blinked consciously and the strength was not too high. It can be seen from the minimum value generated when blinking is conscious and strong, namely 58.

TABLE V
SYSTEM TEST RESULTS TURN ON THE LAMP

Respondents	Attention Value	Time needed (seconds)	Lamp State	Result
1	75	12	On	Suitable
2	75	4	On	Suitable
3	77	9	On	Suitable
4	88	9	On	Suitable
5	77	0	On	Suitable
Avg	**78**	**6.8**		
Max	**88**	**12**		
Min	**75**	**0**		
Standard Deviation	**5.46**	**4.76**		

TABLE VI
SYSTEM TEST RESULTS TURN ON THE FAN

Respondents	Meditation Value	Time needed (seconds)	Fan State	Result
1	78	11	On	Suitable
2	75	36	On	Suitable
3	78	2	On	Suitable
4	74	45	On	Suitable
5	81	0	On	Suitable
Avg	**77**	**18.8**		
Max	**81**	**45**		
Min	**74**	**0**		
Standard Deviation	**2.77**	**20.49**		

Therefore, BlinkStrength values are made in a range like a table IV and the graph in Fig 14. From these data, the highest value range is obtained from conscious blinking, namely 81 – 100. Considering that not everyone can blink hard, the lowest BlinkStrength value is taken from that range, so the BlinkStrength value used for the count program is ≥ 81.

5) Overall System Testing

Overall system testing is carried out to test whether the system can run the system according to what has been designed. This test was carried out on 5 respondents to run the system as a whole. Starting from increasing the Attention value to ≥ 70 to turn on the lamp, increasing the Meditation value to ≥ 74 to turn on the fan, and the BlinkStrength value ≥ 81 to read the number of eyes blinks, where blink 2 times to turn off the lamp, 3 times to turn off the fan, 4 times to turn off both, and 5 times to send help messages through the Telegram bot. The 5 respondents who were asked to do this test were also people who did not experience paralysis (normal). From this test, it is also seen how long it takes to reach these values. The results of testing the system to turn on the lamp can be see in table V.

TABLE VII
SYSTEM TEST RESULTS TURN OFF THE LAMP

Respondents	BlinkStrength Value (On Success)		Result	Lamp State	Number of Failed
1	119	142	Suitable	Off	2
2	120	128	Suitable	Off	0
3	89	98	Suitable	Off	0
4	104	124	Suitable	Off	1
5	94	86	Suitable	Off	1
Avg	**110.4**		**Average % failed = 0.8%**		
Max	**142**				
Min	**86**				
Standard Deviation	**18.79**				

TABLE VIII
SYSTEM TEST RESULTS TURN OFF THE FAN

Respondents	BlinkStrength Value (On Success)			Result	Fan State	Number of Failed
1	99	120	100	Suitable	Off	1
2	126	122	121	Suitable	Off	0
3	113	98	87	Suitable	Off	2
4	199	125	161	Suitable	Off	2
5	115	103	104	Suitable	Off	3
Avg	**119**			**Average % failed = 1.6%**		
Max	**199**					
Min	**87**					
Standard Deviation	**28.1**					

of testing the system to turn on the lamp can be seen in table VI.

From the results of table VI, the average Meditation value of 5 respondents to turn on the fan is 77 and the average time needed to reach this value is 18.8 seconds. Where the state of the fan is on and the results are in accordance with those made by the system. So, the percentage of success of the system turning on the fan is 100%. Furthermore, the results of testing the system to turn off the lamp can be seen in table VII.

From the results of table VII, the average BlinkStrength value of 5 respondents to turn off the lamp is 110. In this test, the number of failures from 2 blinks is also calculated. This is because there are some respondents who still cannot distinguish between strong and weak blinking.

From the 5 respondents, the total failure was 4 times. The average percentage of failure is obtained from the following formula:

$$Average\ \%\ Failed = \frac{total\ fail}{total\ respondents} \quad (1)$$

So that the success rate of the system turning off the lamp by using a strong eye blink 2 times based on testing from 5 respondents is 99.2%. Furthermore, the results of testing the system to turn off the fan can be seen in table VIII.

From the results of table VIII, the average BlinkStrength value of 5 respondents to turn off the fan was 119. From 5 respondents, the total failure was 8 times. So that the success rate of the system turning off the fan using a strong eye blink 3 times based on testing from 5 respondents is 98.4%. Furthermore, the results of testing the system to turn off the lamp and fan can be seen in table IX.

From the results of table IX, the average BlinkStrength value of 5 respondents to turn off the lamp and fan was 123. From 5 respondents, the total failure was 9 times. So that the success rate of the system turning off the lamp and fans by using a strong eye blink 4 times based on testing from 5 respondents is 98.2%. Furthermore, the results of testing the

TABLE IX
SYSTEM TEST RESULTS TURN OFF THE LAMP AND FAN

Respondents	BlinkStrength Value (On Success)				Result	Lamp & Fan State	Number of Failed
1	102	108	109	99	Suitable	Off	0
2	121	111	107	149	Suitable	Off	0
3	185	182	160	159	Suitable	Off	2
4	81	105	117	94	Suitable	Off	3
5	132	125	111	112	Suitable	Off	4
Avg	**123**				**Average % failed = 1.8%**		
Max	**185**						
Min	**81**						
Standard Deviation	**28.85**						

TABLE X
SYSTEM TEST RESULTS SENDING HELP MESSAGE

Respondents	BlinkStrength Value (On Success)					Result	Help Message	Number of Failed
1	121	115	110	121	118	Suitable	Sent	0
2	120	125	117	109	114	Suitable	Sent	0
3	155	165	148	149	134	Suitable	Sent	3
4	146	147	133	136	136	Suitable	Sent	3
5	160	184	149	105	181	Suitable	Sent	4
Avg	**136**					**Average % failed = 2%**		
Max	**184**							
Min	**105**							

From the results of table V, the average Attention value of 5 respondents to turn on the lamp is 78 and the average time needed to reach this value is 6.8 seconds. Where the state of the lamp is on and the results are in accordance with those made by the system. So, the percentage of success of the system turning on the lamp is 100%. Furthermore, the results system for sending help messages via Telegram bot can be seen in table X.

From the results of table X, the average BlinkStrength value of 5 respondents for sending help messages was 136. From 5 respondents, the total failure was 10 times. So that the success rate of the help message delivery system using a strong eye wink 5 times based on testing from 5 respondents is 98%. From the 6 overall system tests it can be concluded that the system can work properly and in accordance with the research objectives.

IV. Conclusions

Based on the results of the implementation, testing and analysis of the smart room system for paralyzed patients with Mindwave EEG sensor control, it can be concluded that: The system successfully turns on the lamp based on reading the value of Attention ≥ 70. The system successfully turns on the fan based on reading the Meditation value ≥ 74. The system successfully turns off the lamp, turn off the fan, turn off both, and send help messages based on the reading of the BlinkStrength value ≥ 81. The system successfully turns off the lamp based on the number of eye blinks 2 times, turns off the fan based on the number of eye blinks 3 times, turns off both based on the number of eye blinks 4 times, and sends help messages based on the number of eye blinks more than 4 times. For further research, it can be developed based on variations and combinations of input from EEG sensors in the form of attention values, meditation values, and eye blink strength to control many devices. then with the addition of Artificial Intelligence methods, the system can provide decisions so that paralysis sufferers can be more independent.

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