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Exploring the Relationship between Eye Blinks and Brainwave and Its Applicationszimeng

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ABSTRACT. *This research reviewed the principles and history of the brain-machine interface and focused on experiments using Neurosky headsets to discover and create real-world applications using this technology. The experiments tested different criteria of blinking, including intensity, duration, number, and left or right eye, and concluded that different kinds of blinks have distinct impact on brainwaves. Later, utilizing the results derived from the experiments, a computer application is developed in Matlab that detects the number and patterns in user's blinks to convey binary informations. Based on researches, experiments, and the application, this work demonstrated the tremendous potential that brain-machine interfaces have in people's daily life, especially in the field of information transfer.*

KEYWORDS: *brain wave, BMI, eye blink, Matlab*

1. Introduction

Brain-machine interface (BMI) is a system that enables humans to send neuronal information from one's brain to external devices, including machines and computers[1]. With its rapid development, currently, BMI has a lot of real-life applications. One of the great demonstrations of its potential is the vital role BMI has in the modern medical field. For instance, deaf patients can hear again with the implantation of cochlear, retinals can be implanted into blind patients to recover their sight, and even Parkinson can be treated using brain stimulation based on the brain-machine interface[2].

The first successful implementation of BMI technology happened in 2006 at the Dalian University of Technology, where professor Tin Li uses the BMI system to gain clear brain waves from his patients[5]. After that, the development of BMI technology grew exponentially. In 2016, Professor Chuan Huan's research at Central China Normal University confirmed that BMI technologies have useful applications in the field of education. Using BMI headsets, Chuan Huan successfully detected the level of concentration of the students in the class. Based on these results, Chuan Huan and his team were able to provide information that improves the productivity of the class. Furthermore, research conducted in 2008 by Professor Yanhong Ying shows that BMI can even help decrease the frequency of car accidents by preventing fatigue driving.[4] Although these advantages demonstrate the promising potential of BMI, its implantation still has drawbacks. For example, researches found that the stimulation BMI devices have on humans can increase the risk of suicide and Parkinson's disease.[3] Even though the number of researches on BMI has been growing extremely fast, there aren't many research results that focus on how to utilize BMI and blinking to convey information. Therefore, this research focused on this specific topic to improve information transfer.

There are three kind of BMIs: invasive, partially-invasive and non-invasive. Invasive BMIs are directly implanted into the brain, which poses high risk on the subject. Partially-invasive BMIs are implanted inside the skull or the spine but outside the Central Nervous System. Non-invasive BMIs are devices such as headsets that don't lead to any harm on the subject, and EEG is its most common form. (Andreas et al.2010).

The equipment that is used in this research is an EEG(Electroencephalograph) headset from Neurosky that attaches to the scalp of the subject. Currently, it is the easiest and least invasive way to gather electrical signals and brainwaves from the subject. Using this headset and the brainwaves it collects, an application that produces numbers from blinking is developed.

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2. Experiment

2.1 Recognition of the Experiment

The brain is made up of tens of thousands of needle-sized nerves. Each time the nerve becomes active, it emits weak electrical signals. When in a specific mental state, the nerves will also emit a specific brainwave. Mind Wave Mobile from Neurosky is a headset that captures these brain waves by physically touching the test subject's forehead with an antenna. It detects the electrical signals and passes the brain wave information collected to the computer constantly for real-time detection. The detected brain waves can then be digitized into voltages; therefore, when a person blink, researchers can constantly see the corresponding voltage values. Mind wave mobile headphones can also read the electrical activity of the human brain and divide the frequency band into different types of brain waves, representing different brain states. However, in addition to electrical activity from the brain, the human body produces many other electrical noises. Therefore, the Mind wave mobile headset is provided with a reference electrode placed on the ear clip that contacts the earlobe, which filters out the electric signals that are not from the brain. Besides, to minimize error and variation, a relatively quiet, low-radiation (low lighting) environment for all experiments is established, and five different subjects are selected.

2.2 Experiment 1: Four Basic Experiments

2.2.1 The Aim of the Experiments

The experiments primarily focused on the impact that different characteristics of the blinks have on the brainwaves. Ultimately, this research aims to use these experimental results to learn not only how to separate the blinks from the noises but also distinguishing the different types of blinks. Moreover, the information gained from learning the various impacts that different types of blinks have on the brain wave will help the research tremendously in building a more efficient way of communication with blinks by providing more options and possibilities.

2.2.2 The Procedure of Experiments

(1) Number Experiment

The experiment begins by putting the EEG headset on the test subject. The subject then is instructed to blink both eyes together for four times during the experiment. After the data is recorded, the experimenter compares the number of peaks in the brain wave displayed on the computer to the number of blinks instructed. If the number of peaks displayed is four, then the experiment demonstrates that there is a direct relationship between the number of blinks and the number of peaks in the brain wave collected.

(2) Strength Experiment

The experiment begins by putting the EEG headset on the test subject. The subject then is instructed to blink with different forces. In the beginning, the subject is instructed to blink relatively lightly, and then the subject is instructed to increase the force of the blink gradually. After the data is recorded, the brainwave is examined to see if there is a trend in the brainwave. If the peaks become increasingly higher or lower with each blink, the experiment will prove that there is an association between the strength of the blinks and the brainwave.

(3) Duration Experiment

The experiment begins by putting the EEG headset on the test subject. The subject is first instructed to do a quick blink, then increase the duration of the blink each time. For example, the first blink will be quick, then the second blink will have a one-second interval between closing and opening of the eye. The brainwave is examined after the data is collected. If there is a clear difference between the long interval blinks and short interval blinks, the experiment will successfully prove that there is an association between the duration of the blink and the brainwave.

(4) Right and Left Eye Experiment

The experiment begins by putting the EEG headset on the test subject. The subject is instructed to blink with only the right eye first, then blink with only the left eye. The process is repeated, and the data will be collected. After the data collection, the brainwave is examined. If there is a difference between the peaks with left eye

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blinking and peaks with right eye blinking, the experiment will prove that there is an association between left or right eye blinking and the brainwave image.

2.3 Experiment 2: Yes or No Experiment

2.3.1 Aim of Experiment

The primary goal of this experiment is to use Matlab to program an application that analyzes brainwave data collected and return data such as yes or no from it. In this experiment, although the logic and codes of the program is relatively basic, those codes can help researchers to design codes in future programs. Moreover, the solutions used to overcome the difficulties in this experiment can give researchers experiences to solve the possible problems in future experiments.

2.3.2 Process of the Experiment

The test subject is instructed to first put on the headset properly. After that, the test subject will blink several times. When the data collection completes, the program will run and analyze the brain wave image collected by finding the number of peaks. Then, the program will determine if the number is odd or not. If the answer is yes, the output of the program will be no, and if the answer is no, the output of the program will be yes.

2.3.3 The Logic of the Program

The program follows the flow chart shown in fig1. Matlab will collect the data and compile the data into a brainwave first. After that, the program will begin to analyze the brainwave data collected. It starts by finding the difference between the adjacent peaks. The reason for this approach is because although the height of the peak usually varies for different test subjects, the difference between a peak that corresponds with a blink and a disturbance will always be significant. Therefore, if the difference between two adjacent peaks is larger than a threshold, the program can guarantee that the larger value among these two adjacent peaks is a blink. This will effectively increase the accuracy of the program by filtering out the noises in the brainwave. After the peaks that correspond with blinks are identified, the program will calculate the total number of peaks. Then, it will determine whether or not the total number is odd. If the total number is odd, the program will return an image shown in fig8, which represents that the test subject wants to say no; otherwise, the program will return an image shown in fig9, which represents that the test subject wants to say yes.

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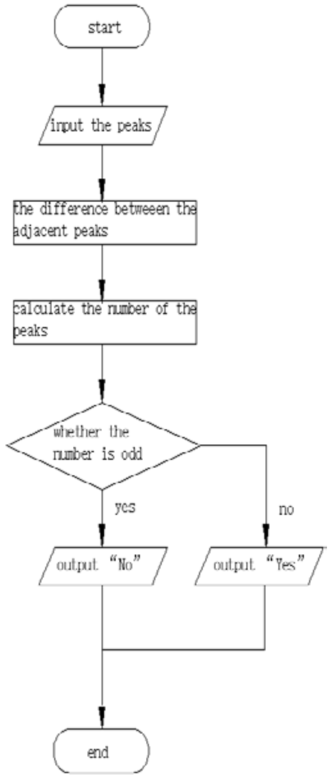

Fig.1 Program Flow Chart

2.4 Experiment 3: Binary Experiment

2.4.1 Purpose of the Experiment

The goal of this experiment is to produce a final program that will distinguish between strong blinks and weak blinks. The program will represent a weak blink with a zero, strong blink with a one, and form binary information from the test subject's blinks. In the end, the program will convert the binary information produced into numbers, and display the numbers into a GUI. The research aim to use this experiment to demonstrate a method that can simplify the information transfer process. Although the idea behind the program is still immature, this program will be a great demonstration of the potential of BMI and a great demonstration of the research concept.

2.4.2 Process of Experiment.

There are lots of trials and errors during the experiment. In the beginning, methods to output binary information by distinguishing between a left eye blink and right eye blink is attempted. This concept is tested by instructing the test subject to wear the EEG device and recording the voltage peak of each left eye blink and right eye blink. After conducting multiple trials, some testers had higher peak voltages in the left eye than the right eye, and some testers have the opposite brain wave characteristics. Miu Aizhu's paper pointed out that 53%~85% of people's dominant eye is the right eye, 12%~40% of people's dominant eye is the left eye, and 0~22% of people have no dominant eye.[6] Because of this huge variation in people's brainwaves, the program cannot use the left or right eye approach to output binary information. Next, an approach to represent 0 and 1 with weak blinks and strong blinks is utilized. This approach is experimented by instructing the test subject to wear the EEG device and test the difference between soft blinks and heavy blinks. During the experiment, the research group recorded the peak voltage of each blink by observing the brainwave displayed each time. After a few trials, a relatively constant threshold that satisfies most situations is found. The algorithm that follows this logic was initially going to output 1 for all voltages that goes below the threshold, and output 0 for all blinks that have voltages larger than the threshold. However, when the experiments are repeated with five different test subjects, the differences between voltage peaks of heavy and weak blinks between personnel due to age and gender is discov-

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ered. Because of this, it is not possible to distinguish between weak and heavy blinks using a threshold. In order to solve this problem and increase the accuracy, an algorithm that uses the maximum value of the maximum peak as the threshold to distinguish between 0 and 1 is developed. After multiple experiments, this strategy still produced several errors since weak and strong blinks' voltage peak is not always stable. To solve this problem, an algorithm is developed which arranged all voltage peaks from small to large, and found the group with the largest difference between the two adjacent voltage peaks, and took the average value from them as the threshold for separating weak blinks and strong blinks. After lots of experiments, this algorithm efficiently solves the problem of low accuracy, and proved to be the best one. This is because although people might have various voltage peaks for weak and heavy blinks, there will always be a significant difference between a weak blink and a strong blink. When the program sorts the voltage peaks from small to large, there will always be a huge gap between the peaks that correspond with the largest weak blink and the smallest strong blink; therefore, by finding the average value between these two values, the algorithm can guarantee a threshold that will separate strong blinks and weak blinks. For the final trial, the test subject was instructed to wear the headset and blink softly in order to return 0 and blink heavily in order to return 1. The researchers had no idea what the test subject intended to output. After the data was recorded and processed by the algorithm, a three-digit phone number was returned. In the end, the test subject was asked about the number he had in mind, and it turned out to match the returned value perfectly.

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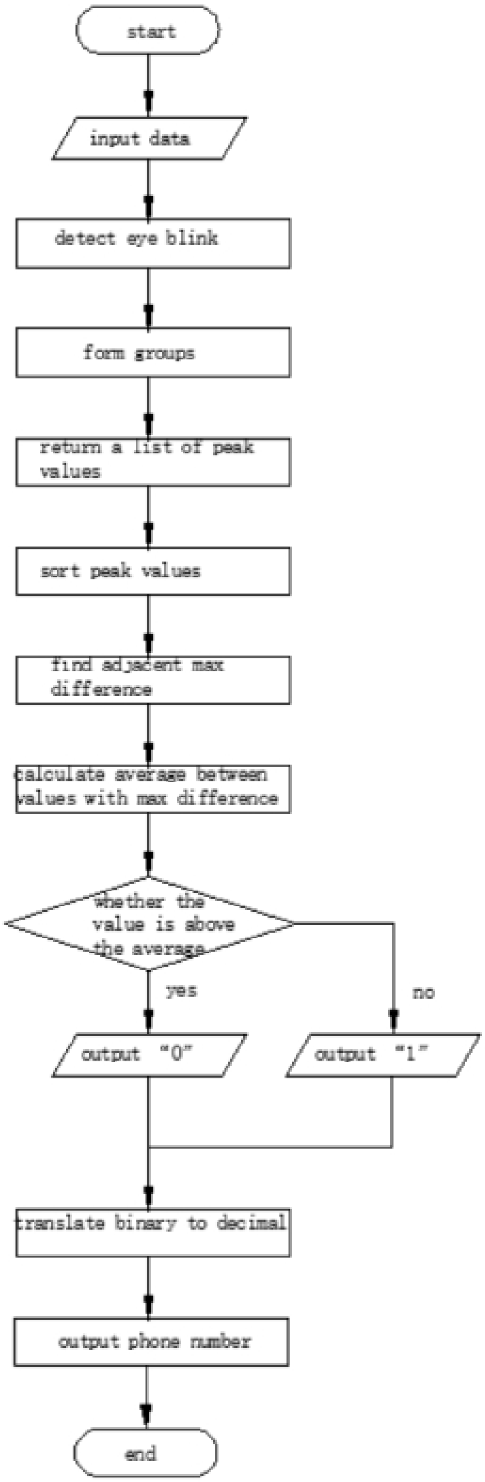

Fig.2 the Progress of Binary Programming.

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3. Results and Discussion

3.1 Four Basic Experiments

3.1.1 Result of Experiments

(1) Number Experiment

With the use of Matlab, data shown in figure3 is collected.

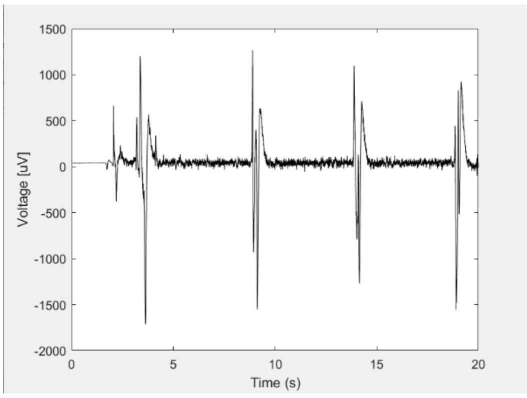

Fig.3 The Relationship between the Number of Blink and Voltage

(2) Strength Experiment

With the use of Matlab, data shown in figure4 is collected.

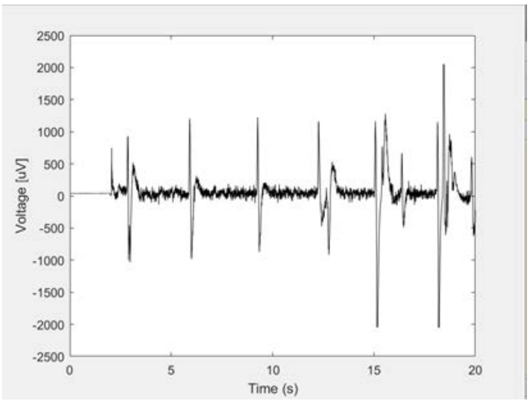

Fig.4 The Relationship between the Strength of Blink and Voltage

(3) Duration Experiment

With the use of Matlab, data shown in figure5 is collected.

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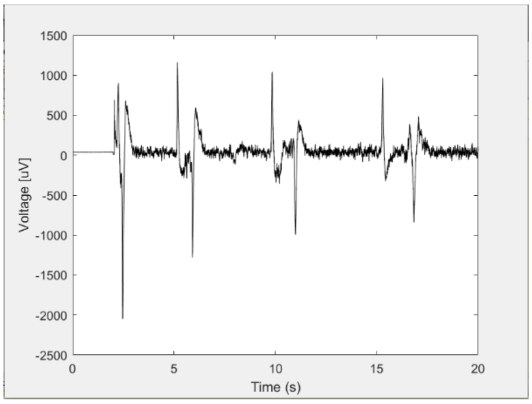

Fig.5 The Relationship between the Duration of Blink and Voltage

(4) Right and Left Eye Experiment

With the use of Matlab, data shown in figure6 is collected.

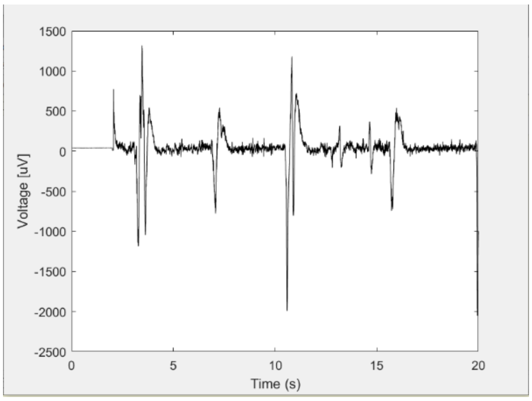

Fig.6 The Difference between the Right Eye and Left Eye

3.1.2 Analysis of Experiments

(1) Number Experiment

With the data collected in figure1, four peaks in the brainwave image is discovered. The number of blinks instructed is the same as the number of peaks recorded in the brainwave image. Thus, the number of times a subject blinks has a one to one relationship with the voltage peaks recorded.

(2) Strength Experiment

By looking at the data collected in figure two, an obvious increasing trend in the peaks is observed. This directly corresponds with the increasing force of the blinks of the test subject; therefore, the experiment successfully proves that there is a direct relationship between the force of the blink and the magnitude of the voltage peaks - increasing the force of the blink will lead to a higher voltage peak.

(3) Duration Experiment

By looking at figure3, an increasing gap between the positive and negative peak for each blink is recognized. This corresponds to the test subject's behavior. Because of this correlation, the experiment successfully proved that with increasing time interval between the closing and opening of the eye, there will be a longer gap between the positive and negative peak of each blink.

(4) Right or Left Experiment

By looking at figure4, the difference in voltage between a left eye only and a right eye only blink is discovered. Right eye only blinks lead to higher voltage peaks. This phenomenon can be explained because the right

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and left eye are controlled by different areas of the brain. The nerve cells that are responsible for controlling the left and right eye are different; thus, the voltages are different.

2.1.3 Problems in the Experiments

While performing the experiments, it is vital to pay attention to the noises in the environment, such as surrounding light, human noises, talking, and disturbance from electronic devices. If the experiments are not executed with the elimination of the disturbances stated above, the final result of the experiment will include a lot of noises. (fig7)

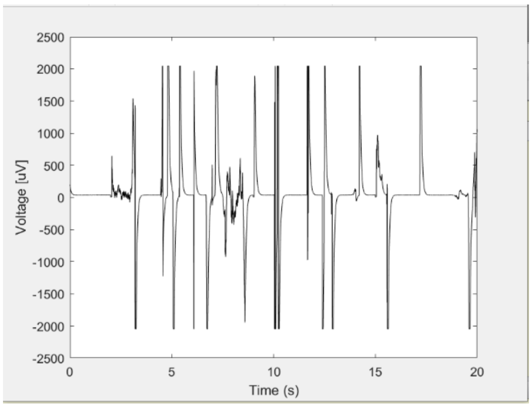

Fig.7 The Signal Was Disturbed by the Environmental Noise

The EGG detective device should be put in the right place. The antenna of the device must be attached to the forehead of the test subject tightly. Otherwise, the result of the experiment might be hard to analyze. (fig8)

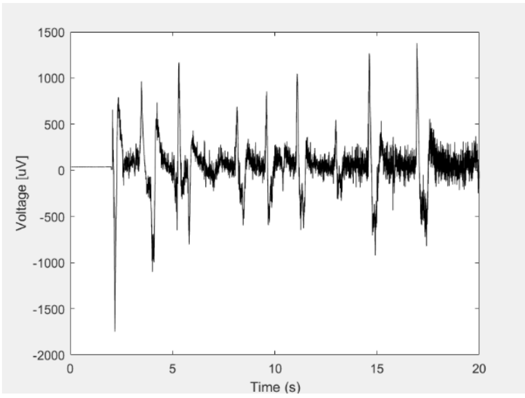

Fig.8 The Headset Was Not Put in the Right Place

3.2 Yes or No Experiment

3.2.1 Results of the Experiment

When the number of blinks is odd, the result is shown by fig9.

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Fig.9 The Times of Blinking is Odd.

When the number of blinks is even, the result is shown by fig10.

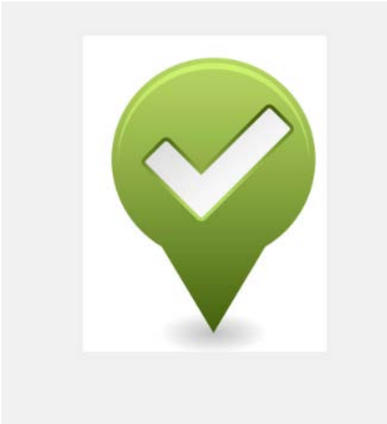

Fig.9 The Times of Blinking is Even.

3.2.2 Analysis of the Experiment.

Because the program returns the correct image repeatedly with repeated testing, the experiment proves that the program is reliable. Not only is this experiment a starting place for future experiments, the code from the experiment can also be utilized effectively in the final experiment.

3.2.3 Problems in the Experiment

During the experiment, there are lots of noises in the data collected. These noises led to some incorrect voltage peaks and created huge discrepancies between the data recorded by Matlab and the data collected artificially. In order to filter out the noises, filtering codes are added to improve the accuracy and precision of the data collection process.

3.3 Binary Experiment

3.3.1 Result of Experiment.

The data is shown by fig10. When the test subject blinks his eyes 12 times, the fifth, the tenth and the eleventh blinks are registered as heavy, which means it outputs 1. The rest outputs 0.

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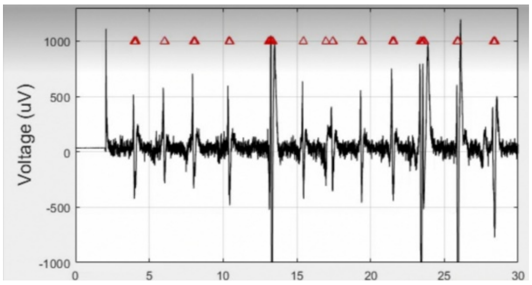

Fig.10 the Times of Blinking is 12.

3.3.2 The Making of the Gui

The original interface used in during the experiments was not very user-friendly. In order to solve this issue, a GUI is produced. GUI is the human-computer interaction graphical user interface design. With the GUI, people can easily operate through windows, menus, buttons, and more. The GUI is visually more acceptable to the user than the command interface used for early calculations and testing. With the GUI added in Matlab, the result of the program became more visible to the user. A picture fo the created GUI is shown by fig11.

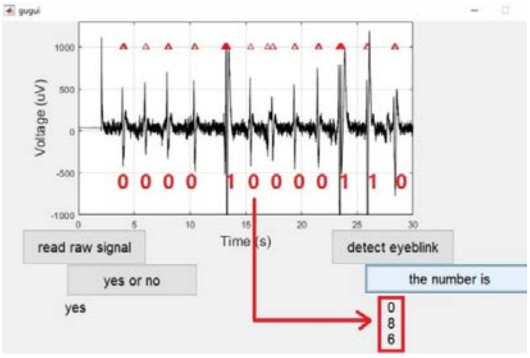

Fig.11 the Gui of the Program

3.3.3 Analysis of Experiment.

By repeatedly testing the program and getting the correct output, the experiment shows that the codes are reliable and repeatable. This program effectively demonstrated the research concept, and proved the potential of BMI.

3.4 Application

Although the research has accomplished lots of interesting applications like yes or no, or even information like phone numbers, there are much more useful ideas that can be fulfilled using BMI. Scientists are already using its tremendous potential to improve the lives of people around the world. To start off with, the heavy uses of BMI in hospitals are currently making a paradigm-shifting effect in the medical field. By learning about how brains transfer information internally and how to use these signals to communicate with commercialized electronics, scientists are making the life of disabled people a lot easier. One of the most distinguished applications was recently discovered in the Brain-Computer Interface Laboratory of Eric Sellers, where he successfully uses brainwaves and BMI to help a disabled patient communicates. The patient, Jean-Dominique Bauby, is a person who suffered from locked-in syndrome for years. Bauby has a clear conscience, but he can't move his body; the only physical interaction that his body is capable of is eye-blink. After almost a year of dedication and hard work, the lab successfully built a personalized communication system based on BMI that helps Bauby communicates efficiently. The way this system works is by using a non-invasive EEG headset and a screen with letters on it. Every time Bauby focuses on a specific letter on the screen, the computer will detect the special brainwave that is produced by this activity, convert it into the letter Bauby was thinking of, and then put it on the screen. Eric Sellers described this system as a "brain keyboard," where the user "types" on the keyboard using

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his brainwaves instead of his hands. This technology is far from being fully mature since it still has some major flaws like long process time and unstable rate of success; however, lots of patients like Bauby are already getting significant life improvements from it. For example, Bauby uses this technology daily to communicate his needs, his feelings, and thoughts. “In terms of scientific discovery BCI research is still in its infancy,” Sellers states, “but we expect to see many advances to profoundly help disabled people in the future.” This research proves that there are still tons of potentials in BMI that are left for future scientists to discover, and these new discoveries and inventions will constantly make significant changes in the electronics field, making the future life of human beings around the world dramatically better.

Simply envisioning a world with fully developed BMI will show you the dramatic impact it can make in human society. Imagine, when you wake up, you can turn on all the electronics you need to help you get ready without moving a finger. Imagine how you can get all the information, like news, messages, or weather, without even picking up your phone. Imagine wireless communication with your friend or colleague by simply thinking about the words you want to say. Imagine a world where disabled people can talk with their brain, move things with their artificial hands, and walk with their artificial legs. The future holds great for the field of BMI and bio-inspired engineering.

4. Conclusion

To conclude, this research have accomplished three things. Firstly, by using the EEG headset and Matlab, the relationships between different kinds of blinks and brainwaves are discovered. Secondly, by carefully planning the codes, a prototype program that detects eye-blinks and outputs information like yes or no is created. Thirdly, utilizing the difference between weak blinks and hard blinks, an app that translates brainwaves into binary messages is built. The work itself shown the tremendous potential of BMI technology in the field of information transfer.

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