



## คลื่นสมองของการพูดโกหกของมนุษย์ โดยใช้วิธีการวัดเพื่อบันทึกกิจกรรมไฟฟ้าในสมองบริเวณรอบๆ หนังศีรษะ ด้วยเครื่องมือนำหนักเบา

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### บทคัดย่อ

การทำงานของสมองในการทำกิจกรรมต่างๆ นั้น ก่อให้เกิดกระบวนการรับส่งสารเคมีผ่านนิเวรอนซึ่งจะก่อให้เกิดคลื่นไฟฟ้าขนาดเล็ก โดยในปัจจุบันได้มีการสร้างอุปกรณ์สำหรับทำการบันทึกข้อมูลคลื่นไฟฟ้าที่เกิดจากสารเคมีในสมองได้หลากหลาย วิธีการที่ง่ายที่สุดคือการใช้วิธีการวัดเพื่อบันทึกกิจกรรมไฟฟ้าในสมองบริเวณรอบๆ หนังศีรษะ (EEG) โดยมีการนำเครื่องมือวัดที่ติดตั้งแผ่นรับสัญญาณอิเล็กทรอนิกส์ไว้บริเวณจุดสำคัญบนหนังศีรษะ ในงานวิจัยนี้ใช้อุปกรณ์ชื่อ NeuroSky Mind-Wave บันทึกกิจกรรมไฟฟ้าในสมองบริเวณรอบๆ หนังศีรษะ (EEG) โดยทำการทดลองตอบคำถามจากการมองเห็นแบบถูกต้องและไม่ถูกต้องจากผู้เข้าร่วมการทดลองจำนวน 5 คน โดยนำภาพสัตว์จำนวน 8 ชนิด มาใช้ในรอบแรกให้ตอบชนิดของสัตว์ให้ถูกต้อง และในรอบที่ 2 ให้ตอบคำถามไม่ถูกต้อง โดยมีการกำหนดระยะเวลาในการเก็บข้อมูล 80 วินาทีในแต่ละรอบ โดยแบ่งให้มีการทำสมาธิ ในวินาทีที่ 1 ถึง 20 และวินาทีที่ 61 ถึง 80 และนำข้อมูลในวินาทีที่ 21 ถึง 60 มาวิเคราะห์ข้อมูล โดยให้ดูภาพละ 8 วินาที หลังจากที่ได้มีการวิเคราะห์ผลของสัญญาณโดยใช้การทดสอบสมมุติฐาน (Hypothesis Testing) โดยใช้ค่า T-test และค่า P แล้วปรากฏว่า สัญญาณคลื่นสมองแอลฟา ที่ตา และแกมมามีการเปลี่ยนแปลงในลักษณะสูงขึ้นกว่าเดิม และเป็นที่ยอมรับทางสถิติ

**คำสำคัญ:** วิธีการวัดเพื่อบันทึกกิจกรรมไฟฟ้าในสมองบริเวณรอบๆ หนังศีรษะ การพูดเท็จของมนุษย์ การเชื่อมโยงสมองกับคอมพิวเตอร์ นิวโรสกาย คลื่นสมอง

การอ้างอิงบทความ: วชิระ หล่อประดิษฐ์, สุรพงษ์ เพ็ชรหาญ และ วีรศักดิ์ ฟองเงิน, “คลื่นสมองของการพูดโกหกของมนุษย์ โดยใช้วิธีการวัดเพื่อบันทึกกิจกรรมไฟฟ้าในสมองบริเวณรอบๆ หนังศีรษะ ด้วยเครื่องมือนำหนักเบา,” วารสารวิชาการพระจอมเกล้าพระนครเหนือ, ปีที่ 32, ฉบับที่ 1, หน้า 134-142, ม.ค.-มี.ค. 2565.



## The EEG Brain Signals Related to Humans Lie Activity by Lightweight Device

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### Abstract

The brain function in human activities generates the chemical transmitting between neurons causing small electricity current. Now, there are several tools to record the chemical electric data in human brain. Accordingly, the easy method of the brainwave collecting is the Electro Encephalo Graphy (EEG) which places the electrode on the important head point. In this paper, authors used NeuroSky MindWave device to record the EEG. Researchers focus on answers, true or false, from 5 participants with 8 animal pictures that they had seen. For first round, the participants should give the type of animals as true answers. For second round, participants gave the type of animals with false answer. In the experiment, we designed the time to collect the wave in 80 seconds for each round. We separated the time range with 1 to 20 seconds and 61 to 80 seconds for meditation and we analyzed the wave in 21 to 60 seconds ranging by the time looking at each picture for 5 seconds. After that, we analyzed the results based on the hypothesis testing with t-test score and *p*-value. Finally, we found a higher change on alpha, theta and gamma signals with the statistically significant acceptance.

**Keywords:** Electroencephalography, Lie Speaking, Brain Computer Interface, NeuroSky, Brain Wave



## 1. Introduction

The human brain is the important part of the human body that function the human activities. Accordingly, the brain consists of two main cells, neurons and glial cells [1]. First, Neurons transmit the data and communicate with other cells by using the chemical substance that produce the small electricity. Second, Glial cells perform to protect neurons. The scientists discovered the abnormal states of the human by monitoring the brain function by several devices such as Electro Encephalo Graphy (EEG) that place the electrode on the scalp, Electro Cortico Graphy (ECoG) that place the electrode on the surface of the brain, Magneto Encephalo Graphy (MEG), Positron Emission Tomography (PET), functional Magnetic Resonance Imaging (fMRI), and Functional Near InfraRed (fNIR) [2].

The brain signals contain many types of the wave including Delta, Theta, Alpha, Beta and Gamma [3]. First, the Delta wave was the lowest frequency at 0.1 Hz to 3 Hz. This wave show the Deep, dreamless sleep, non-REM sleep and unconscious mental states [3]. Second, Theta wave has the range between 4 Hz and 7 Hz. This signal show the states of intuitive, creative, recall, fantasy, imaginary and dream [3]. Third, the wave with the mental states of relaxed, but not drowsy, tranquil and conscious [3] is Alpha wave which includes the frequency of 8 Hz to 12 Hz. Fourth, Beta wave has the frequency between 12 Hz and 30 Hz and this wave is formerly SMR, relaxed yet focused, integrated, thinking, aware of self & surroundings, alertness and agitation states [3]. Fifth, the frequency in range of 30 Hz to 100 Hz are Gamma wave that has the highest values of this device. Gamma show motor functions and higher

mental activity [3]. Accordingly, each wave can show the mental states of humans.

In this research, the researchers focus on the brain signals that generate by normal human when they lie. We observe the signal activity when people lie others. Researcher try to know which EEG waves important to the human lie. Now, there are many research works with the brain signal and show which signals are affect to somethings. Juti *et al.* [4] worked about the sound affect to the brain. They observed the effects of binaural beat and instrumental relaxing music by analyze the EEG dataset. Phakharawat *et al.* [5] said about EEG signals which show the spatial ability in adult obesity. They used NeuroSky Mindwave device to collect the dataset. The result revealed the important wave that effect to activity by statistically significant. Genete *et al.* [6] pointed the work with ThinkGear pattern recognition algorithm for body movements using relativity. They showed the technique to collects wearer's brainwave signals. The signal pulled out from hand gripping and hand relaxation activity. Then, they analyzed the signal by mathematical analysis and show the accuracy value. Pawana *et al.* [7] observed the EEG power spectra during stroop color word task. They collected the brain wave activity by NeuroSky device. After that, they used paired t-test and independent t-test to analyze the difference between stroop color word test and baseline and they show the signal that important to obese patients when they active with stroop color word test.

## 2. Materials and Methods

### 2.1 Participants

The experiment was done with 5 volunteers,

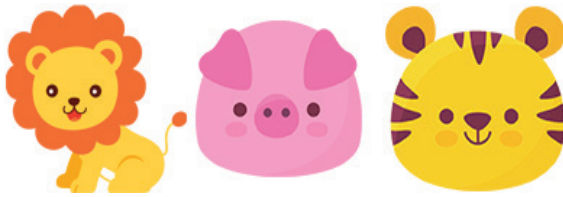


Figure 1: Examples of animal picture stimulus.

aged between 21–27 years old, who are a good health and not use drugs or medicines before test. Furthermore, they were 3 men and 2 women. Before start the experiment, researchers explained about the device and experiment. Then, 5 volunteers were waiting in the recreation room about 10 minutes. After that, assistant wore the device, move them to the experimental room by once and try out the experiment.

## 2.2 Stimulus

In this paper, researchers focus on the brain signals when human lie. We used 8 pictures that relate to animals. These animal picture types that show in Figure 1 are common known, for example, cat and fish. Pictures are separated print out by using color print. Additionally, we selected the pictures of cat, lion, tiger, elephant, octopus, crap, fish, starfish, turtle and pig for this research. We simulated situation like human lie by answering about the not-true type of animal they see.

## 2.3 Brain-Computer Interface

Brain-Computer Interface (BCI) sensors were produced in many company. The sensor can obtains the brain signals and send to computer by using the various computer connection types. In this research, researchers focus on the common waves,

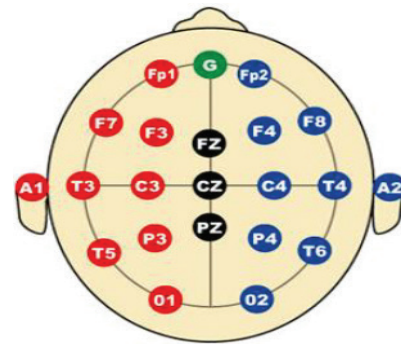


Figure 2: The 10–20 System-Standardized placement of electrodes on scalp for EEG measurements and FP1 position [2].

for example, Delta, Theta, Alpha, Beta and Gamma. So, we recorded the signals from the brain by using NeuroSky MindWave device. This dry EEG electrode sensor were placed in the FP1 position in international 10–20 system like Figure 2. We connected the device to the computer via Bluetooth connection.

## 2.4 NeuroSky MindWave device

NeuroSky Mindwave [3] is the commercial Brain-Computer Interface (BCI) device from NeuroSky, Inc. NeuroSky MindWave headset is the device carry with dry type sensor on the front position [8], [9]. In addition, NeuroSky MindWave device contains a ThinkGear chipset which interface between brain and computer with Bluetooth channel like Figure 3 Furthermore, ThinkGear chipset can filter the electrical noise by itself.

The frequency type from the NeuroSky MindWave device are Delta, Theta, Alpha, Beta, Gamma and eSense (attention and meditation values) [9]. The following frequency were considered: Delta band values is 0.1–3 Hz; Theta band values is 4–7 Hz; Alpha band values is 8–12 Hz; Beta band values is



Figure 3: NeuroSky MindWave Device.

12–30 Hz and Gamma band values is 30–100 Hz. In another one, the eSense values of the attention is 0–100 and meditation is 0–100. The brain wave were captured from NeuroSky MindWave device and connect them via MATLAB [10] with Bluetooth channel. In this research, authors controlled a device by computer via Think Gear library [11]. We used data type in library by separated to Delta, Theta, Low Alpha, High Alpha, Low Beta, High Alpha, Low Gamma and Medium Gamma. These library command refreshed every 1 second that control by library file and coding command [12]. In additional, we set up the baud rate value to 57600 [12].

### 2.5 Data collection

The five volunteered students from the same major in the same university was selected. They had an age between 21 and 27 years old with three males and two females. The experimentation was set up in the following steps like Figure 4. In each round, the experiment collected the data for 80 seconds and separate to 3 parts like Figure 5. First, participants were meditation for 20 seconds. Second, they taked the lie test method for 40 seconds. The experimenter could recognize and speak type of animal within 5 second before we change to the

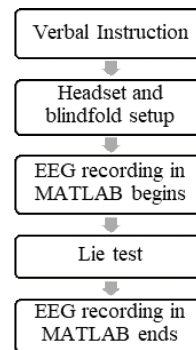


Figure 4: Data collecting methods.

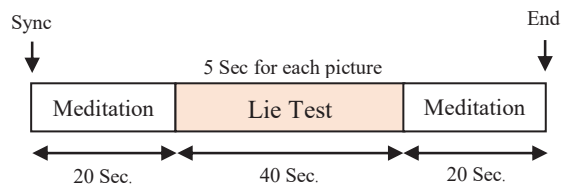


Figure 5: Timing diagram.

next pictures. Third, they were meditation again for 20 seconds.

1) First, participants got the verbal instruction about the research and methods.

2) Second, subjects were set up NeuroSky Mindwave to FP1 position of 10/20 System and moved them to the experimental room by assistant.

3) Third, the subjects got the instruction to meditate themselves for 20 seconds.

4) After that, the subjects got the verbal instruction to look at 8 pictures by once and they answered types of the animal pictures by sequentially like Figure 5. This method illustrated about the true or not lie situation. Then, researchers recorded EEG brain signals in MATLAB. After that, we mentioned them to take meditation for 20 seconds. This method was baseline.

5) Next, the subjects got the verbal instruction to look at 8 pictures by once and they answered the false types of the animal pictures by sequentially like



Figure 6: Lie task.

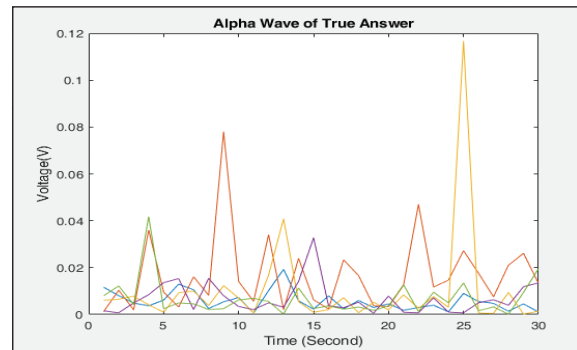


Figure 8: Example of true answer Alpha wave.

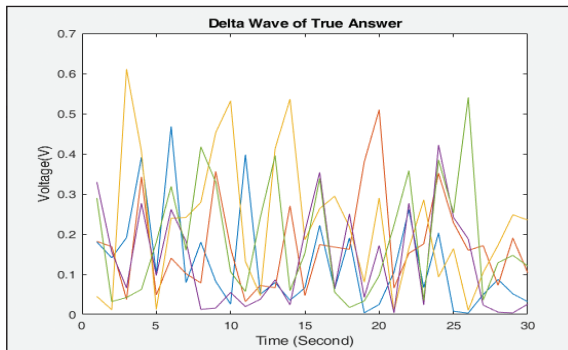


Figure 7: Example of true answer Delta wave.

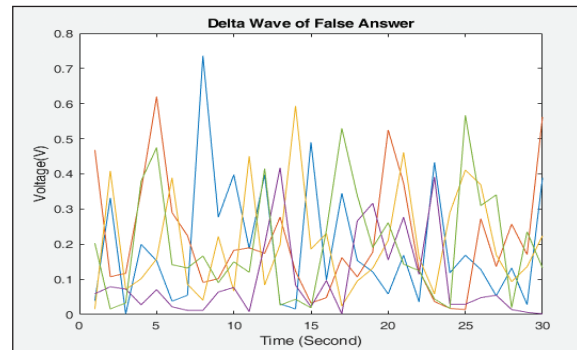


Figure 9: Example of false answer Delta wave.

Figure 6. This method illustrated about lie situation. Then, researchers recorded EEG brain signals in MATLAB. After that, we mentioned them to take meditation for 20 seconds. This method is lie task.

6) Authors did 2–5 steps for other participants repeatedly.

After the experiment, researcher prepared to analysis the EEG raw data in MATLAB. The dataset was separated to each wave, Delta, Theta, Alpha, Beta and Gamma. The example wave of the true answer action shows in Figure 7 and Figure 8. Otherwise, the example wave of the false answer action shows in Figure 9 and Figure 10. With pictures, each color mean each participant. Then, we selected only 21 to 60 second range for analyze.

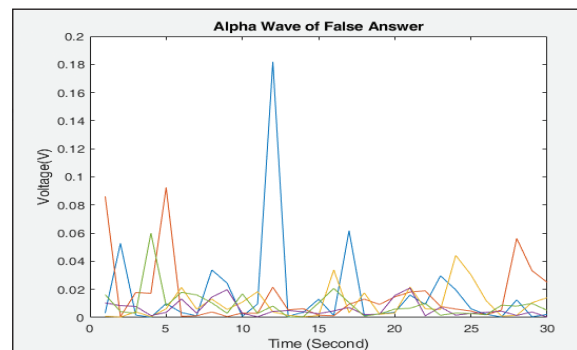


Figure 10: Example of false answer Alpha wave.

We calculated 32-bits standard big-endian IEEE 754 values [9] to voltage by MATLAB program. In this research, we analyzed 5 waves to describe the result of the experiment. We show the answer in result and discuss section.



## 2.6 Data analysis

The EEG data of 5 volunteers were analyzed by using descriptive analysis with qualitative data summarized in term of frequency and percentage and quantitative data summarize in term of average and standard deviation. Researchers used hypothesis testing to compare each type of EEG signal between baselines and lie tasks with t-test score. We set the statistic significant at  $p < 0.05$ .

## 3. Results and Discussion

In this research, the average age of 5 volunteers is 23. Authors analyzed the dataset by Hypothesis Testing with t-test score like Figure 11 and  $p$ -value that compare with standard values by following equation (1).

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} \quad (1)$$

The equation include various variable,  $\bar{x}$  is mean of each EEG signal value,  $\mu$  is hypothesis,  $s$  is variance of each EEG signal and  $n$  is number of EEG signal.

In the Table 1, the researcher shows the  $p$ -values of all waves by using Equation (1). We found the Delta, Theta, Alpha and Gamma wave are increased but beta wave is decreased after lying test. The Table 1 shows the Theta, Alpha and Gamma is increased by significant at 0.05.

According to the Table 2, it was found the Theta wave is increased and has the significant at 0.05 level with 0.0355  $p$ -value. Researcher compared to baseline with 0.0359 value and the voltage of lying test wave with 0.0424. Then, we calculated the t-score for 2.4436 by using Equation (1).

**Table 1:** comparison of the EEG brainwave voltage powers between baseline and lying experimental

EEG Band	Baseline		Lying Test		$p$ -value
	Mean	SD	Mean	SD	
Delta	0.1689	0.0410	0.1812	0.0455	0.1192
Theta	0.0359	0.0143	0.0424	0.0124	0.0355*
Alpha	0.0092	0.0045	0.0117	0.0047	0.0442*
Beta	0.0061	0.0056	0.0057	0.0034	0.7176
Gamma	0.0020	0.0014	0.0030	0.0018	0.0027*

\* $p < 0.05$

**Table 2:** Theta wave voltage powers when performing the lying experimental

EEG Band	Baseline		Lying Test		t-score	$p$ -value
	Mean	SD	Mean	SD		
Theta	0.0359	0.0143	0.0424	0.0124	2.4436	0.0355*

\* $p < 0.05$

In the Table 3, we found the Alpha band is increased. It had the significant value at 0.05 level for 0.0442 with Equation (1). After that, we compared to baseline value, 0.0092, with 0.0117 lying test Alpha wave. We found t-score of this wave be 2.2420.

**Table 3:** Alpha wave voltage powers when performing the lying experimental

EEG Band	Baseline		Lying Test		t-score	$p$ -value
	Mean	SD	Mean	SD		
Alpha	0.0092	0.0045	0.0117	0.0047	2.2420	0.0442*

\* $p < 0.05$

Next, we found the Gamma wave is increased like Table 4. T-score values of this wave are 5.4631. It had the significant value, 0.0027, at 0.05 statistic significant level. Researcher compared baseline value, 0.0020, and the Gamma lying test with 0.0030 by using Equation (1).

**Table 4:** Gamma wave voltage powers when performing the lying experimental

EEG Band	Baseline		Lying Test		t-score	p-value
	Mean	SD	Mean	SD		
Gamma	0.0020	0.0014	0.0030	0.0018	5.4631	0.0027*

\* $p < 0.05$

Following the Table 5, researchers were found the Delta band is few increased by using Equation (1). It was not change during the lying activity. We compared to the 0.1689 baseline value with 0.1812 lying test value but 0.01192  $p$ -value was not relate to statistic significant at 0.05. T-score of this wave is 1.3848.

**Table 5:** Delta wave voltage powers when performing the lying experimental

EEG Band	Baseline		Lying Test		t-score	p-value
	Mean	SD	Mean	SD		
Delta	0.1689	0.0410	0.1812	0.0455	1.3848	0.1192

\* $p < 0.05$

With the calculation by Equation (1), the Table 6 was found the Beta wave is decreased. It had the 0.7176 significant values. We compared to baseline with 0.0061 value and the voltage of wave in lying test with 0.0057 and we calculate the t-score which is  $-0.6268$ .

**Table 6:** Beta wave voltage powers when performing the lying experimental

EEG Band	Baseline		Lying Test		t-score	p-value
	Mean	SD	Mean	SD		
Beta	0.0061	0.0056	0.0057	0.0034	$-0.6268$	0.7176

\* $p < 0.05$

The result showed the important signals are Theta, Alpha and Gamma that related to the human lie activity because of the statistic significant values

( $p$ -value) were accepted at 0.05 significant level. Some  $p$ -values were higher than 0.05, we didn't accept their hypothesis, for example, Delta and Beta wave. So, researchers observed the result t-score and  $p$ -value of all EEG waves. We found the highest  $p$ -value is Beta, Delta and Alpha wave by sequence. From the experiment, researcher found the Theta wave was increased with statistic significant at 0.05 level. This result showed the participants usually use to imagine, creative and recall somethings from the brain [7]. Following the result, we found the Alpha wave was increased. This result showed the experimenters tried to awareness and not thinking more [7]. The next one, we found the Gamma wave was increased but not more value. This result showed the participants use some activity about motor functions like mouth movement. This research showed the relation between the human lie and EEG waves which related to the Alpha, Theta and Gamma wave. These 3 waves are important for thinking when they want to speak opposite the truth. With the result, when human want to lie or speak opposite, they will try to imagine, recall something and awareness [7] which relate to Alpha, Theta and Gamma wave before speaking.

#### 4. Conclusions

This study shows the introduction to Electro Encephalo Graphic (EEG) brain waves were change after the lie activity of the human. The researchers found the increasement of the wave in Alpha, Theta and Gamma that were accepted at 0.05 significant level. These waves show the human try to use the brain to image the result that they want to lie or opposite speak. These studies examine which wave's





changes are associated with changes in cognition and perception when the human lie. These paper show what's wave important to human lie activities.

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