# Identification of L-Theanine Acid Effectiveness in Oolong Tea on Human Brain Memorization and Meditation

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**ABSTRACT**

Oolong tea has L-theanine acid, which have an impact on human brain wave activity, especially for memorization and meditation. To describe the change in the mentioned states, it requires investigating theta and alpha waves. Higher attention frequency of brain waves indicates an improvement mental activity. Therefore, this study proposes a method to identify the effect level of L-theanine acid in Oolong tea focused on changing memorization and meditation states individually. It performs the detection of electroencephalography (EEG), statistical analysis, and data classification with specific factors to digest the distinct effect levels. The human brain waves are detected via Neurosky Mindwave Mobile during the book reading state, comparing before drinking and after drinking conditions. The detected signals are converted into voltage values and analyzed a paired sample t-test for defining the difference between the two states statistically. Moreover, an artificial neural network is used to classify the effect level with associated factors including gender, age, and body mass index (BMI) into low, medium, and high levels. It provides 90% accuracy of 17 participants with low, 13 participants with medium, and 6 participants with high levels. The experimental results show that the level of both memorization and meditation is statistically significantly increased after drinking. The instances are presented as scattered data separately. Although L-theanine in Oolong tea increases the mental state, it does not involve the specific factors in this study. Hence, it has different effects on a particular person.

**Keywords**: Human brain, Memorization, Meditation, Oolong Tea, L-theanine, Neural Network, Electroencephalography

## 1. INTRODUCTION

Besides water, tea is the cheapest beverage for consumers. Nevertheless, the low price is not the only reason that raises the amount of tea consumption. Shreds of evidence support that tea has many health benefits [1]. It is the best reason why tea is widely popular in the common health markets. Previously, the investigation of tea product exportation in China, the largest tea-producing country stated that green tea is about 50%, black tea is about 30%, and others are 20% of the total exported tea [2]. Naturally, tea has famous properties to dissolve the fat in the arteries and slow aging by having substances working against free radicals. A tea leaf contains lots of nutrients, which benefit a human health, especially by providing body refreshment. There are amino acids, e.g., catechin polyphenols, caffeine, protein, potassium, some vitamin types, and plenty of other nutrients inside.

L-Theanine is one of the predominant amino acids found in typical tea leaves, which directly affects the mental state [3]. It can help to block the binding of L-glutamic acid to the glutamate receptor in the brain. L-theanine in traditional tea is proven to have their beneficial effects regarding moods [4]. In addition to other popular tea types, Oolong tea also has sufficient L-theanine to relax the human brain. It has been tested with lab mice by Osaka Institute for Health Care Science in Japan [5]. The results indicated that the stress of experimental mice had been lowered up to 18% due to the natural polyphenols is the main stress reducer.

Since tea is one of the most popular beverages, there have been many types of research about L-theanine acid and human brain interaction. The previous study performed electroencephalographic (EEG) to demonstrate the effect of L-theanine acid on human brain waves [6]. Increasing alpha wave activity is related to the state of relaxation or meditation in the human central nervous system [7]. Consuming L-theanine and caffeine can also improve intersensory attention, especially learning ability related to theta wave for improvement of memorization [8]. Normally, the central nervous system can be alert and relaxed at the same time. However, a condition of relaxation from the effect of L-theanine does not in-

duce the drowsiness status after drinking [9]. It could be most effective when consuming 50-200 mg within 30-40 min [10]. Moreover, it will last for 8 hours, depending on the consumption quantity.

Furthermore, the human brain has unique brain-wave frequencies. It can identify five types of brain waves. There are gamma, beta, alpha, theta, and delta waves on the sequence in two depths of consciousness. Consciousness is a brain function, which precisely means a brain state [11]. The conscious mind indicates the characteristic of the learning mind separately. This status can typically occur during the wake-up period. On the other hand, the subconscious mind refers an imagined status while being unconscious in deep sleep (dreamless).

Besides, brainwave frequencies can be indicated in cycles per second (Hz), and can vary depending on any specific level. The EEG graphs with descriptions of each brain wave are shown in Fig.1.
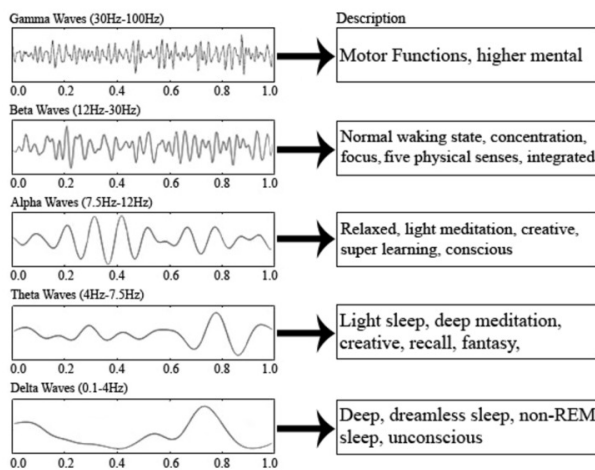


**Fig.1:** *Brainwave Frequencies and Descriptions [12].*

According to Fig.1, the gamma wave has the highest range of frequency, which indicates the fastest frequency like a motor function with stress and anxiety. The beta wave is a swift brain wave which is commonly related to the five physical senses of a human for critical thinking while awake. The delta wave is the slowest frequency activity, which occurs during deep sleep for the restoration and healing process. This frequency range is a part of brain recovery.

Significantly, an alpha wave occurs during consciousness and partially covers a gap of subconscious states. The fluctuations in rhythmic activity are related to different variables such as closing or opening eyes, blood sugar level, and hormones [13]. It refers to slow brain activity with relaxation and light meditation conditions. The human brain has optimal learning in this state. Consequently, this frequency is the best choice for positive learning ability [14]. Also, the theta wave occurs during drowsy status with deep meditation circumstances. It involves

daydreaming and natural mind status. It benefits creative and intuition brain activity. Previously, a research study demonstrated that the theta frequency band promotes adaptive activities for memorization [15]. An alteration of slow delta waves can also improve the decision making of theta frequency activity [16], while the optimal gamma frequency in the range between 80 - 100 Hz can increase the performance of memorization during theta peak [17].

Besides, the relationship testing between human brain waves for mindfulness meditation and memorization are conducted through the study of the questionnaire. It performed EEG recording in the relaxing and questionnaire answering state [18]. It revealed that theta and alpha waves have a higher frequency when participants drove right into concentration, similar to Yoga activity. The increase in the alpha frequency band caused a higher meditation levels while theta waves played a role in short-term memory function in accordance with the effectiveness of L-theanine acid in the human brain [19].

Although previous experiments presented some impacts of L-theanine [3-5], no experiment demonstrated the effect of it through Oolong drinking. Therefore, this research proposes a method to identify the effect of levels of L-theanine in Oolong tea by defining memorization and meditation via theta and alpha frequency bands during the book reading state. To investigate the different effects on brain waves, this study used EEG equipment with statistical analysis and classification method took into account associated factors. The result is promising to indicate that how L-theanine acid in Oolong tea affected the participants. The following sections are presented: materials and methods, results and discussion, and conclusion.

## 2. MATERIALS AND METHODS

This section describes the equipment and related theories which were used in the present study. It consists of information about Electroencephalogram recording, sample preparation, artificial neural network, and statistical analysis.

### 2.1 Electroencephalogram Recording

Human brain waves are detected via the commercial EEG equipment. This research used NeuroSky Mindwave Mobile, shown in Fig.2. The reliability of this equipment has been tested and compared with other equipment in measuring memorization and meditation [20].

The device is designed to interpret the electrical activity that occurs in brain waves [22]. The raw value of brain waves can be collected via a sensor tip, placed on the left side of the forehead (frontal lobe). It has been explained that the frontal lobe involves increasing or decreasing beta waves and alpha
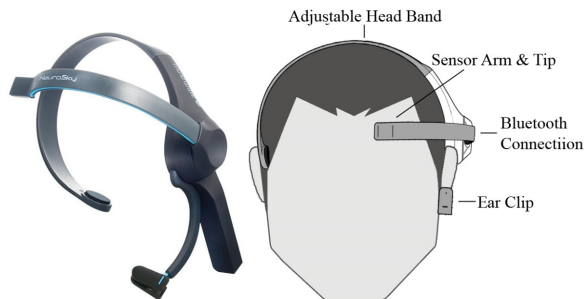
**Fig.2:** *NeuroSky Mindwave Mobile [21].*

waves [23]. Alpha waves reflect the attentional modulation in the bilateral frontal lobe [24]. In addition, this equipment is used to record the change of relative power of theta and alpha waves in the recording frontal lobe as a relaxation indicator [25]. Frontal theta waves have also been tested for increasing and reducing memory load in working memory tasks [26]. Since L-theanine involves changing the activity of alpha waves and theta waves in a relaxing mind [27], it is appropriate to employ this equipment for specific brain wave detection.

The frequency band can vary with an individuals age [28]. To accurately determine the memorization and meditation or relaxation, this study specifically focuses on both theta and alpha frequency bands while reading a book for 5 minutes. The measurement of each frequency band is implemented before and after drinking Oolong tea.

Moreover, this equipment is applied by communicating with the NeuroExperimenter application through a Bluetooth connection. The sample of frequency measurement via brain wave visualization application is shown in Fig.3.
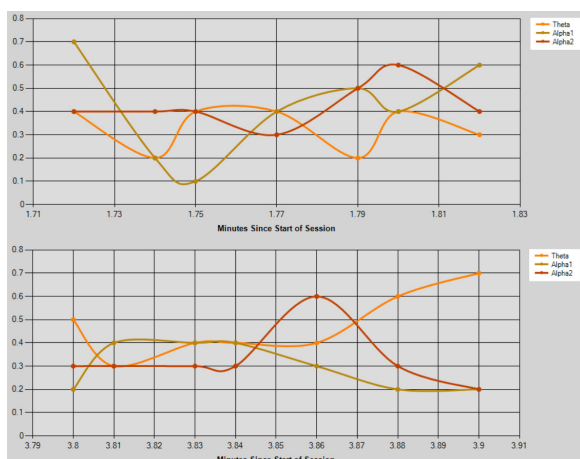


**Fig.3:** *A Sample of Brainwave Measurement by NeuroExperimenter Application.*

This application provides raw values which must be converted. For the relative scale of TGAT-based

hardware devices such as TGAT, TGAM, MindSet, Mindwave, and Mindwave Mobile, the detected raw values can be converted into a voltage value ($\mu v$) by equation 1.

$$V_v = \frac{\left(R_v * \frac{1.8}{4096}\right)}{2000} \qquad (1)$$

$V_v$ is the voltage value, and $R_v$ is the average of the raw value. Gain is 2000. The value range is fixed as 4096. The input voltage is 1.8.

## 2.2 Samples Preparation

In this study, Oolong tea products are taken from the local market in Chiang Rai, Thailand, in January 2018. In the previous study, it was shown that one gram sample of Oolong tea brewed in 100 ml 80°C water for 3 minutes can provide 6.09 mg/g, which is an appropriate amount to effect on the human brain [29]. L-theanine extraction is founded around 2.5 minutes after the tea is brewed. However, for maximum extraction, this brewed tea still needed steeping up to 20 minutes before taking a dose. It appears to increase alpha wave within 30-40 minutes [30], accordingly with relaxation and attention task performance [31]. Moreover, a combination of supplements showed that it increased theta wave function [32]. Thus, the participants in the present study are supposed to have a rest for 40 minutes before brainwave measurement is done.

In addition, the 40 participants were aged between 20-60 years old. Participants were split into 4 groups including 20-30, 31-40, 41-50, and 51-60 years old (10 participants per age group). They are unusual tea or alcohol drinker (no consumption in daily life). Each group contains two genders with 5 male and 5 female participants.

## 2.3 Statistical Analysis

A paired sample t-test is performed to determine whether the null hypothesis is rejected or accepted. This statistical analysis describes the statistical differences between two conditions before and after drinking. A statistical significance value is commonly interpreted via P-value [33]. It is considered that a P-value less than 0.05, or 5%, is an acceptable and statistically significant result [34].

The present study specifies the hypothesized mean difference as 0 for two samples. The mean value between two cases was set as 0.05.

## 2.4 Artificial Neural Network

A neural network or artificial neural network (ANN) is a computational model that is designed in the concept of the bioelectric neural network [35]. A computational model for the neural network was created by Warren McCulloch and Walter Pitts [36]. This model is exclusively used for biological processes.

It consists of neurons and synapses, a structure that passes a neuron through an electrical network [37]. It is basically based on node collection, namely artificial neurons. Entire neurons are organized in layer base and perform different input transformations. There is a real number or weight between each artificial neuron. Also, the connections between neurons are called edges. There is a weight between neurons and edges. It performs an adjustment of learning proceeds. According to Fig.4, the structure of the neural network consists of many nodes. It exposes three layers, an input layer, a hidden layer, and an output layer.
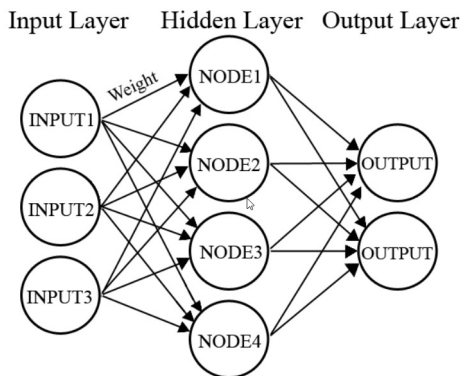


**Fig.4:** *Artificial Neural Network Structure.*

The input layer consists of several attributes of input data. There are three inputs as shown in the above figure. The hidden layer nodes consist of the divided nodes, which can calculate by attributes plus one class, then be divided by two. The output layers are the results of the calculation. An output of each neuron is calculated in a non-linear pattern. It is provided by activation function. Usually, the sigmoid function is used as the activation function. The clustering is based on nerve cells, which is working together between multiple layers, called Multi-layer perceptron or MLP. It is a universal function approximation using a limited number of neurons on the linear connection [38].

Since the dataset is specifically represented as a nonlinear model, this classification process is properly operated by running a neural network algorithm via the WEKA clustering tool in order to provide high accuracy of classification.

## 3. RESULTS AND DISCUSSION

The system procedure of this study relies on the conceptual design and system flowchart showed in Fig.5.

The experimental results based on Fig.5 will be presented step by step.

### 3.1 Electroencephalogram Conversion

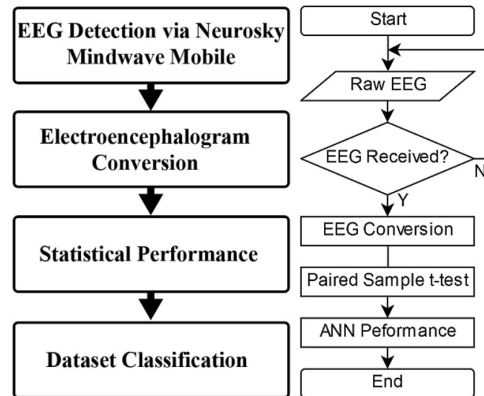The detected fluctuation voltages of brain waves are detected via Neurosky Mindwave Mobile. It was



**Fig.5:** *Conceptual Design and System Flowchart.*

converted through equation 1 and results are shown in Table 1 with the demographic data.

### 3.2 Statistical Performance

A paired sample t-test is performed for the significance testing. The statistical results of theta and alpha waves are shown in Table 2 and Table 3 respectively.

**Table 1:** *Demographic and Converted Data.*

| Age | Gender | BMI | Before | | After | |
|---|---|---|---|---|---|---|
| | | | Drinking Oolong Tea | | | |
| | | | Theta ($\mu v$) | Alpha ($\mu v$) | Theta ($\mu v$) | Alpha ($\mu v$) |
| 21 | M | 24.2 | 0.0104 | 0.0044 | 0.0178 | 0.0047 |
| 21 | M | 29.4 | 0.0145 | 0.0041 | 0.0157 | 0.0047 |
| 21 | M | 21.8 | 0.0271 | 0.0048 | 0.0261 | 0.0054 |
| 22 | M | 25.1 | 0.0110 | 0.0031 | 0.0225 | 0.0050 |
| 20 | M | 27.7 | 0.0297 | 0.0060 | 0.0587 | 0.0077 |
| 21 | F | 19.7 | 0.0149 | 0.0040 | 0.0197 | 0.0046 |
| 21 | F | 21.8 | 0.0214 | 0.0045 | 0.0318 | 0.0057 |
| 21 | F | 24.2 | 0.0155 | 0.0048 | 0.0157 | 0.0063 |
| 21 | F | 19.0 | 0.0196 | 0.0044 | 0.0327 | 0.0053 |
| 21 | F | 18.8 | 0.0271 | 0.0047 | 0.0424 | 0.0056 |
| 34 | M | 18.9 | 0.0331 | 0.0052 | 0.0559 | 0.0056 |
| 32 | M | 23.1 | 0.0162 | 0.0043 | 0.0242 | 0.0083 |
| 32 | M | 27.0 | 0.0096 | 0.0047 | 0.0047 | 0.0065 |
| 34 | M | 23.7 | 0.0212 | 0.0052 | 0.0240 | 0.0042 |
| 34 | M | 20.7 | 0.0208 | 0.0042 | 0.0356 | 0.0086 |
| 34 | F | 19.2 | 0.0085 | 0.0030 | 0.0117 | 0.0038 |
| 36 | F | 19.0 | 0.0105 | 0.0032 | 0.0572 | 0.0063 |
| 35 | F | 20.3 | 0.0146 | 0.0031 | 0.0300 | 0.0033 |
| 38 | F | 20.5 | 0.0108 | 0.0030 | 0.0467 | 0.0047 |
| 34 | F | 20.4 | 0.0104 | 0.0034 | 0.0159 | 0.0043 |
| 45 | M | 22.3 | 0.0030 | 0.0046 | 0.0113 | 0.0046 |
| 44 | M | 24.1 | 0.0121 | 0.0022 | 0.0116 | 0.0058 |
| 48 | M | 20.5 | 0.0110 | 0.0034 | 0.0177 | 0.0054 |
| 48 | M | 20.7 | 0.0042 | 0.0054 | 0.0078 | 0.0057 |
| 48 | M | 21.9 | 0.0048 | 0.0025 | 0.0145 | 0.0042 |

| 46 | F | 20.4 | 0.0036 | 0.0022 | 0.0139 | 0.0056 |
|----|---|------|--------|--------|--------|--------|
| 45 | F | 21.4 | 0.0045 | 0.0046 | 0.0125 | 0.0058 |
| 48 | F | 18.7 | 0.0046 | 0.0028 | 0.0153 | 0.0031 |
| 42 | F | 20.7 | 0.0038 | 0.0033 | 0.0124 | 0.0044 |
| 44 | F | 22.0 | 0.0034 | 0.0025 | 0.0197 | 0.0053 |
| 58 | M | 23.6 | 0.0043 | 0.0034 | 0.0139 | 0.0045 |
| 59 | M | 24.2 | 0.0040 | 0.0024 | 0.0077 | 0.0026 |
| 57 | M | 23.2 | 0.0037 | 0.0032 | 0.0044 | 0.0044 |
| 58 | M | 22.9 | 0.0042 | 0.0029 | 0.0043 | 0.0035 |
| 58 | M | 22.3 | 0.0118 | 0.0039 | 0.0136 | 0.0039 |
| 56 | F | 21.1 | 0.0164 | 0.0030 | 0.0311 | 0.0040 |
| 59 | F | 19.9 | 0.0036 | 0.0021 | 0.0038 | 0.0038 |
| 55 | F | 23.4 | 0.0038 | 0.0019 | 0.0040 | 0.0026 |
| 55 | F | 24.1 | 0.0056 | 0.0022 | 0.0133 | 0.0045 |
| 55 | F | 22.0 | 0.0030 | 0.0022 | 0.0093 | 0.0035 |

**Table 2:** *Statistical Results of Theta Wave.*

| Conditions | Age | Mean | S.D. | $t$ | P-value |
|------------|-------|---------|---------|---------|---------|
| A | 20-30 | 0.0192 | 0.00005 | -3.2368 | 0.0051 |
| B | 20-30 | 0.0284 | 0.0002 | | |
| A | 31-40 | 0.0156 | 8.00006 | -2.9560 | 0.008 |
| B | 31-40 | 0.0306 | 0.0003 | | |
| A | 41-50 | 0.0055 | 0.00001 | -5.8214 | 0.0001 |
| B | 41-50 | 0.0137 | 0.00001 | | |
| A | 51-60 | 0.0061 | 0.00002 | -2.8606 | 0.0094 |
| B | 51-60 | 0.0106 | 0.00007 | | |

**Table 3:** *Statistical Results of Alpha Wave.*

| Conditions | Age | Mean | S.D. | $t$ | P-value |
|------------|-------|--------|----------|---------|---------|
| A | 20-30 | 0.0045 | 5.5546 | -6.1051 | 0.0001 |
| B | 20-30 | 0.0056 | 8.8913 | | |
| A | 31-40 | 0.0039 | 8.0612 | -2.9841 | 0.0077 |
| B | 31-40 | 0.0056 | 0.000003 | | |
| A | 41-50 | 0.0034 | 1.3242 | -4.0425 | 0.0015 |
| B | 41-50 | 0.0051 | 7.8663 | | |
| A | 51-60 | 0.0028 | 4.2249 | -4.6785 | 0.0005 |
| B | 51-60 | 0.0038 | 4.7897 | | |

Condition A denotes the before-drinking condition and B stands for the after-drinking condition. According to Tables 2 and 3, there is a statistical difference between the two conditions. The null hypothesis is rejected due to the fact that both theta and alpha waves showed a statistically significant difference as $p < 0.05$ in all cases.

It is highly statistically significant at $p < 0.001$ in the alpha wave of participants aged between 41-50 years old and 51-60 years old. Also, there is extremely

statistical significant at $p < 0.0001$ level in both of theta and alpha waves in participants aged between 41-50 years old (theta wave) and 20-30 years old (alpha wave). There are less than one in a thousand or ten thousand chances of being wrong in statistics. The difference between the two conditions is precisely presented. The participants who consumed Oolong tea in a specific amount have a higher intensity of brainwave frequency bands.

## 3.3 Dataset Classification

The data classification via ANN is evaluated by 40 instances of training data and 7 attributes (Age, Gender, BMI, theta (before drinking), theta (after drinking), alpha (before drinking) and alpha (after drinking).

The classified data is shown in Tables 4 and 5.

**Table 4:** *Input Node and Weights.*

| Input Node | Weights | | | | |
|------------|--------|--------|--------|--------|--------|
| | Node 1 | Node 2 | Node 3 | Node 4 | Node 5 |
| Age | -2.98 | -0.66 | -1.06 | -1.99 | 1.21 |
| Gender | 0.30 | 0.48 | -0.39 | -0.82 | -0.09 |
| BMI | 0.07 | 0.63 | -1.10 | -2.09 | -0.21 |
| Theta A | -0.92 | 0.09 | 0.77 | 1.87 | -0.36 |
| Alpha A | -0.72 | 0.53 | -1.15 | -2.66 | -0.63 |
| Theta B | 6.65 | -0.59 | 3.84 | 5.51 | -1.39 |
| Alpha B | -11.68 | 2.09 | -8.05 | -11.85 | 2.31 |

All attributes in the input layer are loaded into hidden layers (5 nodes). There is a specific weight between the input node and the hidden node. The value of the various nodes was multiplied by a weight and then provides outputs. The calculation of output values was conducted with the sigmoid function in this experiment. Additionally, the weights between the hidden nodes and the output nodes are shown in Table 5.

**Table 5:** *Hidden Node and Output Weights.*

| List of Hidden Nodes | Output Weights |
|----------------------|----------------|
| Node 1 | 0.78 |
| Node 2 | -2.53 |
| Node 3 | 5.98 |
| Node 4 | 7.4 |
| Node 5 | -2.52 |
| Threshold | -4.08 |

There are three classes of classified data levels in this experiment: low, medium, and high levels. It refers to the level of effectiveness for each participant. The confusion matrix results are shown in Table 6.

Instances are classified in the following orders; 17 participants for a low level, 13 participants for a

**Table 6:** *Confusion Matrix.*

| Classes | a | b | c |
|---|---|---|---|
| Low (a) | 17 | 1 | 0 |
| Medium (b) | 0 | 13 | 1 |
| High (c) | 0 | 2 | 6 |

medium level, and 6 participants for a high level. The accuracy rates are shown in Table 7.

**Table 7:** *Detailed Accuracy by Class.*

| Classes | TP Rate | FP Rate | Precision | Recall |
|---|---|---|---|---|
| Low | 0.94 | 0.00 | 1.00 | 0.94 |
| Medium | 0.93 | 0.12 | 0.81 | 0.93 |
| High | 0.75 | 0.03 | 0.86 | 0.75 |
| Weighted Avg. | 0.90 | 0.05 | 0.91 | 0.90 |

Weighted average is 90%, which is acceptable. The rest number (10%) in the record is considered as error detection. Furthermore, in order to evaluate the relation between the effectiveness level and associated factors, prediction plots are applied and presented in Fig.6, Fig.7, and Fig.8.
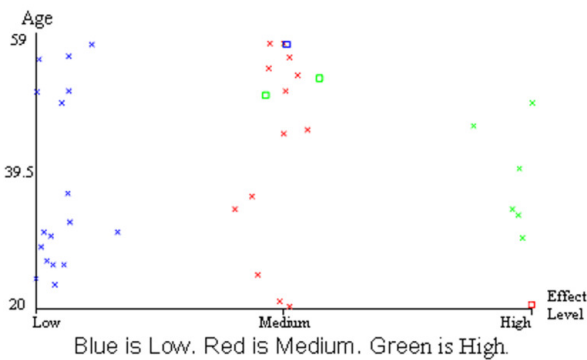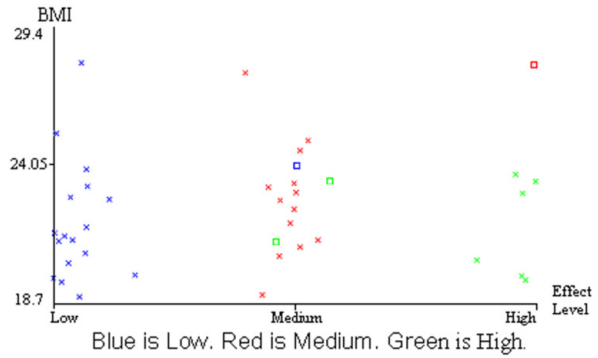


**Fig.6:** *The Relation between Effect Level and Age.*
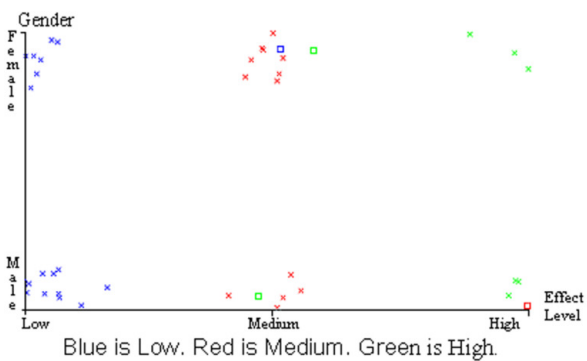


**Fig.7:** *The Relation between Effect Level and Gender.*

As a result, the prediction plots indicate that those instances are disrupted. Instances do not belong to a



**Fig.8:** *The Relation between Effect Level and BMI.*

specific group. It is shown that age, gender, and BMI do not involve L-theanines effect level in the present study. Though the statistical results show that two conditions (before drinking and after drinking) have a change in meditation and memorization, there is a different effect on each particular person in this study.

## 4. CONCLUSION

In conclusion, the results indicate that the participants who drank Oolong tea by a defined amount have higher levels of theta and alpha waves compared to what participants were before drinking. Regarding the statistical analysis, it shows that the level of both memorization and meditation is statistically significantly increased. Nevertheless, the dataset is classified into low, medium, and high levels in order to investigate the distinct effect levels. The classification method provides 90% accuracy with the results of 17 participants with a low level, 13 participants with a medium level, and 6 participants with a high level. Since prediction plots show that instance is presented as scattered data, it can be concluded that L-theanine in Oolong tea increases the mental state of participants but does not involve the factors of age, gender, and BMI in this study. Therefore, it has a different effect on each individual participant, specifically.

Moreover, this preliminary result intended to add the value of Oolong tea through measuring and understanding its medicinal properties. Thus, future work will focus on a larger scale of samples and other related factors for a more precise description of the effect of Oolong tea on the human brain.

## ACKNOWLEDGEMENT

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