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CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER AND LEARNING DISABILITY DETECTION VIA BRAINWAVE MEASUREMENTS

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Abstract. *The development of EEG-based Cognitive Test App (ECT App) replaces the general intelligence tests on paper to enhance the convenience of cognitive assessment. The contribution of this research is to verify concurrent validity of ECT App, also explore the correlation ADHD, LD children and general healthy children's intelligence performance and brain wave state on ECT App and WISC-IV. The subjects were by the 11 ADHD and LD children consisting of experimental group (8 boys and 3 girls, mean age 8.55 years old), 23 general healthy children consisting of control group (11 boys and 12 girls, mean age 9.3 years old). Age range is between 6 to 12 years old. The measurement MISC-IV and ECT App will be applied to each user. They use Neurosky MindWave Mobile measuring brain waves in the test ECT App. ECT App developed is not only to assess the cognitive abilities, also discuss in depth cognitive performance and brain waves statistically significant correlation. Therefore, if we can expand and test different types of cognitive impairment groups we can enhance the reliability and validity of the test. It is believed that the characteristics of the ECT App's immediateness and convenience should be globally applicable to children's cognitive ability test and provide reference for clinical application of children's medicine.*

Keywords: EEG brainwaves, ADHD detection, Cognitive test

1. **Introduction.** The symptoms of mental disorders in children are learning disabilities, lack of intelligence, autism and hyperactivity. To understand whether a child has the above symptoms, some tests of exclusive conditions, such as intelligence test, behavioral level identification, background data establishment can be conducted. In addition, medical and neurological tests can also be used, for example, brain wave map test Electroencephalogram, referred to as EEG, Computed Tomography (CT), Magnetic Resonance Imaging (MRI) [1]. This study uses brainwave testing because many of the current obstacles are related to brain wave abnormalities, especially in the case of learning disorders and attention deficit hyperactivity disorder that are discussed widely in the brainwaves implementation lately. Due to the fact that abnormal brain waves of children's disorders will make poor performance in the test process, which affects the scores of the intelligence test, it can be considered that intelligence is related to brain waves.

In the market, there are many paper tests that measure intelligence and cognition. Most of them include language, graphics, memory, reasoning, and arithmetic. They all have some common advantages and scaling model. Calculate scores, IQ, and accumulate large amounts of data in clinical applications. There are also common shortcomings, because the tools which are required, and the test contains the instruction manual, the title book, and the answer sheet. During the test, it may be necessary to prepare the materials table to calculate the time and also record the score for each question. When the test

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is completed, because it is a manual review, you need to use a computer to calculate the relevant scores. Also, compare the results in the instruction manual to sort out the total IQ score. The above is a rough process of the paper test, but the overall process is confusing, the time and effort spent are relatively increased, and there may be some errors in manual recording and scoring.

According to the analysis report in [2], with the popularity of smart phones or tablets, the user's age of using smart phones or tablets is getting younger. Secondly, according to the statistics of the Ministry of Education, the usage rate of smart phones of all ages is as high as 85.2%. The stage of contact and frequent use of smart phones is mostly to surf the Internet and play game. However, in recent years, the number of game in brain tests has increased in popularity [3].

In traditional paper-based test methods, many challenges occur as incorrect calculation scores, user's conditions, test's environments, and comparison process with paper test. In [12], authors proposed the combination of MOOCs-based teaching method with EEG brainwave to measure student attention in attention and meditation of the study process. Although similar to [12], this paper integrates the intelligence test of paper and develops the EEG-based Cognitive Test App (ECT App). ECT App has added brainwave measurement to observe the condition of the user during the answering process. In addition the application also increases the child's willingness to take the test; it is also convenient to carry, easy to operate, and quick to calculate.

2. **Related Work.** In this section, we will give a brief description of the related work of the brainwaves and the explanation of ADHD and LD liabilities.

2.1. **Symptoms of disabilities.** Cognition is the process of an individual receiving information from the outside world and acquiring knowledge according to perception, feeling, memory, concept and imagination. It can be natural or artificial, conscious or unconscious in the process of cognition [4, 5]. Cognitive function is an intellectual process that allows people to handle tasks, reasoning, and problem solving [6]. The disabilities to process or receive information from outside world and acquiring knowledge accordingly is called learning liabilities or attention deficit/hyperactivity disorder (ADHD). The symptoms of children with disabilities in this paper are divided into children with learning disabilities and attention deficit/hyperactivity disorder.

According to the statistics of the Association of Learning Disabilities in the Republic of China [7], the number of people with learning disabilities is about 3% to 5%. It is estimated that there are 200,000 to 300,000 children with learning disabilities in Taiwan. Learning disabilities are a general term for learning anomalies, but they are not generally difficult to learn and must meet the following principles [8]. 1) Students with learning disabilities generally have moderate intelligence. 2) There are one or more significant difficulties in learning, listening, speaking, reading, writing, reasoning, and computing. 3) Although the mentally retarded person has normal intelligence, there may be a large gap between the learning achievement and the potential ability, or the difference between the individual's own abilities (i.e., one or several abilities are particularly low, but other abilities have performed well, and there are inconspicuous contradictions).

In school, children with learning disabilities having learning anomalies will become more obvious, and the following difficulties usually occur [8]. 1) Difficulties in reading: It is difficult to recognize a Chinese character or spelling a phonetic transcription. The reading speed is very slow and often errors occur. They often could not calm. 2) Difficulties in writing: The spelling of the phonetic, the imitation or writing of the Chinese characters is difficult, the strokes are difficult to recognize, or the sentences are incomplete. 3) Difficulties in computing: The concept of numbers cannot be understood, cannot calculate correctly by finger or practice. 4) Difficulties in reasoning: Poor understanding of the

article or mathematical concepts. 5) Difficulties in hearing processing: It is impossible to understand the complicated instructions of the teacher. 6) Difficulties in speaking: It is difficult to express ideas using words.

2.2. **ADHD disorder.** It is estimated that the prevalence of hyperactivity in Taiwan is 7.5% [9], and the symptoms persist until adolescence or even to adults [10]. DSM-V (Diagnostic and Statistical Manual of Mental Disorders, 5th edition) is a standard tool for diagnosing attention deficit hyperactivity disorder. It is mainly divided into attention deficit, over-activity and impulsive symptoms. The following is attention deficit hyperactivity. Diagnosis of disease [11]: (A) Among the following nine inattention symptoms, there are 6 or more, and the symptoms persist for at least 6 months, enough to achieve direct social and academic/occupational effects and cause it to have the degree of development does not match, it is called inattention. (B) Among the following 13 hyperactivity-impulsivity symptoms, there are 6 or more, and the symptoms persist for at least 6 months, which is enough to achieve direct social and academic/occupational effects and cause some development degrees are not consistent, it is called over-action and impulsive.

2.3. **Brainwaves.** Brain waves are similar to ECG measurements, and they do not harm brain cells or harm the human body. After the brain wave is measured by the instrument, it can detect the potential changes generated in different states, and different potentials will generate different wave patterns, as shown in Figure 1 [13]. The following are common brain wave signals [14]. 1) Delta wave: A slow, high-amplitude wave with a frequency of 0.1 to 4 Hz belongs to the brain wave state at the unconscious level and is related to sleepiness and lethargy [15]. 2) Theta wave: The frequency is 4 to 7 Hz, which is the brainwave state of the subconscious level, which is related to dreaming, lethargy [16], and distraction [17]. 3) Alpha wave: A slow wave with a frequency of 8 to 12 Hz, which is generated when the consciousness is awake and the body is in a relaxed state, and is also related to inhibition or inattention [18, 19]. 4) Beta wave: A fast, low-amplitude wave with a frequency of 12 to 30 Hz. The state of the brain wave generated by this wave during waking is reflected in the prefrontal cortex and is related to concentrated attention [20]. 5) Gamma wave: The frequency is 30 to 100+ Hz, which is a wide frequency signal,

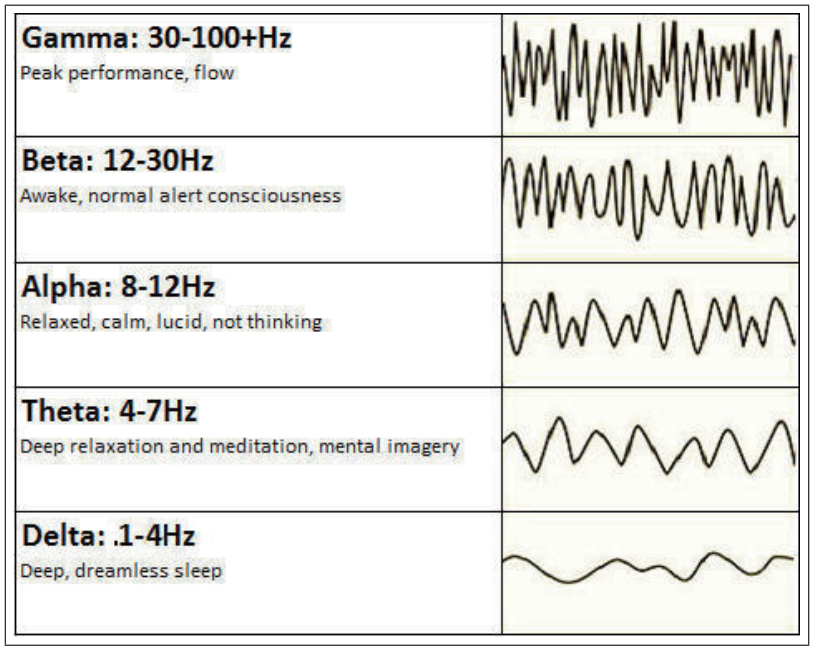


FIGURE 1. The waveform of brainwaves [13]

usually the stronger the signal when the brain is active. When the visual cortical neurons in the brain are dealing with stimuli, attention increases as the Gamma waves rise [21].

3. **Proposed Methodology.** In this section we will describe the proposed methodology to combine ECT App test with brainwave measurement value. Figure 2 shows the architecture of the ECT App. This App test is based on cognitive tests combined with evaluation algorithms and brain wave value algorithms. The evaluation algorithm is to calculate the number of correct answers and wrong answers, the correct rate and error rate, the number of unanswered questions, the score, the time for each question and the total answer time; the brain wave value algorithm is to calculate the average brain wave value of each question. The average brainwave value is from all tests. The ECT App requires users to use brainwaves devices while taking the test. The results are combined between evaluation algorithm and their brainwaves values. Combination scores are summed up from the two measurements.

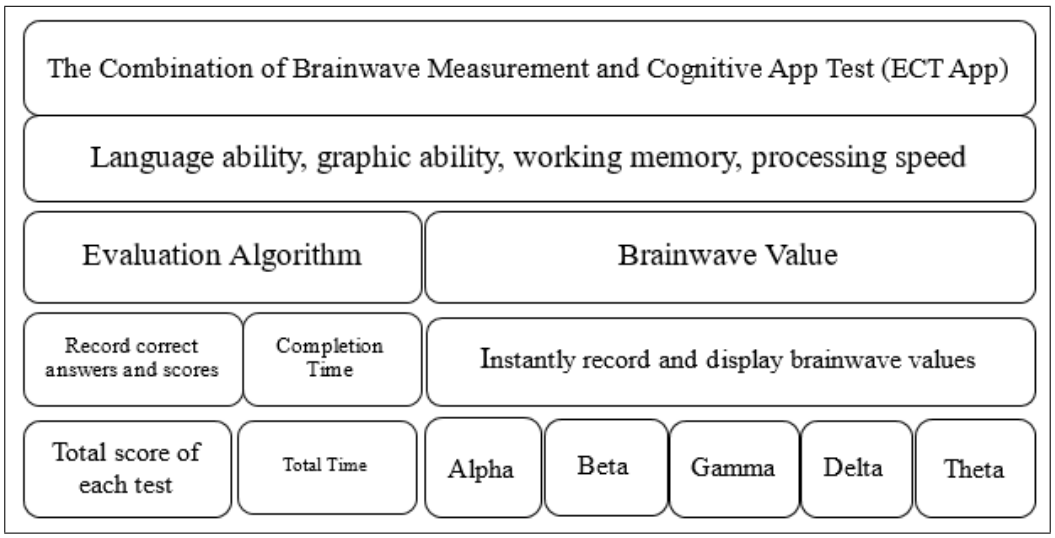


FIGURE 2. The combination of brainwave measurement and cognitive App test architecture

Figure 3 shows the ECT App processing flow, showing the main sequence of doing the App test. After entering the basic data, select the cognitive test (language ability, graphics ability, working memory, processing speed), and then start to answer, the correct answer will be recorded in the process. Numbers and scores also present immediate concentration and relaxation, and record immediate brainwave values (Alpha, Beta, Delta, Theta, Gamma waves) in the background. After the end of the answer, the system will output the total score of the test, the total answer time and the detailed brain wave average data. Figure 4 shows our system design and implementation in mobile App.

4. **Experiments and Results.** The dataset of this paper is collected from 34 users with disabilities and healthy people. Table 1 is a correlation analysis between the brain wave of the control group and the cognitive performance of the ECT App from 9 to 10 years old. This analysis is because the current control group has a large number of middle-aged patients, so as to observe which subtests the control group has, which brainwaves will be affected. The results showed that in the Delta wave, the fallacy ($r = -0.671$, $p < 0.05$), the calculation ($r = -0.57$, $p < 0.05$), and the screening ($r = -0.555$, $p < 0.05$) were significantly negatively correlated; in the Theta wave, the computational test was significantly negatively correlated ($r = -0.682$, $p < 0.05$); in the Beta wave, the digital memory was significantly positively correlated ($r = 0.709$, $p < 0.01$). It can be seen from the above that the scores of the positive correlation test are higher, the brain wave value

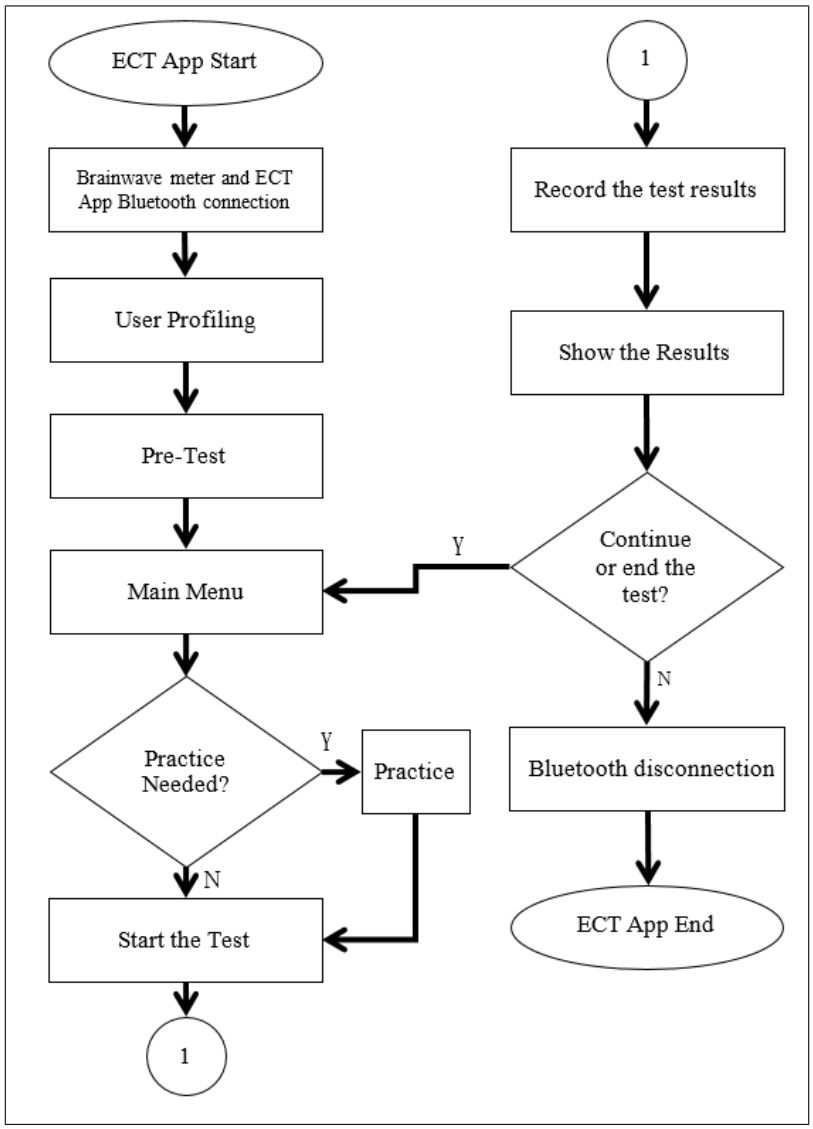
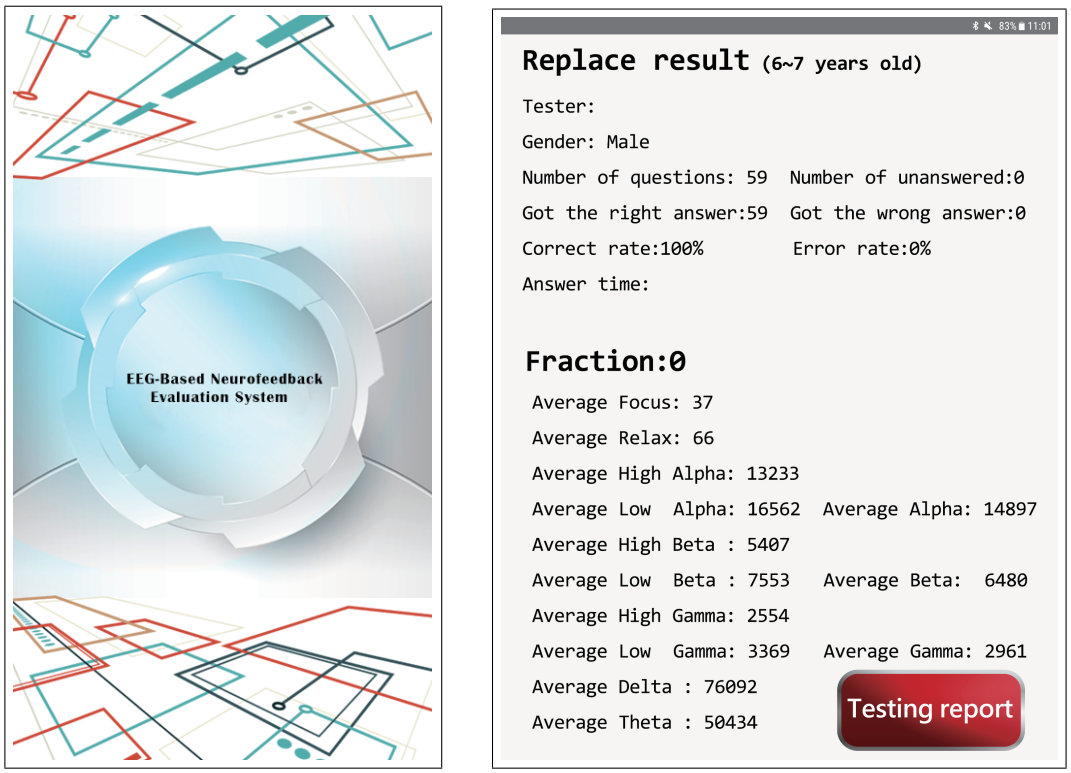


FIGURE 3. The flowchart combination of brainwave measurement and cognitive App test architecture

will be higher, and vice versa; the scores of the negative correlation test will be higher, and the brain wave value will be lower, and vice versa. The following will examine the test and brainwave analysis with significant differences one by one. 1) In the fallacy, calculation, and screening tests, if the scores of the middle-aged control group are higher, the Delta wave will decrease, indicating that there is no distraction in the middle-aged control group. 2) In the calculation test, if the score of the middle-aged control group is higher, Theta wave will decrease, indicating that there is no distraction in the middle-aged control group. 3) In the digital memory test, if the score of the middle-aged control group is higher, the Beta wave will rise, indicating that the middle-aged control group is in a high-concentration state. 4) From the overall analysis, it can be observed that Delta, Theta and Beta waves easily affect the performance of working memory.

Figure 5 shows the differences or error and relationship between the ECT App test scores with scores test diagram in measure of the detection of ADHD disorder in children. After two years of careful collection and analysis of brainwave data, the development of a set of training for children, the development of ideas is very simple, is "easy to play, simple to learn", in the game to achieve various training indicators, and at home and abroad. The major intellectual norms have a simultaneous validity of more than 0.8.



(a) (b)

FIGURE 4. ECT App implementation results: (a) main interface; (b) measurement ADHD results

TABLE 1. Correlation between brainwave and ECT App scores in the control group from 9-10 years old

ECT App		Delta	Theta	Alpha	Beta	Gamma
Speaking	Analogy	$r = -.006$	$r = -.224$	$r = -.097$	$r = -.011$	$r = -.316$
	Word Meaning	$r = -.282$	$r = .100$	$r = -.201$	$r = -.016$	$r = -.041$
	Thinking	$r = -.325$	$r = -.045$	$r = -.127$	$r = -.123$	$r = -.181$
	Know How	$r = .337$	$r = .138$	$r = -.099$	$r = -.301$	$r = -.135$
Reading	Graph. Analysis	$r = -.149$	$r = -.182$	$r = .421$	$r = -.239$	$r = -.259$
	Classification	$r = .079$	$r = .511$	$r = .008$	$r = -.287$	$r = -.181$
	Fill in the Map	$r = -.073$	$r = .081$	$r = .090$	$r = -.513$	$r = -.503$
	Error	$r = -.671^{*}$	$r = -.273$	$r = -.356$	$r = .035$	$r = -.283$
Working	Digit Memory	$r = .336$	$r = .172$	$r = .190$	$r = .709^{**}$	$r = .122$
	Numb. Memory	$r = -.121$	$r = .252$	$r = -.123$	$r = .136$	$r = -.119$
	Calculation	$r = -.570^{*}$	$r = -.682^{*}$	$r = -.529$	$r = -.431$	$r = -.370$
Manage	Search	$r = .256$	$r = -.334$	$r = .132$	$r = -.110$	$r = -.004$
	Replace	$r = .248$	$r = .140$	$r = .161$	$r = -.158$	$r = -.114$
	Filter	$r = -.555^{*}$	$r = .358$	$r = .041$	$r = -.191$	$r = .448$

$^{*}p < 0.05$, $^{**}p < 0.01$
$r = 0.1 - 0.39$ is low correlation, $r = 0.4 - 0.69$ is moderate correlation
$r = 0.7 - 0.99$ is highly correlated.

The system provides focused feedback training to enhance children's learning. Integrate visual and auditory feedback training to enhance children's alertness, persistence, selectivity, and distracting attention. The game also combines the major intelligence norms at home and abroad, and can accurately measure IQ.

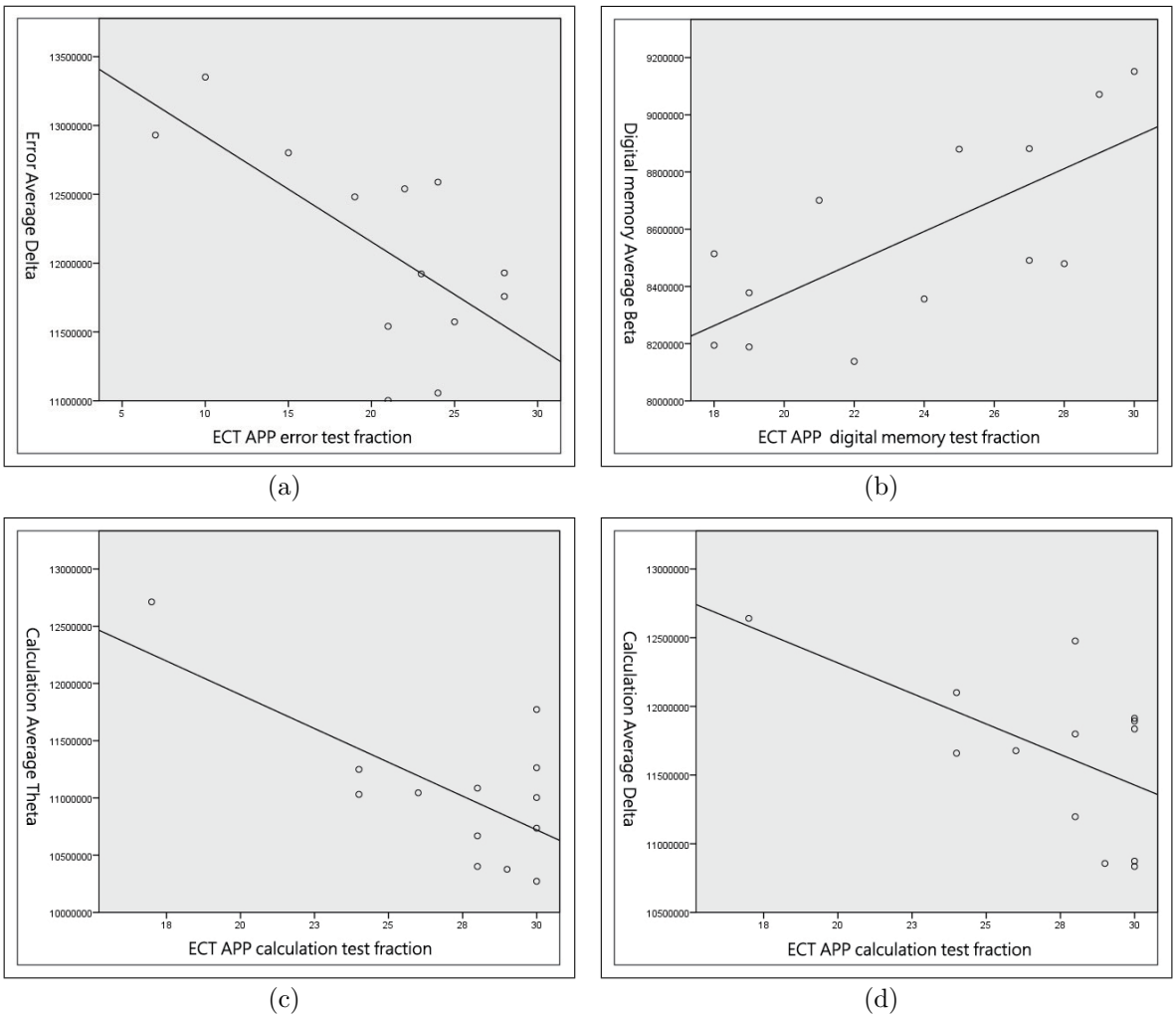


FIGURE 5. Experiments results diagram: (a) Delta wave test error and scores test error diagram; (b) Beta wave test error and scores test error diagram; (c) Theta wave test error and scores test error diagram; (d) Brainwave and scores test relationship diagram

5. **Conclusions.** In order to transform the paper intelligence test into an electronic intelligence test app, this paper developed a combination of brainwave measurement and Cognitive Test App (ECT App). Through the ECT App, you can measure the brainwave value while doing an intelligence test, so you can observe the brainwaves and performance trends of the test. It was found that Delta and Theta waves were significantly negatively correlated, and Beta waves were significantly positively correlated. The better the inference performance, the higher the Beta wave and the higher the concentration.

For future work, we need to measure the ADHD disorder with more variation of environment and external factors, such as learning environment, parents background, and combine with other parameters such as emotion, stress, and attention/meditation values.

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