

## Suggesting a new alternative method of measuring mental disorders without the use of Paper-Pencil tests based on EEG

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### ABSTRACT

**Background and aims:** Paper-pencil tests have always its own problems in the mental disorders evaluation, including learning questions, bad or good blazon are the problems with this methodology. This study aimed to propose a new alternative method of measuring mental disorders without paper-pencil test using EEG.

**Methods:** The research society involved depressed patients referred the psychiatrist clinics in Tabriz. 107 patients were selected as samples using a convenient sampling method. The Beck test was conducted. The EEG was recorded from the F4 point concurrent with displaying the film of 5 animated emotional images from Normed Images database (IAPS). The specialized screen of this recording was designed by the author in the Biograph Infinity software of device. Other software was written by the author in order to separate the  $\alpha_{\text{peak frequency}}$  average associated with any image of the recorded EEG. Then the research variables  $\alpha^1_{\text{peak}}$ ,  $\alpha^2_{\text{peak}}$ ,  $\alpha^3_{\text{peak}}$ ,  $\alpha^4_{\text{peak}}$ ,  $\alpha^5_{\text{peak}}$  of each patient were analyzed with SPSS. After all, another 26 patients were selected to measure the Golden Standard, sensitivity, Positive predictability, Negative predictability and ROC.

**Results:** The results of the multiple regression analysis showed that  $\alpha^1_{\text{peak}}$  associated with  $\alpha_{\text{peak frequency}}$  of image 1 had more explanatory power with a beta value of 0.289 compared with other variables. Then  $\alpha^3_{\text{peak}}$  had a high explanatory power. The regression equation for the predicting the score based on his/her EEG was found in terms of  $\alpha_{\text{peak frequency}}$ .

**Conclusion:** This research showed that Beck's depression score was predictable without using any questionnaire but according to EEG with a high sensitivity (100%), specificity (30.8%), PPV (59.1%), NPPV (100%), and ROC (57.4%).

**Keywords:** Paper-pencil tests, Depression, Multiple regression, Roc.

### INTRODUCTION

Measurement is to assign numbers to individuals through a regular way to demonstrate their specificity, but the test is an objective and standard measure of a behavior quality. As it can be derived from the definition, the concept of measurement

includes the test, too. A test evaluates only a sample of a behavior. Each test consists of several questions that will determine the subject's position in the measured traits. Although activity in the field of psychological tests has begun scientifically since the late of

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the 19th century, but the idea of human knowledge to achieve different objectives existed since ancient times. For example, in the ancient Chinese empire the state organization's employees were tested every 3 years using oral exams, and the results of these tests were used as the criteria for performance evaluation as well as the employees' improvement. The first psychological test was literally the Intelligence Scale of Binet - Simon which was built in 1905 to measure the intelligence of children. For this reason, Binet is called the father of psychological tests. The emergence of psychological tests and activities thanks to the efforts of many scientists, including Fekhner, Wundt, Cattell, Galton and so on.<sup>1</sup> Due to the indefinite nature of mental disorders, their measurement is different from the physical disorders measurement; so, requires different measurement methods. Until now, psychologists and psychiatrists have been used widely the normalized Paper-Pencil test for this purpose. However, different problems such as learning the test, refusal the disease, good or bad blazon of oneself, and the resistance and other problems will result in new ways to enter this field, including other new methods which are computer-based tests. Computers have a large impact on the performance of the tests. One of the important assignments for these tests is the computer adaptive test. These tests are more consistent approaches to assess progress and viewpoints, and often 1, 2 or 3 small set of questions with an average difficulty is presented to the subjects to estimate the individual ability. Depending on the subject's answer to the question, the next question will be presented such that has the most coordination with his/her abilities. So, if all the questions were answered incorrectly, the next question arises easier. If all questions are answered

successfully, the next question or questions will be designed more difficult. If the question is answered correctly, another question with the same degree of difficulty is replaced as a marker. Marker question is a question that specifies the total power. Extensive researches have been conducted about the comparability of computer questionnaire with standardized one.

Wilson conducted an attitude test on 98 female students, both in computerized and paper-pencil methods. They demonstrated that the average and variances obtained by the 2 methods were comparable by modifying the methods.<sup>2</sup>

Helden and Hykman, developed the 2 methods, computerized and the paper-pencil, from Jenkins activity scale.<sup>3</sup> This scale is used to identify people with type A personality. 60 people participated in all forms of the test. The results suggested the comparability of variances, averages, test reliability and validity. Martin and Rush implemented Helden and Hykman method on Eysenck Personality Inventory and Carl depression rating.<sup>4</sup> Half of the subjects answered to the computerized questionnaire and the other half responded to the standardized questionnaire. The mean and standard deviation of 2 methods were comparable. Also, the researchers have studied the Neuro-psychological computer- adaptive tests. Pellegrino, compared a collection of 10 computer test of spatial abilities with Paper-Pencil tests.<sup>5</sup> The results showed that using computerized tests to spatial abilities can replace the standard paper-pencil tests. Furthermore, Pellegrino compared the Halsted computer-based classified test with the original one.<sup>5</sup> This test was conducted on a group of people with neuro-psychiatric deficits. Their report shows that the computer-based tests are similar to the Halsted standard test. However, there are some researches with

confusing results. French and Beaumont, For example, reported a meaningful difference between the computerized and Progressive Matrices of standard tests and concluded that they couldn't be used interchangeably.<sup>6</sup>

In this study, we sought a new method did not face with these problems, but some studies have been started before us, including the extraction of an individual preference from his/her from EEG, which is in Neuromarketing area.<sup>7,8</sup>

Another similar study is called QEEG-based treatment in which the QEEG was used for treatment. QEEG is a diagnostic tool that analyzes brain waves from analog mode (EEG) to digital one. This makes the study of the electrical potentials resulted of the brain cell processes during mental activities possible (such as attention, memory, decision-making, etc.). QEEG also called brain map, displays the recorded electrical activity on the surface of the skull as a range of different colors that reflect the activity level of the brain cells in different parts. Among this type of studies, is the QEEG based OCD neurofeedback therapy or the treatment of personality disorders based on QEEG that use QEEG technology to apply more successful neurofeedback treatment of their patients. In the case of paper-pencil test is not conducted on subjects. But the weak point of the method that the present study makes up is the meaningful internal evaluation based on QEEG for a software such as Neuroguide that perform based on a normal curve and lacks of an external golden standard such as Beck test; so, the vacancy of the method appears even in QEEG-based treatment.

Another interesting series of studies compare an individual EEG by Paper-Pencil tests, as in the studies conducted by Merkelberch, Morris, and Horslnberg.<sup>9</sup>

So, according to the above, the aim of this study is to determine the degree of mental disorder based on the EEG. As demonstrated by previous findings in Neuromarketing, alpha peak frequency in F4 is the best parameter for the right-handed people to extract the Preference and emotions from EEG.<sup>7,8</sup> According to the Davidson there are 3 assumptions in the EEG of depressed and normal people:<sup>10</sup>

A) Right hemisphere alpha of the normal people is larger than their left hemisphere. This is different in depressed people; B) Alpha has a negative relationship with brain activity; C) The right and the left hemispheres which are associated with negative and positive emotions, respectively.

Therefore, in depression treatment when there is an asymmetry neurofeedback  $\alpha$  decreases in F3 and increases simultaneously in F4 when 2-channel assembly. Prefrontal cortex in neural networks involved in processing the mood and emotion. Furthermore, there are some differences between the 2 hemispheres in terms of positive and negative emotions. So, the right hemisphere involves more in negative emotions and the left hemisphere involves more in positive emotions. Numerous studies have shown that the dorsal lateral side of the left prefrontal cortex (DLPFC) becomes more active in positive emotions. The left DLPFC injury following stroke, trauma or epilepsy or depression is often associated with the right DLPFC, while the damage in the right DLPFC studies associated with elevated mood.<sup>11</sup>

It has been found that stimulation of DLPFC using direct current electricity is associated with a positive emotional changes.<sup>11</sup> Recent studies with the aim of changing the activity of the prefrontal cortex and balancing between left and right have shown the significant effects of

TDCS on decreased symptoms of major depressive disorder.<sup>12</sup> Also, in confirming this assumption it must be said that SSRIs also reduce the alpha on F3.

## METHOD

The present study is a correlation one that has been conducted by the regression and correlation method. The data were collected in this field. This is a cross sectional as well as an applied study.

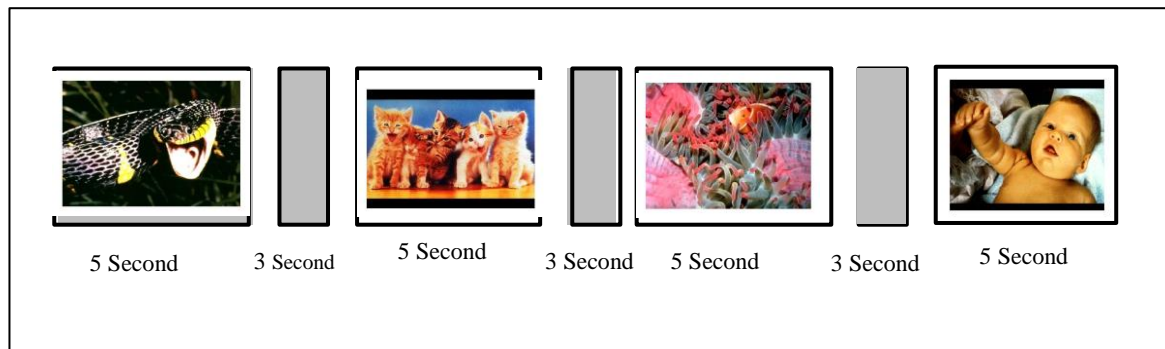
Because of a widespread of depression among people and the necessity of designing a methodology to eliminate the problems related to paper-pencil test, the disease (depression) was chosen for this case. The sample size consists of 107 subjects with convenience sampling methods who were introduced as a statistical sample of depression from Tabriz psychiatrists to the researcher. After the introduction and explanation the test process, the Beck test conducted on the subjects to assess baseline Depression.

In compliance with the professional ethics in referrals as well as at the top of the Beck questionnaire that was provided to patients, assured them that no electricity entered their body through the use of ProComm device electrode. Also, a written consent was received from each subject to conduct the test and publishes the results.

Research instruments in the present study consisted of Procomp Infinity to take EEG and the Beck depression inventory.

Beck depression inventory (version 2), (BDI.II): It consists of 21 questions and their answers are scored in the range of 0 to 3.<sup>13</sup> The inventory has a 71% correlation with Hamilton's depression scoring and the validity of a one-week retesting is 93%.

EEG device: in the present study a 2-channel device (Procomp 2, made by Thought Technology), with the frequency range from 0.5 to 40 Hertz was used. A sampling rate of 8 Hertz and a single-channel recording on the point F4 of the brain were used.








**Figure 1:** The displayed images in movie

Neurofeedback device (Procomp2 Infinity) was used to extract the traits from EEG as a device that displayed five images selected from emotional images of global database to the user, and the EEG was recorded, concurrently. The necessary changes have been previously applied to fit its hardware and software to the researcher's

test. IAPS is a global database of emotional pictures on the web belonging to the University of California that has classified the images according to their emotional excitation power. 5 photos from 5 different categories and different emotional conditions were selected by researcher and a 40-second film was made of them.

Each image displayed for 5 seconds, then a neutral image for 3 seconds and again

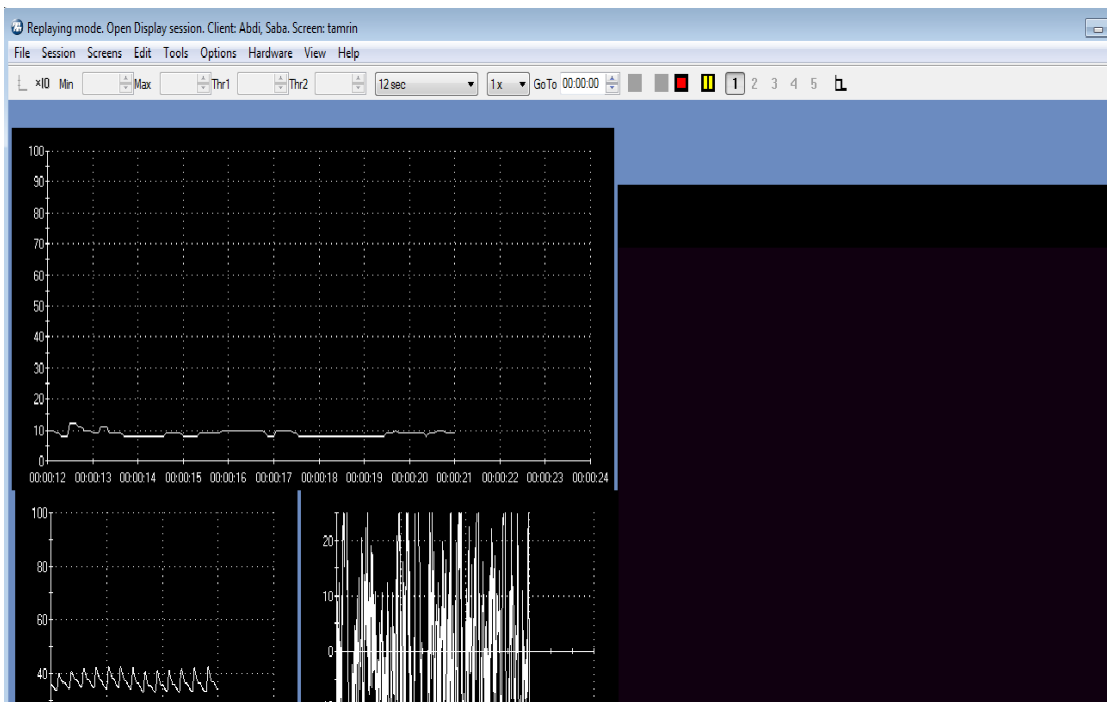
the next image until the end of the displaying. Finally, the individual EEG was recorded.

Selected images from the IAPS global database and their properties				
1	2	3	4	5
Fear	Entertainment	Nature	Satisfaction	Disgust
				
Angry snake	Happy Cats	Fish in the ocean	Happy child	Fly on the cake
International IAPS No. 1052	International IAPS No. 1463	International IAPS No. 1900	International IAPS No. 2058	International IAPS No. 7360

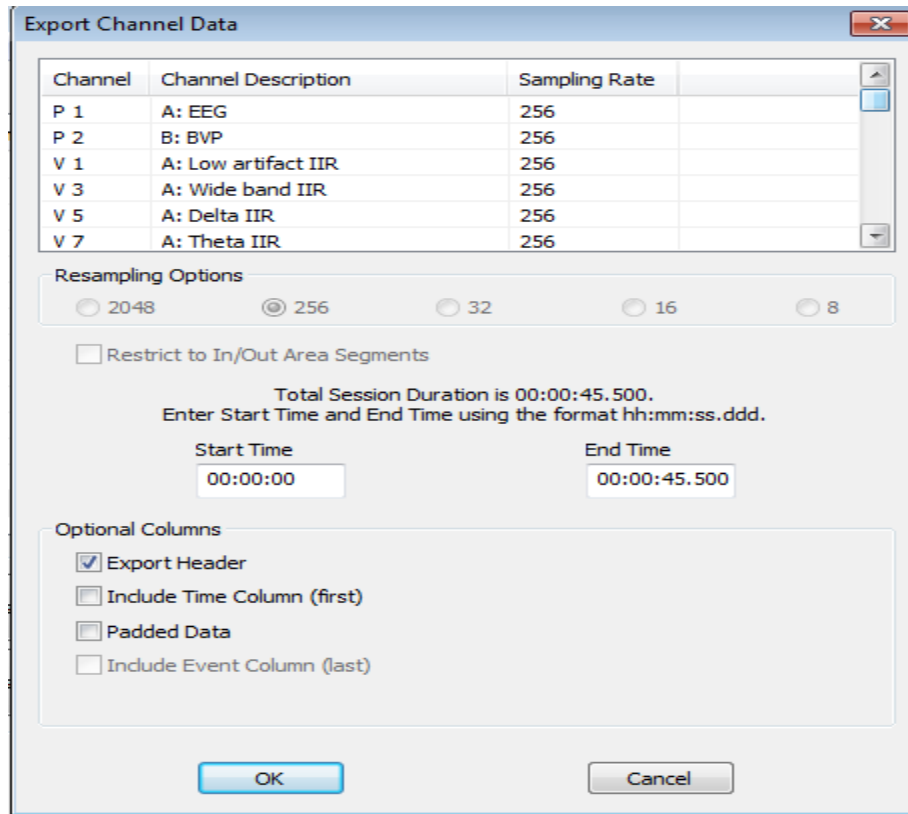
**Figure 2:** The displayed images and their IAPS number

The input of this model includes 5 extracted characteristics from EEG recorded from the F4 point of the brain of patients with depression which is called  $\alpha_{peak}$  frequency. The point, that is F4 and  $\alpha_{peak}$  was selected according to the previous studies. The data gathering screen which was conducted in Procomp Infinity (feedback device) is

observed in Figure 3. In right side, a film of 5 pictures is displayed and was seen via monitors in front of the subjects. On the left side the EEG and the Alpha peak diagram is seen. After the recording process from the Export Data (Figure 4) the Alpha peak of EEG is extracted. In fact, at this stage the analogues are changed to digital data.



**Figure 3:** The EEG recording window of Procomp infinity



**Figure 4:** The EEG data extraction window in the text format of Procomp Infinity software

A computer program written by the author divided the raw EEG to 5-bits, pieces of  $\alpha^1_{peak}$  and  $\alpha^2_{peak}$  and  $\alpha^3_{peak}$  and  $\alpha^4_{peak}$  and  $\alpha^5_{peak}$ .

In this program, the alpha time series at peak frequency was read about each patient and the mean  $\alpha_{peak\ frequency}$  value associated with animated image inserts according to the table:

**Table 1:** Times associated with the animated images

Times associated with the animated images	$\alpha_{peak\ frequency}$ mean
0 to 5 seconds	$\alpha^1_{peak}$
8 to 13 seconds	$\alpha^2_{peak}$
16 to 21 seconds	$\alpha^3_{peak}$
24 to 29 seconds	$\alpha^4_{peak}$
32 to 37 seconds	$\alpha^5_{peak}$

Then, the average of  $\alpha_{peak\ frequency}$  was obtained at limits. Finally, the data entered into SPSS and multiple regression analysis was performed.

The reason for choosing F4 to scan: In a recent double-blind randomized controlled trial with sham (sham is similar to placebo that is used in interventions such as ECT in which the patient is connected to a power-off device) that was pointed out by Fregni, has been used in depression therapy and the results of this study showed significant effects of antidepressants after anodic polarization in the dorsa-lateral prefrontal cortex-accessories (DLPFC).<sup>14</sup> Paulo Sergio Boggio, compared 3 groups consisted of 40 patients with the major depression in a randomized double-blinded clinical trial.<sup>15</sup> Hamilton Depression Scale to measure the highest symptoms (HDRS) was observed in the group that received the DLPFC stimulation anode. The group had a 40%

reduction in symptoms, while a group in which the occipital electrodes were installed, demonstrated a 21% decrease and the control group had a 10 percent reduction. 5 patients had a full recovery in DLPFC group and no full recovery was observed in the 2 other groups. Antidepressant effect had remained one month after the last treatment in the DLPFC group. These findings should be confirmed and repeated by other centers.

In a multiple regression model, a set of independent variables was entered the equation to determine the coefficient of determination ( $R^2$ ) and the weight of each variable (Beta). Moreover, in order to determine the contribution of each variable to explain the dependent variable in the multiple regression technique Enter method is used. In this method the independent

variables entered simultaneously into the analysis and their effects on the dependent variable is determined.

Independent variables which were entered into a multivariate regression equation are:  $\alpha^1_{peak}$  and  $\alpha^2_{peak}$  and  $\alpha^3_{peak}$  and  $\alpha^4_{peak}$  and  $\alpha^5_{peak}$

Multiple correlation coefficient R is equal to 0.823 and modified coefficient of determination ( $R^2$ ) is 0.725 that is, 79.1% of depression changes relating to the understudied variables in this research. Thus, it can be said that the variables are important to explain how those involved in. To understand the significance of a regression equation, refer to the analysis of the regression variance table.

**Table 2:** Results of regression variance analysis

Model	Total squares	Degree of freedom	Average of squares	F	Significance level
Regression	13.967	9	1.552	8.752	0.000
Remaining	42.209	238	0.177		
Total	56.177	247			

Based on the data of regression variance analysis the F-value is equal to 8.725. Due to the smaller significance level than the error level, the regression equation is approved thus; the observed determination coefficient of the regression equation is statistically significant. To

know which one of the variables is more important to explain the depression refers to the standardized beta coefficients table.

In the below table, the 4 understudied variables and the importance and influence of each of the variables of depression are shown.

**Table 3:** Estimate the regression coefficient of assumptions

Models	Nonstandard coefficients		Standard coefficients	T	P
	Beta	Estimation error	Beta		
(Constant)	45.135	36.067		1.251	0.225
$\alpha^1_{peak}$	-6.516	2.969	-0.524	-2.195	0.040
$\alpha^2_{peak}$	-1.077	3.235	-0.075	-0.333	0.743
$\alpha^3_{peak}$	9.133	3.236	0.591	2.822	0.011
$\alpha^4_{peak}$	-5.408	3.273	-0.346	-1.653	0.114
$\alpha^5_{peak}$	0.343	3.375	0.028	0.129	0.899

## RESULTS

Given the significance of the model with  $P < 0.0001$  and  $F = 8.752$  on ANOVA test and relatively high power of the model  $R^2 = 79.1\%$ , only 2 variables out of 5 (ie, 2 images of 5) at  $P < 0.05$  were remained in the equation and considered significant and the others removed from the equation. Both variables ( $\alpha^1_{\text{peak}}$  and  $\alpha^3_{\text{peak}}$ ) and according to  $\beta$  had almost similar influence on the individual. So, regression equation of the Beck prediction from the individual EEG based on the first and third picture is as follows:

$$\text{Bek} = 6.516 \alpha^1_{\text{peak frequency}} + 9 \alpha^3_{\text{peak frequency}}$$

The results of the present study as well as the regression analysis showed that the score of an individual depression without using a questionnaire and only based on EEG on F4 which is stimulated by the first and third images visually and real-time is predictable.

The diagnostic performance measures, including sensitivity, specificity, negative and positive predictability were calculated. The sensitivity is called the correct positives which were identified by the test; while, the property is called the ratio of the correct negatives identified by the test. The negative predictability shows the possibility of the absence of disease if the test result is negative. The positive predictability shows the possibility of the presence of disease if the test result is positive.

A group comprised of 26 patients was selected randomly to measure sensitivity, specificity, positive and negative predictability. The clinical psychologist's opinion was recorded as a golden standard via clinical interview and according to Beck's test for each patient's depression and its rate.

The regression equation obtained from 2,  $\alpha^1_{\text{peak}}$  and  $\alpha^3_{\text{peak}}$ , variables were used to calculate the values from the EEG. So, the

values of sensitivity, specificity, positive and negative predictability were obtained.

$$\text{Bek} = 6.516 \alpha^1_{\text{peak frequency}} + 9 \alpha^3_{\text{peak frequency}}$$

The obtained values of sensitivity, specificity, positive and negative predictability were 100%, 30.8%, 59.1%, and 100% respectively. Therefore, considering the high sensitivity of the methodology, the test could identified correctly all the patients. The relatively modest value of specificity explains the modest power of the methodology in separating the healthy group. The area under the curve was 57.4% in terms of sensitivity and specificity:

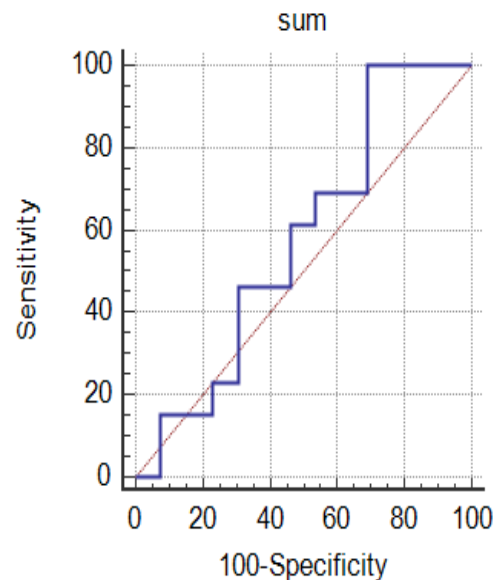


Figure 5: Roc curve

## DISCUSSION

Paper-pencil tests have always its own problems in the mental disorders evaluation, including learning questions, bad or good blazon, the denial of disease and other problems, that they are the problems with this methodology. This study aimed to propose a new alternative method of measuring mental disorders without paper-pencil test.



Considering the limited access to the patients the available sampling method was used in which the subjects with an early detection of depression by a psychiatrist were introduced to a clinical psychologist to conduct Beck's test. The subjects also introduced to a researcher on Feb., Mar., Apr., and Mar. in 2015 to obtain the golden standard.



In a multiple regression model to predict the depression, with respect to the mentioned components, as well as determining the coefficient of determination (R2) and the weight of each variable (Beta) a set of independent variables was entered into the equation. The results revealed that  $\alpha^1_{peak}$  with  $\beta=0.591$  was more determinant than other variables. This means that the more powerful  $\alpha^1_{peak}$ , the more increased level of depression. Then  $\alpha^3_{peak}$  variable with  $\beta=0.521$  had a more determinative than other variables. The obtained values of sensitivity, specificity, positive and negative predictability were 100%, 30.8%, 59.1%, and 100% respectively. Therefore, considering the high sensitivity of the methodology, the test could identify correctly all the patients. The relatively modest value of specificity explains the modest power of the methodology in separating the healthy group. The area under the curve was 57.4% in terms of sensitivity and specificity. Although the earlier studies on alpha peak frequency and recording have been conducted only on f4 point, this research generally is the first one of this kind in which the aim is psychological-clinical disorders rather than neuro marketing.

The present study is consistent with the in terms of the location of EEG scan at F3 or F4 in dorsa-lateral Prefrontal Cortex as well as the relevant component extraction of alpha peak frequency.<sup>7,8,10</sup>

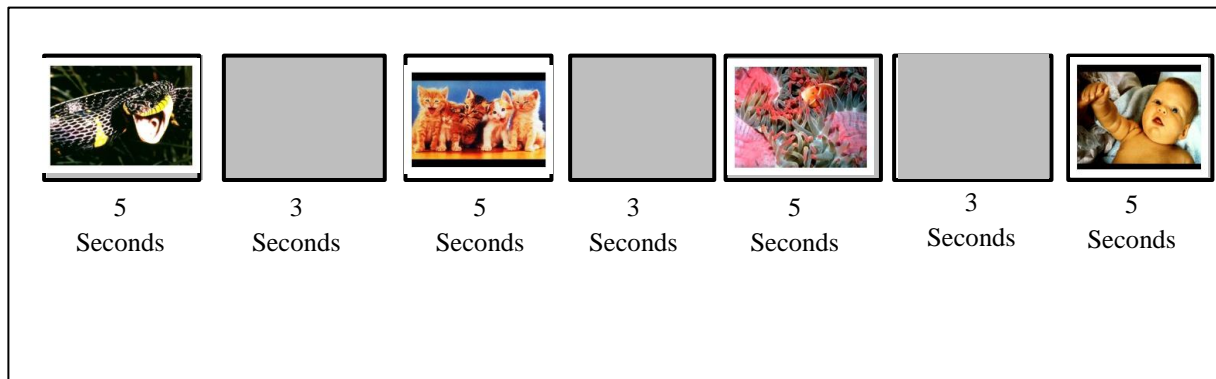
Aurup and Akgunduz in their study “Preference Extraction from EEG” obtained an accuracy of 90% agreement in predicting the subject's emotional favors using alpha peak frequency of EEG which has been recorded from the f4 point.<sup>7</sup> Aurup in another research called “Pair-Wise Preference Comparisons Using Alpha-Peak Frequencies” in which the recording process had been conducted to explain that low alpha peak of the F4 point suggested a stronger preference compared with another item.<sup>8</sup> In the present study there is a strong relationship between alpha peak waves and the rate of depression.

## CONCLUSION

Considering the obtained results of this study it is recommended that when using this method for new depressed patients with the aim of predicting the Beck’s depression score (without using paper-pencil test), it will be better to make a film of the first and third images:

$\alpha_1$	$\alpha_3$
1	3
Nature	Fear
	
Angry snake	Fish in ocean
International IAPS	International IAPS
NO: 1052	NO: 1052

**Figure 6:** Related pictures of significant  $\alpha^1_{peak}$  frequency ( $\alpha^1_{peak}$  frequency) and  $\alpha^3_{peak}$  frequency ( $\alpha^3_{peak}$  frequency)



**Figure 7:** Initial scenario of pictures

Also, it is recommended to decrease the brain scan time from 40 seconds to 5 seconds + 3 neutral seconds + 5 animated seconds, that is 13 seconds and to create the following time stripe:



**Figure 8:** Final scenario of pictures

Considering the study conducted by Aurup and Akgunduz called “extraction of users’ prefers from EEG”, in which they obtained an accuracy of 90% agreement in predicting the subjects’ emotional favors using alpha peak frequency of EEG which has been recorded from the f4 point as well as in the study conducted by Aurup called “Pair-Wise Preference Comparisons Using Alpha-Peak Frequencies”, in which the recording process had been conducted explained that low alpha peak of the F4 point suggested a stronger preference compared with another item. In the present study, as well there is a strong relationship

between alpha peak waves and the rate of depression recorded from the F4 point.<sup>7,8</sup>

The present study can be the first step in the prediction and even the depression diagnosis using direct data of the brain without any questionnaire and even diagnosis by a specialist. Although there is a long way to that point, this type of studies show that it can be possible to move in this way and being closer to the aim by determining carefully the cerebral point, careful recording and data processing via effective instruments and methods.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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