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K-Nearest neighbor classification for detection of the effect of game addiction on cognitive activity in the late adolescent phase based on brainwave signals

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ABSTRACT

World Health Organization (WHO) has determined that Gaming disorder is included in the International Classification of Diseases (ICD-11). The behavior of playing digital games included in the Gaming disorder category is characterized by impaired control of the game, increasing the priority given to the game more than other activities insofar as the game takes precedence over other daily interests and activities, and the continuation or improvement of the game despite negative consequences. The influence of video games on children's development has always been a polemic because in adolescence not only adopts cognitive abilities in learning activities, but also various strategies related to managing activities in learning, playing and socializing to improve cognitive abilities. Therefore, this research was conducted to analyze the cognitive activity of late teens in learning and playing games based on brainwave signals and to find out the impact of games on cognitive activity in adolescents. Prediction of the effect of the game on cognitive activity will be done by applying Fast Fourier Transform for feature extraction and K-Nearest Neighbor for classification. The results of the expert assessment showed the percentage of respondents with superior cognitive category but game addiction was 63.3% and respondents with cognitive categorization were average but were addicted by 36.6%. The percentage of accuracy produced by the system shows 80% in games and cognitive by using k values of 1, 6, and 7. The correlation test results show a percentage of 0.089, so it is concluded that there is no influence of the game on cognitive activity in late adolescents.

1. Intoduction

According to WHO on its website shows the study that a game disruption in someone who is involved in video-game activities only affects a small part. However, it was also explained that game interruptions included in ICD-11 as a form of game interruption with three criteria, namely that they really need a game with symptoms of withdrawing from the environment, cannot control themselves when playing games or prioritize games, and do not care about other activities. International Disease Classification (ICD), which is a basis for identifying trends and statistics globally is also an international standard in reporting a disease and health condition. ICD is also used by medical practitioners throughout the world to diagnose a condition and is used by researchers to categorize a condition [1]. Video games are very popular in various parts of the world and have also become a form of recreation. Many studies have examined minorities related to problems caused by excessive play [2]. There is also another thing that makes video games popular because in a sophisticated game

designed to attract the curiosity of the players to continue playing. In attracting players, in video games, games are made with images and sounds that seem real [3]. In some cases, involvement in the use of video games can cause problems with addictive player behavior [4]. In video games many players who provoke, easily speak harshly so that it has a negative impact on their daily lives [5].

There are studies that show the results of research can prove that playing video-games for a long time can cause clinically significant negative impacts on adolescent sleep time, thus affecting normal sleep time [6]. Global problems related to the game are increasingly being recognized because they can have psychological effects [7]. Educational activities can be diverted to the use of electronic media for a certain period of time which negatively impacts school performance. A recent survey involving teens and children in America stated that around 23% who used light media received good grades in school while 47% who used heavy media received poor grades. Teenagers who in school education cannot concentrate, tend to pay attention to games that can negatively affect their school performance [8].

In 1995 Goldberg gave the term "Internet addiction" namely: (1). excessive game play is explained as game addiction (2). there are reports that 90% of American teens play video games and that among them are addicted to maybe 15% (3). The impact of a game has been placed in category III DSM-5 (4). However, there is not enough research-based evidence related to the impact of playing games that have not been classified. Presentations of the impact of games can occur from mild psychological pressure to psychological stress in adolescent behavior [9].

The signal that appears on the bio-signal is Electroencephalography (EEG). EEG can also show an electrical activity in the brain. The electoencephalogram can also be applied to the system to make the acquisition of signals into data to realize risk factors and diagnostic performance. electoencephalogram also contains useful information about the state of the brain [10]. The technique that can communicate with users and systems is the Brain Computer Interface (BCI). Signal electroencephalogram (EEG) is a means of communication methods used between users and systems can also be used to detect brain signals [11]. EEG is divided into two categories namely primary and secondary signals. Primary EEG signals can be observed and interpreted directly during EEG recording on the system [12]. Quantitative EEG is the processing of EEG signals, where EEG signals can be investigated with a frequency spectrum. electroencephalogram (EEG) can observe most of the brain activity, brain waves and nerve function of the brain [13].

The brain-wave signal is one of the typical characteristics produced by the body [14]. Brain wave activity can be analyzed using EEG, so that different levels of work are found in each part of the brain [15]. Brain waves are divided into 5 types of waves at each signal frequency, such as delta, theta, alpha, beta, and gamma waves [16]. The ability to focus attention on a particular activity requires different concentrations of each person. Several factors, such as fatigue and the environment, become one of the causes of loss of concentration. The difficulty of concentrating is experienced by various occupations, both students and workers [14].

The purpose of data acquisition is to get a model, and stated as data to be executed, then used to do the classification. The amount of energy, knowledge, and creativity depends on the successful involvement of data mining that is entered by the designer [17].

In previous studies EEG signals were used to distinguish between sleepiness and sleep, alertness, emotional conditions, some also used EEG signals to distinguish open and closed eyes, move external devices, identify hand movements, move the cursor through finger movements, knowing the writing and grasping conditions of EEG signals, identification of epilepsy. In addition, some stimuli can affect the results of EEG signals obtained such as sound stimuli, musical stimuli that can affect emotional conditions. Extraction stage is used to take every feature that is on the EEG signal obtained [18].

K-Nearest Neighbor is one of the techniques to get information on the data most widely used in classification problems [19]. The classification for finding k-nearest neighbors is a classification to get good accuracy for the optimal value of k. In K-NN, the test sample is given a class to represent among the closest training samples k. If there are two or more classes, the test sample looks for classes at minimum average distance [20]. there is a major weakness in classifying KNN which is that it requires large memory to store the entire sample. If the sample is very large, the response time on the computer becomes slow [19].

Fast Fourier Transform (FFT) is a fast algorithm. for example, in the calculation of discrete Fourier transforms (DFT) with low complexity, a limited abelian group is performed. one of the most important algorithms in applied mathematics, engineering, and in computer science is FFT, also specifically for signal processing [21]. FFT is used to describe a set of data to be transformed into a series of smaller data sets functionally. At each stage of processing a data using FFT, the results of the previous stage are combined in a special way [22].

2. Previous Research

In previous study by [23], The results of this study obtained data which is then extracted to get the right features. Feature extraction in this study uses first-order statistical features that aim to get information from the signal data obtained. The results of the classification of concentration levels with high, medium, and low categories show an accuracy rate of 70%.

This research refers to research conducted by [24] with the title "The Effect of Play Gamer Computer Education Play Therapy on Cognitive Development in Pre-School Children at Shining Star Malang Kindergarten ". In this study H1 was accepted meaning that there was an influence after the administration of computer game education on cognitive development in pre-school children at Shining Star Kindergarten. The results of this study indicate that: the results of the study found that 18 children (45%) had sufficient cognitive abilities before being given a computer education game and as many as 35 children (87.5%) had good cognitive development after being given a computer education game.

In a study conducted by [25] with the title "Development of Interactive Learning Multimedia in the form of Games to Stimulate Cognitive Aspects". This study uses a research and development (R&D) model that refers to the Alessi & Trolip model through 3 phases, namely standard, ongoing evaluation, and project management. The results of this study indicate that: games can be used to stimulate cognitive and language aspects in accordance with the school curriculum, consisting of 4 types of games, are porTable and standalone, can run with low specification computers, the products produced meet the criteria very feasible to use, products The result is very appropriate to be used to stimulate cognitive and language aspects of Group B kindergarten children in terms of usefulness.

In other study conducted by [2] The results obtained are addicted players around 1.4%, problem players about 7.3%, players involved around 3.9%, and normal players around 87.4%. Game addiction can have a negative impact if associated with awareness and positively related to neuroticism. some of these factors provide information related to the field of game addiction, and illustrate how individuals who are at risk of becoming game addicts can be identified.

Where in other studies in research conducted by [18] with the title "EEG Signal Classification of Three Conditions of Mind Using Autoregressive and Adaptive Backpropagation". Research in this journal constructs an EEG signal classification system for three states of mind using Autoregressive for EEG signal extraction and classification using Adaptive Backpropagation with three conditions of mind reviewed are the conditions of counting, writing and not thinking about something. The testing process in this study is divided into testing training parameters and testing the use of variations of the Autoregressive order value used when extracting data. The results of this study indicate that: The test results show the best accuracy is obtained by extracting using the order 30 with an accuracy of 82% of the 90 data sets used.

3. Method

3.1. Proposed Method

The proposed method can be seen in a flowchart in Fig. 1.

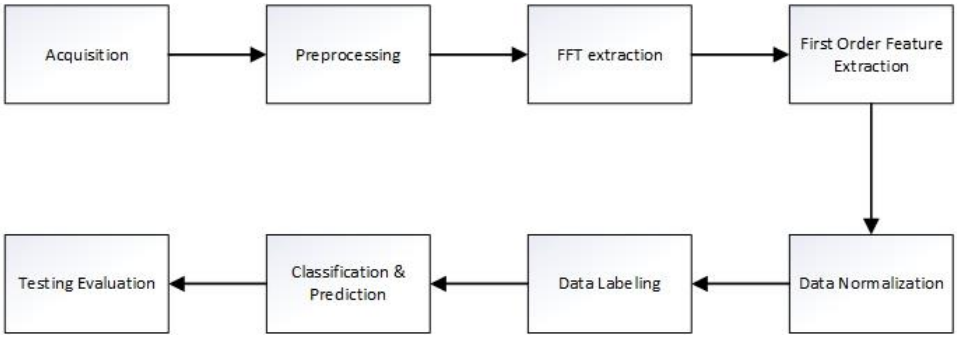

Fig. 1. Block diagram proposed method

3.2. Block Diagram of EEG Data Acquisition

This data retrieval stage is drawn using a Flowchart. Following are the stages of data retrieval can be seen in Fig. 2.

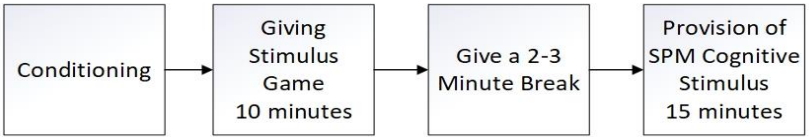

Fig. 2. Data acquisition stage

Data acquisition is a method of data retrieval using an EEG tool that is paired with game stimulus and cognitive tasks in the form of SPM. Data acquisition systems are being used to collect information to store or analyze some phenomenon [26]. In this study three times the data collection was carried out, the time span of data collection from the first data collection to the second data collection was two weeks, with respondents numbering 30 people, aged 18-21 years. In this data collection using the NeuroSky Mindwave with the number of sensors one electrode in the position of Fp1 and MyndPlayerPro software as a signal data recorder.

3.3. Standard Progressive Matrics (SPM)

Standard Progressive Matrices (SPM) is a tool to measure a person's level of intelligence SPM tests are oriented toward abstract relationships. The SPM test is globally considered the best test because there are abstract or non-verbal reasoning skills [27]. The SPM test consists of 60 questions divided into five series, namely series A, B, C, D and E, each series consisting of 12 questions in the form of pictures. SPM results are presented in the form of intellectual level in Table 1.

Table 1. SPM Test Result Categories

Categories	Explanation
Grade I	Intellectually superior
Grade II	Difenitelly above the avarage in intellectual capacity
Grade III	Intellectually average
Grade IV	Difenitelly below the avarage in intellectual capacity
Grade V	Intellectually defective

3.4. Preprocessing

At this stage the data processing is done as the second step after the signal data that has been acquired on the process of respondent data processing to retrieve the signal wave data that has been taken using an EEG tool. Before measuring brain waves, respondents will be asked to use an EEG device mounted on the head with recorded brain waves when given a game stimulus and SPM cognitive task questions to retrieve the existing signal data on the NeuroSky Mindwave after recording is finished will be stored in the form of a log that is still unreadable, so that you can read the data export log file to CSV format using MyndPlayerPro. All data from 30 respondents recorded in the Export Log File to Ms. data. Excel, after that the data from Ms. Excel is loaded into matlab for further processing using Fast Fourier Transform.

3.5. Fast Fourier Transform

Fast Fourie transform rarely uses several dimensional reduction methods to do frequency signal processing in the time domain, which suppresses frequency domain information from high to low dimensions [28]. This stage aims to display the peak point of the signal with the highest frequency every 0.25 Hz from the extraction of the original FFT signal and erase the baseline or baseline in the EEG signal to get the output of the FFT extraction signal. The results of the EEG signal are analyzed using Fast Fourier Transform to obtain a noise-free EEG signal to extract all important frequency components of the EEG signal such as: alpha, beta, gamma, delta, and theta. Fast Fourier Transform is used for grouping and detecting brainwaves where brain waves provide different features using equation (1).

$$s(f) = \int_{-\infty}^{\infty} s(t)\, e^{-j2\pi ft} dt \tag{1}$$

3.6. Statistical Feature Extraction

Feature extraction is a method of characterization based on image histogram characteristics. From the values in the resulting histogram, several parameters of the first order characteristic can be calculated, including the mean, skewness, variance, kurtosis, and entropy. This feature extraction is done by using first-order characteristic statistics in the form of mean, entropy, standard deviation, skewness, and kurtosis. In extraction, it uses the first-order statistical features to find out the features needed. Feature extraction, obviously, is a transformation of large input data into a low dimensional feature vector, which is an input to classification or a machine learning algorithm [29].

a. Mean

Mean is the average of data and is a measure of data centering [30]. The mean also shows the size of the dispersion of a data can be seen in equation (2).

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{2}$$

b. Standard Deviation (*s*)

Measuring the standard deviation of a data, by getting the value of the square or the value of the variance. Can be seen in equation (3).

$$s^2 = \frac{(x_i + \bar{x})^2 + \cdots + (x_i + \bar{x})^2}{n}$$
$$s = \sqrt{s^2} \tag{3}$$

c. Skewness (*sk*)

Measuring the slope of a data, skewness is seen in equation (4).

$$sk = \frac{\bar{x} - Median}{s} \tag{4}$$

d. Kurtosis (α_4)

Measuring the height of a data, kurtosis is seen in equation (5).

$$\alpha_4 = \frac{\frac{1}{n}(x_i - \bar{x})^4}{s^4} \tag{5}$$

e. Entropy (H)

Measuring the deviation in the shape of a data, entropy is seen in equation 6.

$$Entropi\ (S) = \sum_{j=1}^{k} - p_j\ log_2\ p_j \quad (6)$$

3.7. Normalization Data

Data normalization stage is the stage before classification so that the features obtained can be more sTable. This normalization stage uses a simple and widely used method, namely linear normalization by scaling within range [-1,1]. to scale within range [-1,1], the equation (7) can be used for data normalization.

$$\hat{x}_{ik} = \frac{2x_k - (\max(x_k) + \min(x_k))}{\max(x_k) - \min\ (x_k)} \quad (7)$$

3.8. K-Nearest Neighbor

The K-NN method is very easy to apply for example if "x" has the closest k where there are features and the majority of them have the same label "y", then "x" belongs to "y" [31]. Classification using K-Nearest Neighbor is done to group training data and test data based on the proximity of the location (distance) of a data with other data with the Euclidean formula. To get the distance from the data that the category is looking for then the closest K-data value will be determined. The K-Nearest Neighbor method is also used to predict the influence of a game on cognitive activity in late teens. Determining the value of K to get predictions and good accuracy, as well as training data and test data used must also be good. The following K-Nearest Neighbor is formulated in the equation (8).

$$d_i = \sqrt{\sum_{i=1}^{p} (x_{2i} - x_{1i})^2} \quad (8)$$

3.9. Evaluation

Evaluation of testing is the final stage after the research is completed, the evaluation phase of this test aims to get an accurate accuracy of the results of the predicted value of the system. The results of the predicted values are then compared with the original data that the category has been known for. In the final stage of this study using accuracy testing or performance testing using Confusion Matrix.

Evaluating the classification model requires a set of test data that is missing or not used in the Training Data. In evaluating, certain measures can be used where TP, TN, FP, and FN. Explanation of these points can be explained as in Table 2.

Table 2. Evaluation measurement

	Predict	**Real**
True Positive	Positive (Y)	Positive (Y)
False Positive	Positive (Y)	Negative (N)
True Negative	Negative (N)	Negative (N)
False Negative	Negative (N)	Positive (Y)

Explanation of each term from the Confusion matrix above can be illustrated as in Table 3.

Table 3. Confusion matrix

		Prediction Class	
		True	**False**
Real Class	**True**	TP (True Positive)	FP (False Positive)
	False	FN (False Negative)	TN (True Negative)

Confusion matrix is very useful for analyzing the quality of classification models in recognizing tuples from existing classes. TP and TN state that the classification model correctly recognizes tuples, meaning that positive tuples are recognized as positive and negative tuples are known as negative. In contrast, FP and FN state that the classification model is wrong in recognizing tuples, negative tuples are known as positive and negative tuples are known as positive. P 'is the number of labels given a positive label $(TP + FP)$ while N' is the number of labels given a negative label $(TN + FN)$. Meanwhile the total number of tuples can be expressed as $(TP + TN + FP + FN)$ or $(P + N)$ or $(P' + N')$ [32]. In general, precision, recall and accuracy can be formulated as follows:

1) Accuracy

Accuracy is the level of recognition expressed as a percentage of the number of tuples in the test data that is classified correctly. The accuracy is formulated in equation (9).

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} * 100\% \quad (9)$$

2) Precision

Precision is a measure of certainty, that is, what percentage of tuples that are labeled as true in reality. The precision is formulated in equation (10).

$$Precision = \frac{TP}{TP + FP} * 100\% \quad (10)$$

3) Recall

Recall is a measure of completeness, with what percentage of positive tuples are labeled as positive. Thus, recalls equal sensitivity or true positive levels. Recall is formulated in equation (11).

$$Recall = \frac{TP}{TP + FN} * 100\% \quad (11)$$

4. Results and Discussion

The results of this study include several discussions relating to the process of data acquisition, preprocessing, data filtering, feature extraction, implementation and classification, and system evaluation.

4.1. Acquisition Data

The data acquisition process is done with 3 times the collection time span of 14 days or two weeks. In this study there were 30 people who were willing to become respondents for their brainwave data retrieval using stimulus games and cognitive tasks with EEGs mounted on their heads when playing games with 10 minutes and doing SPM tests with 15 minutes. The assessment results obtained by experts can be seen in Table 4.

Table 4. Grouping of respondent data

Subjects	Intake 1	Intake 2	Intake 3
Respondent 1	G. 1	G. 1	G. 1
Respondent 2	G. 2	G. 2	G. 2
Respondent 3	G. 3	G. 3	G. 3
Respondent 4	G. 3	G. 2	G. 1
Respondent 5	G. 1	G. 1	G. 1
Respondent 6	G. 2	G. 2	G. 2
Respondent 7	G. 3	G. 3	G. 2
Respondent 8	G. 3	G. 3	G. 3
Respondent 9	G. 3	G. 2	G. 2
Respondent 10	G. 3	G. 2	G. 2
Respondent 11	G. 3	G. 3	G. 3
Respondent 12	G. 3	G. 3	G. 3
Respondent 13	G. 2	G. 3	G. 2

Subjects	Intake 1	Intake 2	Intake 3
Respondent 14	G. 3	G. 3	G. 3
Respondent 15	G. 2	G. 2	G. 2
Respondent 16	G. 3	G. 3	G. 3
Respondent 17	G. 3	G. 2	G. 2
Respondent 18	G. 2	G. 3	G. 2
Respondent 19	G. 3	G. 3	G. 2
Respondent 20	G. 2	G. 2	G. 1
Respondent 21	G. 2	G. 2	G. 2
Respondent 22	G. 2	G. 1	G. 1
Respondent 23	G. 2	G. 2	G. 1
Respondent 24	G. 3	G. 2	G. 2
Respondent 25	G. 3	G. 3	G. 2
Respondent 26	G. 2	G. 2	G. 1
Respondent 27	G. 2	G. 1	G. 1
Respondent 28	G. 2	G. 2	G. 2
Respondent 29	G. 3	G. 2	G. 3
Respondent 30	G. 2	G. 2	G. 2

4.2. Preprocessing

Data that has been opened in MyndPlayerPro is exported to csv (comma separated values) format, which is a data format in a database where each record is separated by a comma (,) or semicolon (;). In this study the results of brain wave records with the .log format will be exported to CSV to see the results of brain wave data obtained. For the export data results in MyndPlayerPro will be three parts, including log.csv data, log.proses.csv data, and log.raw.csv. Raw data can be processed on certain computer software for further analysis. The form of raw data can be a binary data set or a collection of data in other forms. All data recorded by respondents during brainwave retrieval in the Export Log File to .csv data.

4.3. Fast Fourier Transform (FFT) Filter

EEG signal results were analyzed using Fast Fourier Transform to get a noise-free EEG signal to filter all important frequency components of EEG signals such as alpha, betha, gamma, delta, and theta. The initial signal can be seen in Fig. 3 and the signal from the FFT filter can be seen in Fig. 4.

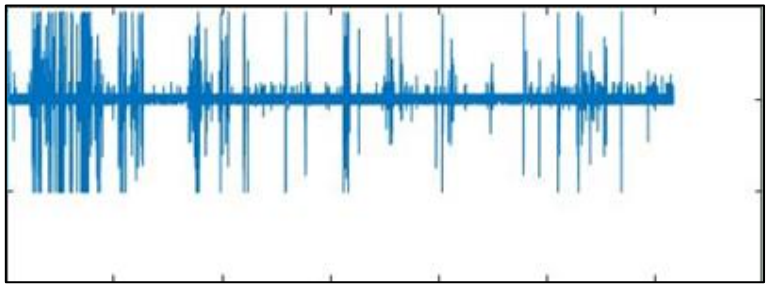

Fig. 3. Early signals

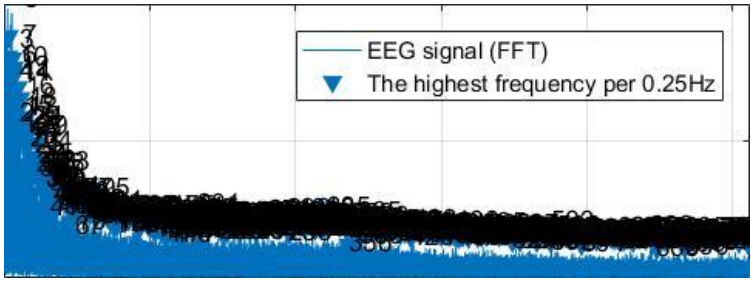

Fig. 4. FFT filter signal results with the highest frequency every 0.25 Hz

4.4. Feature Extraction and Normalization

After extracting features that are first order features to obtain a statistical information in the form of mean, entropy, standard deviation, skewness, and kurtosis. Then the normalization process

from the data of 30 respondents who had extracted the first-level feature features of both the game stimulus and the SPM cognitive stimulus were carried out. The results of the game data before

normalization and after normalization in the form of Scatter charts can be seen in Fig. 5, Fig. 6, Fig. 7, Fig. 8 and Fig. 9. While the results of SPM data before normalization and after normalization in the form of scatter charts can be seen in Fig. 10, Fig. 11, Fig. 12, Fig. 13 and Fig. 14.

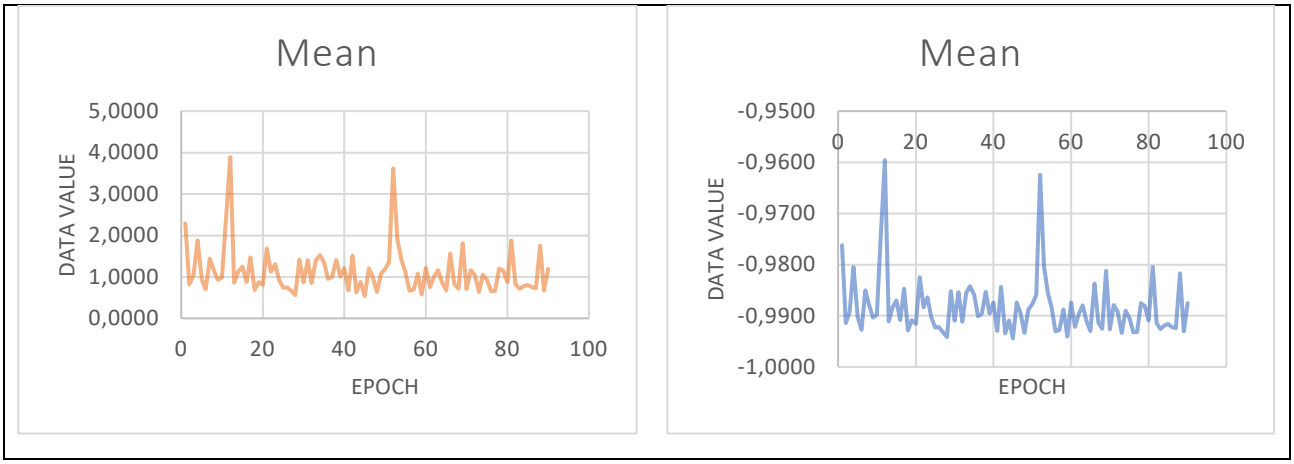

Fig. 5. Data 1 before and after game data normalization

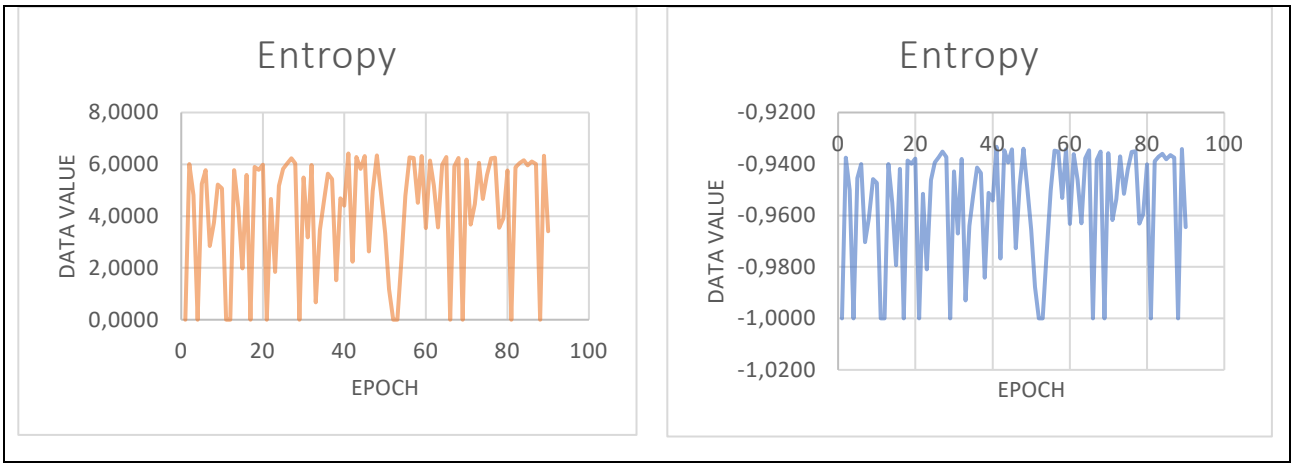

Fig. 6. Data 2 before and after game data normalization

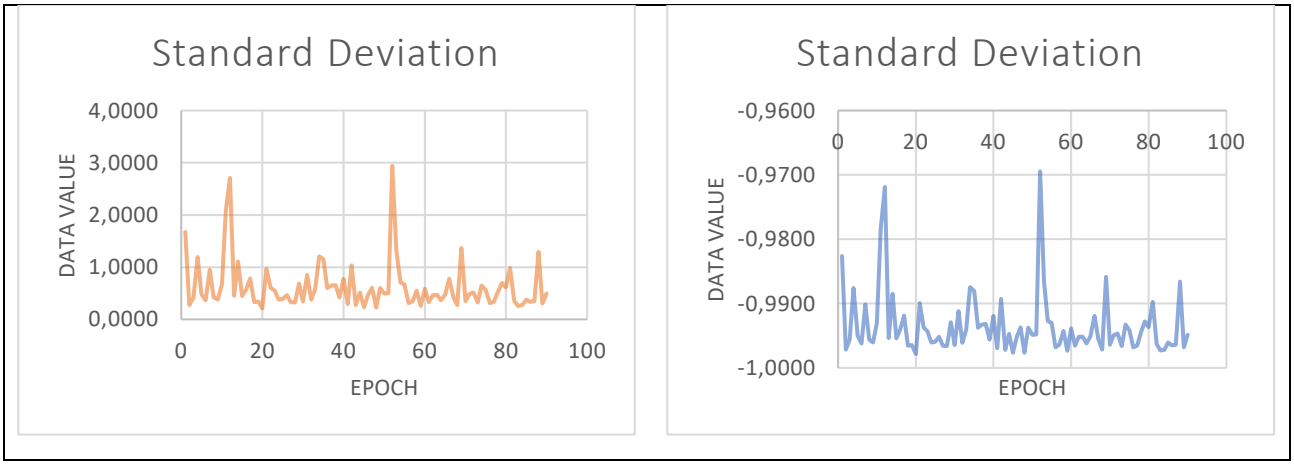

Fig. 7. Data 3 before and after game data normalization

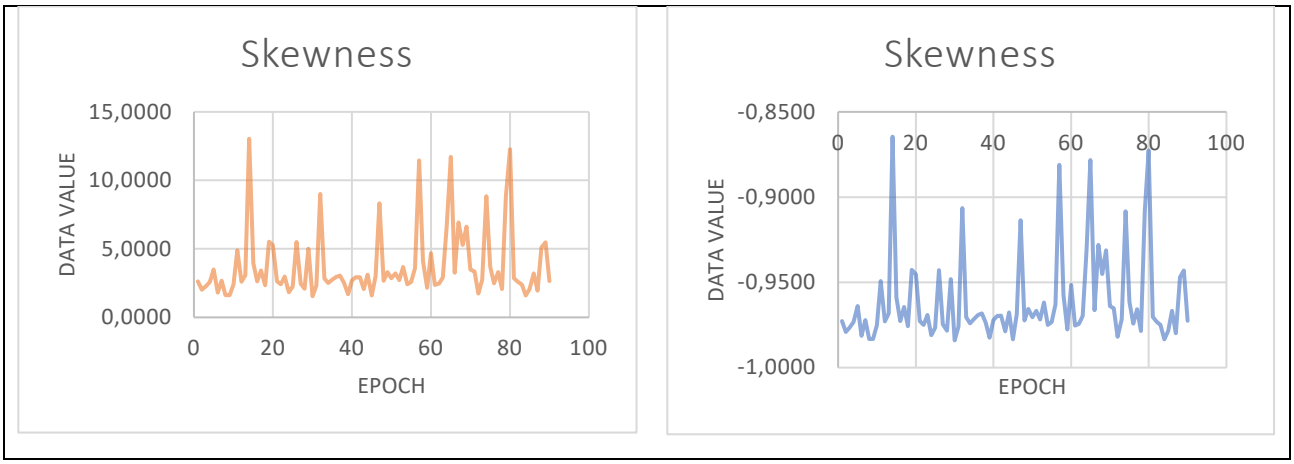

Fig. 8. Data 4 before and after game data normalization

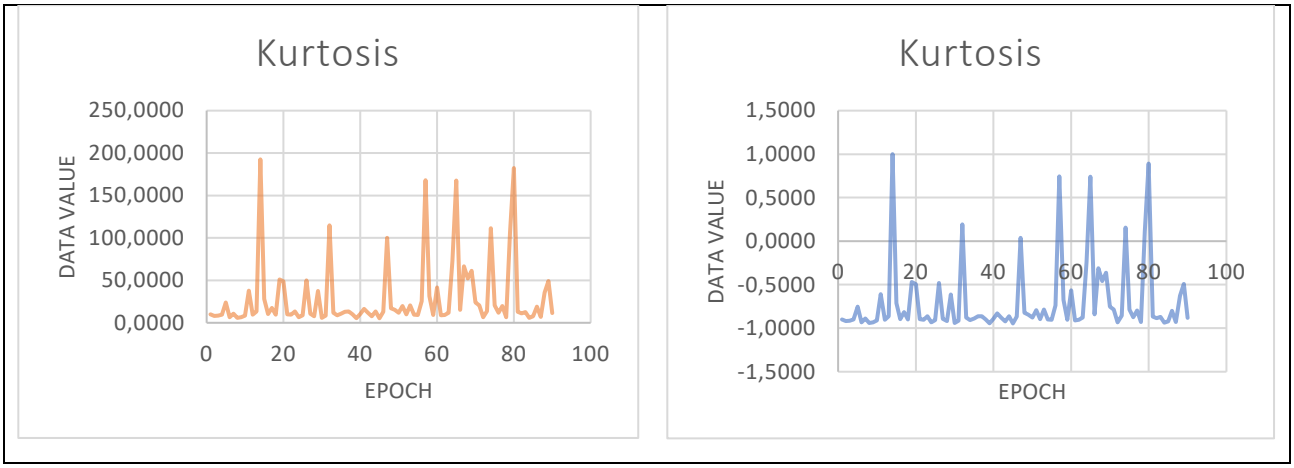

Fig. 9. Data 5 before and after game data normalization

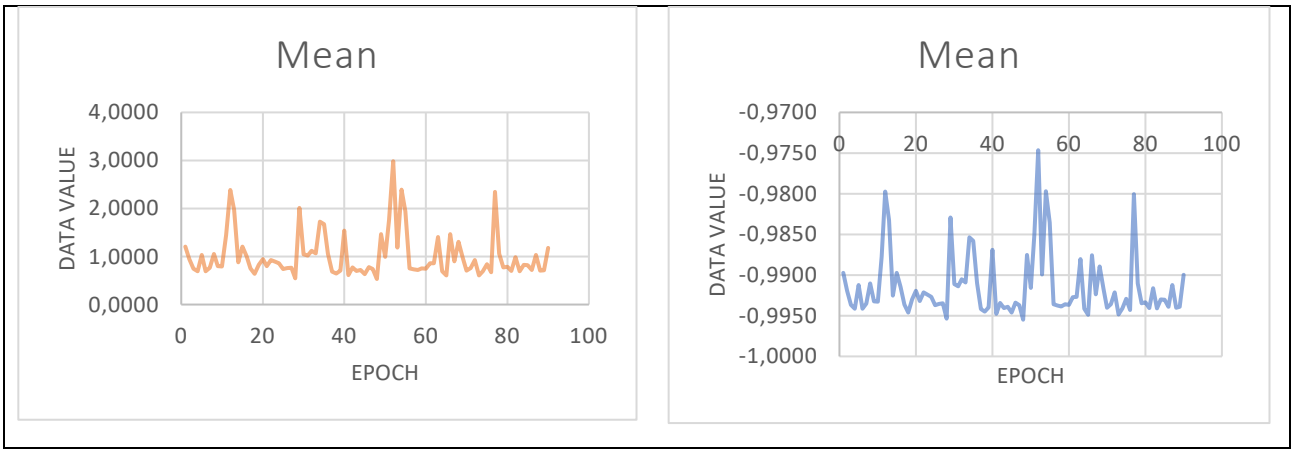

Fig. 10. Data 1 before and after SPM data normalization

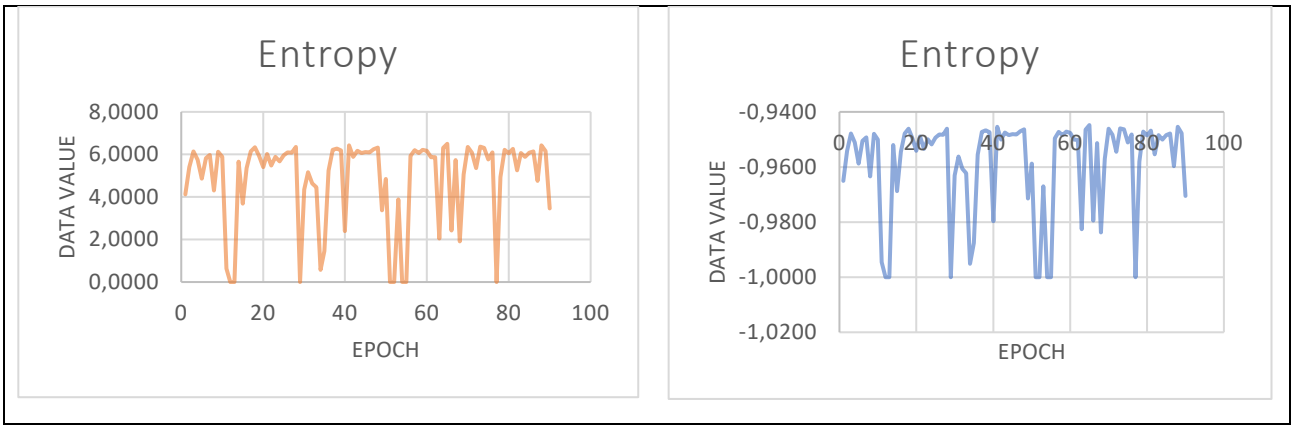

Fig. 11. Data 2 before and after SPM data normalization

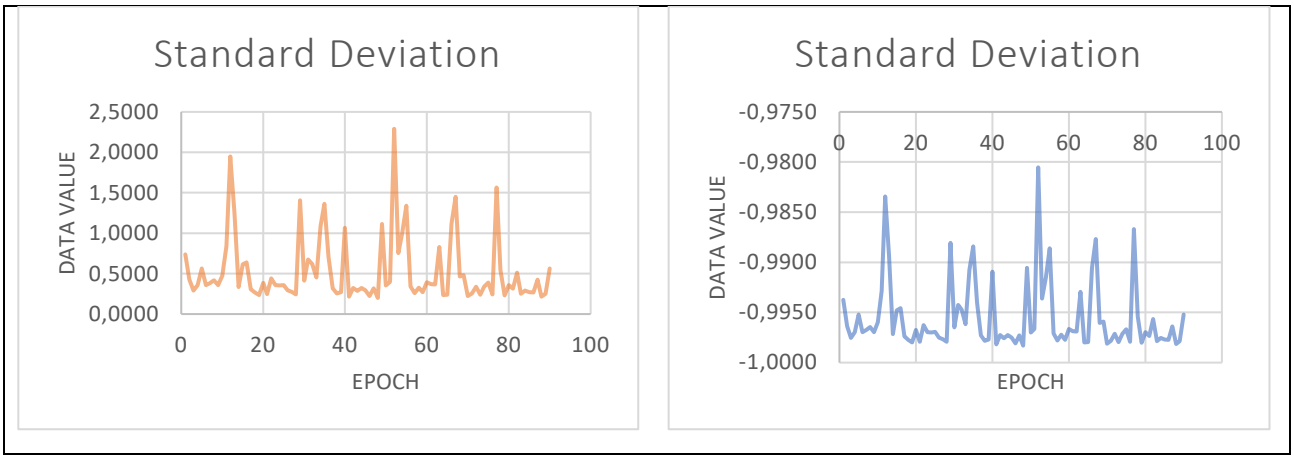

Fig. 12. Data 3 before and after SPM data normalization

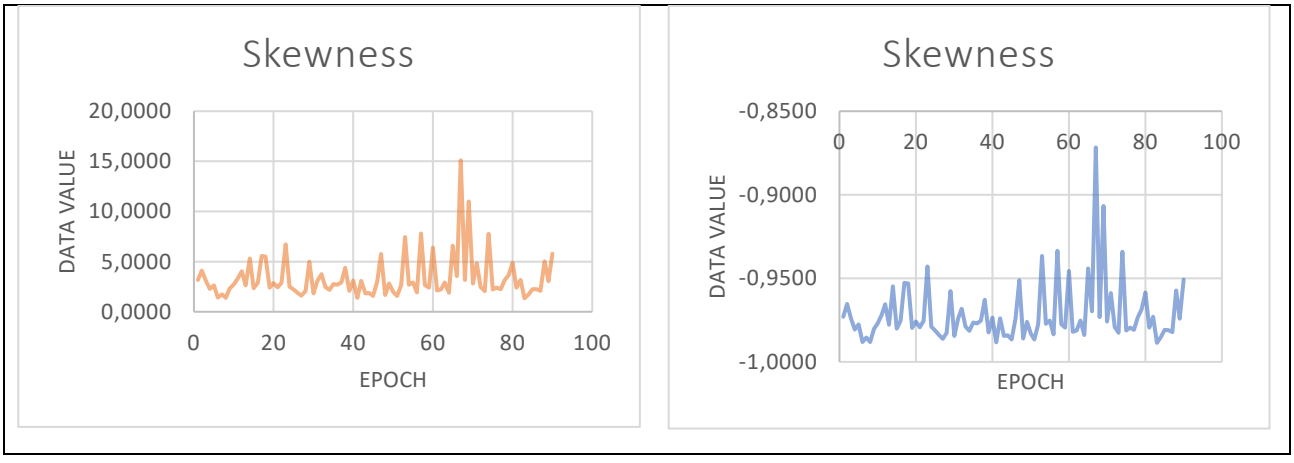

Fig. 13. Data 4 before and after SPM data normalization

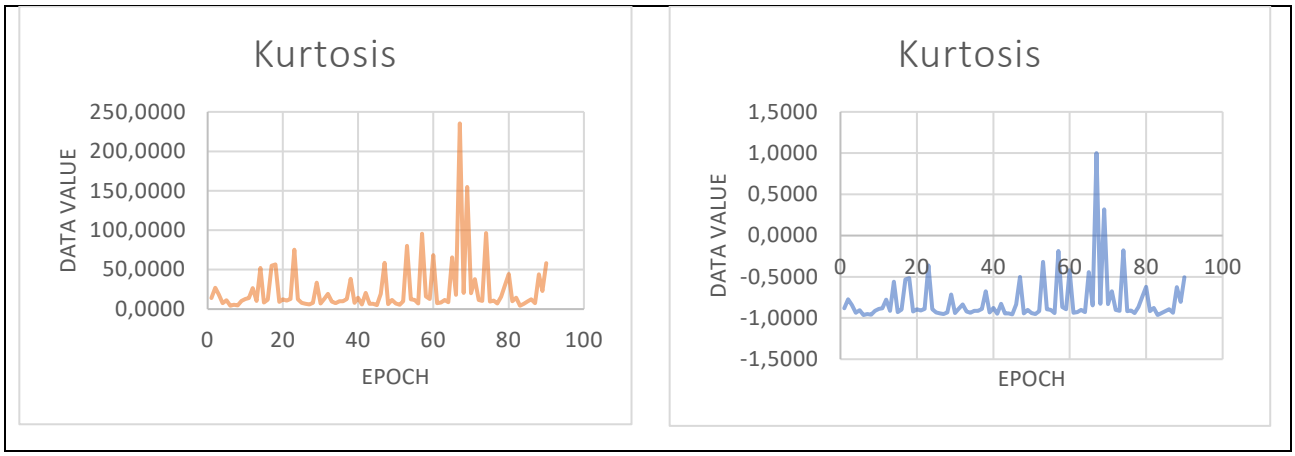

Fig. 14. Data 5 before and after SPM data normalization

4.5. Graphical User Interface (GUI) System

The implementation phase is used to fulfill all stages of the system designed, starting from the acquisition process to the classification and evaluation. The appearance of the implementation interface can be seen in Fig. 15.

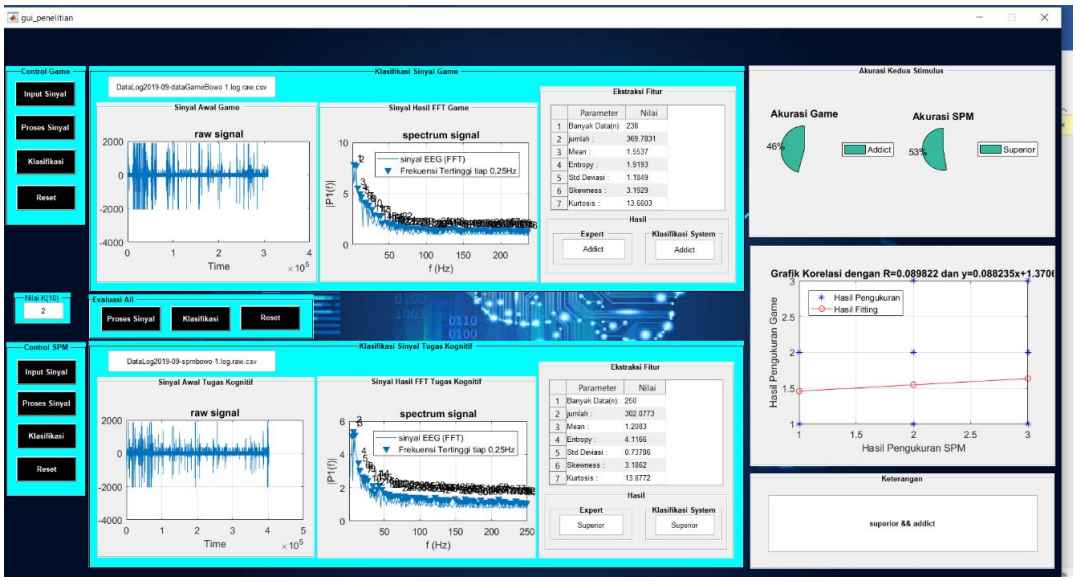

Fig. 15. GUI implementation

4.6. Testing

a. Game Accuracy Testing

Before testing the accuracy of the results of system testing with experts in each category, and the results of the prediction of numbers with K 1, 6, and 7 in Table 7. Calculation of the accuracy of the prediction results of game data can be seen in Table 8 The results of the calculation of the accuracy of the game.

Table 5. Game performance evaluation result

K-Value	K-1	K-6	K-10
TP	24	24	24
TN	0	0	0
FP	6	6	6
FN	0	0	0

Table 6. Game accuracy calculation results

K-Value	Percentage		
	K-1	K-6	K-7
Accuracy	80%	80%	80%
Precision	80%	80%	80%
Recall	100%	100%	100%

b. SPM Accuracy Level Testing

Before testing the accuracy of the results of system testing with experts in each category. The category Table can be seen in Table 7 and the system prediction results with K 1.6, and 7 in Table 8. Calculation of accuracy on the results of SPM prediction data can be seen in Table 10. SPM accuracy calculation results.

Table 7. SPM performance evaluation results

K-Value	K-1	K-6	K-7
TP	24	24	24
TN	0	0	0
FP	6	6	6
FN	0	0	0

Table 8. SPM accuracy calculation results

K-Value	Percentage		
	K-1	K-6	K-7
Accuracy	80%	80%	80%
Precision	80%	80%	80%
Recall	100%	100%	100%

5. Conclusion

a. Accuracy System

Conclusion of the accuracy value in the manual calculation of game stimulus and SPM Cognitive stimulus can be seen in Table 9 The results of the calculation of accuracy.

Table 9. System accuracy calculation results

Stimulus Type	K-Value	Category				
		SuiTable	Not suiTable	Accuracy	Precision	Recall
Game	**K-1**	26	4	80%	80%	100%
	K-6	28	2	80%	80%	100%
	K-7	29	1	80%	80%	100%
SPM	**K-1**	24	6	80%	80%	100%
	K-6	23	7	80%	80%	100%
	K-7	24	6	80%	80%	100%

The results of the calculation of accuracy in the system built are 80% and 80%

b. Expert System Accuracy

Respondents data are Superior but Addict and Respondents are Average but Addict can be calculated the percentage in Fig. 16.

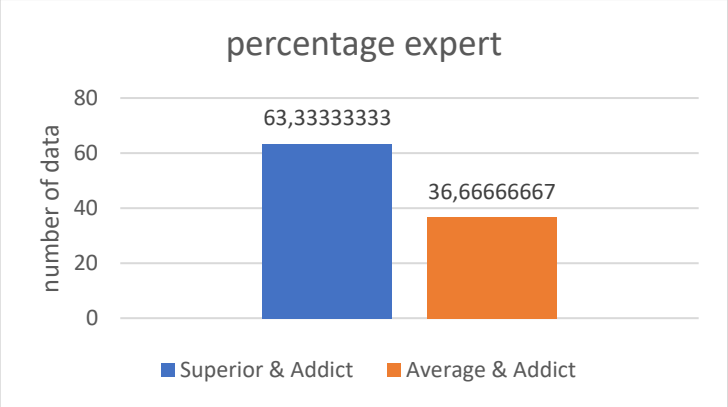

Fig. 16. Accuracy of expert results

In Fig. 6 the percentage of results from experts with respondents who are addicted but superior is equal to 63.3% and the percentage of respondents who are average but addicted is equal to 36.6%.

c. Correlation Between the Two Game Stimulus Data and SPM Stimulus

The correlation obtained in the two stimulus namely game stimulus and SPM stimulus has a correlation of 0.089822409 can be seen in Fig. 17.

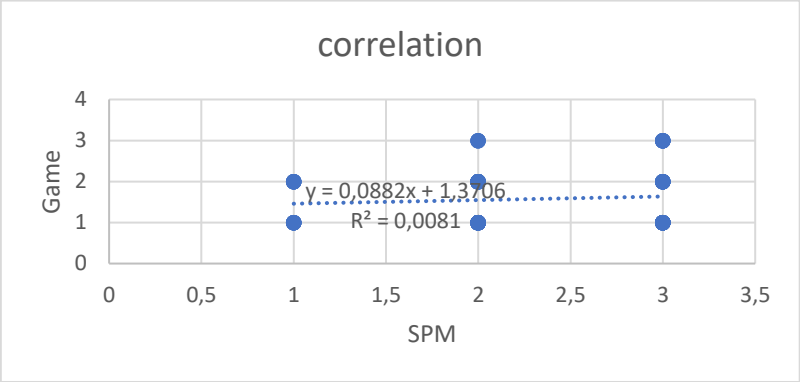

Fig. 17. Correlation between two types of stimulus

The K-Nearest Neighbor method is used to get predictions and accuracy on the system. The results of testing the accuracy of routine data retrieval with (3 times taking) get an accuracy value of 80% of game stimulus and 80% of SPM stimulus. While the percentage of results from expert respondents who were superior but addicted was 63.3% and the percentage of respondents who were average but addicted was 36.6% with a correlation level between Game and SPM of 0.089822409. So, it is concluded that there is no influence of the game on cognitive activity in late adolescents.

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