Classification of Concentration Levels in Adult-Early Phase using Brainwave Signals by Applying K-Nearest Neighbor

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ABSTRACT

The brain controls the center of human life. Through the brain, all activities of living can be done. One of them is cognitive activity. Brain performance is influenced by mental conditions, lifestyle, and age. Cognitive activity is an observation of mental action, so it includes psychological symptoms that involve memory in the brain's memory, information processing, and future planning. In this study, the concentration level was measured at the age of the adult-early phase (18-30 years) because in this phase, the brain thinks more abstractly and mental conditions influence it. The purpose of this study was to see the level of concentration in the adult-early phase with a stimulus in the form of cognitive activity using IQ tests with the type of Standard Progressive Matrices (SPM) tests. To find out the IQ test results require a long time, so in this study, a recording was done to get brain waves so that the results of the concentration level can be obtained quickly.

EEG data was taken using an Electroencephalogram (EEG) by applying the SPM test as a stimulus. The acquisition takes three times for each respondent, with a total of 10 respondents. The method implemented in this study is a classification with the k-Nearest Neighbor (kNN) algorithm. Before using this method, preprocessing is done first by reducing the signal and filtering the beta signal (13-30 Hz).

The results of the data taken will be extracted first to get the right features, feature extraction in this study using first-order statistical characteristics that aim to find out the typical information from the signals obtained. The results of this study are the classification of concentration levels in the categories of high, medium, and low. Finally, the results of this study show an accuracy rate of 70%.

1. Introduction

In general, the brain waves of each individual are different because brain waves cannot be copied or read by people. A person's cognitive quality can be obtained using information from the Electroencephalogram (EEG) signal. EEG signals are bioelectric signals originating from the surface of human skin, these signals are complex and can be used as a source of information on brain function [1].

EEG signals are generally measured based on specific frequency and recording time. The results of recording EEG signals consist of waves, signal orientation, and rhythm forms. EEG signals are recorded to inform electrical activity in the brain. EEG signals have been widely used in the medical field to diagnose brain damage and mental illness. EEG signals are also easy to use to find out a person's condition including the quality of cognitive activity [2][3].

IQ tests are used to determine the level of concentration in a person. However, the IQ test results cannot be immediately concluded because it requires justification from experts. In this case, the experts mentioned are Psychologists. Psychologists need time to calculate the right and wrong answers from each series of SPM test questions, one type of IQ test. IQ test results require a maximum duration of one week, therefore to simplify and shorten the time of calculation of results, a computational method is used, as in this study, by using EEG to record brain waves recorded while answering IQ tests.

This research was conducted to determine the level of concentration during the adult-early phase where in this phase was influenced by several variables such as age change which caused emotional, mental, and also activity instability because at this phase it was the phase of searching for identity or identity. Brain waves will be recorded with the Neurosky Mindset EEG Headset with an electrode located on the front of the head (Fp1). The EEG tool used is Neurosky Mindwave, can be seen in Fig. 1, while the placement of the electrode on the front head (Fp1) can be seen in Fig. 2 which is indicated by a red circle.

Fig. 1. Neurosky Mindwave

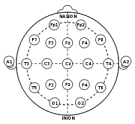

Fig. 2.EEG Electrode on FP1

In this study, the concentration level grouping based on cognitive activity applied the k-Nearest Neighbor algorithm. Preprocessing is done after getting the results from EEG recording. In this process, the beta signal is separated from other brain signals (Gamma, Alpha, Delta, and Theta). Beta signals have a frequency of 13-30 Hz and noise. The preprocessing stage produces a beta signal that is free from noise and other signals. The next step is to search for first-order characteristic values (mean, standard deviation, kurtosis, and skewness) to see the stability of the signal. Feature Signals that have been obtained in the form of statistical values are then grouped by applying the kNN algorithm, by first determining the value of k. Outputs are in the form of three levels of concentration, namely, high, medium, and low.

2. Previous Research

First, Research conducted by [4] with the title "Comparative Analysis of Alfa and Beta EEG Signal Patterns for Classification of Relaxed Conditions in Active Smokers by Using kNN" aims to analyze signal patterns using kNN which produces an accuracy rate of alpha 90% and beta signals 96.67 %.

In the 2016 study, a study of relaxed identification of EEG signals was carried out using Wavelet and Learning Vector Quantization. From this study, it is known that several variables affect EEG signals, namely the level of attention, the level of fatigue, the level of alertness. In this study, the identification carried out resulted in two classes, namely relaxed and not relaxed when the system recording used was a 10-20 system. In the previous research, relaxed conditions were in alpha, beta, and theta waves. When alpha wave relaxes conditions become dominant compared to other waves, on the contrary, when the conditions do not relax, the waves that appear are beta waves and theta — in this study, using ten respondents who were recorded with an EEG sampling frequency of 512 Hz. The recording is done for one minute and repeated ten times. Respondents were given stimulation in the form of music to create a relaxed atmosphere and to guess the picture to get as many scores as possible for the condition to not relax. The test used in this study aims to check the quality of the learning process so that it can be used for the testing process and get good accuracy.

In the 2016 study by [2], identification was done to determine the concentration level with EEG signals using Wavelet transformation and Adaptive Backpropagation and produced two class categories, including concentration classes and lack of concentration. This study recorded ten respondents aged 20-25 years using EEG by placing electrodes on the Fp1 channel. In the recording process, the stimulus used is a game of basic mathematical calculations. The recording is done for one minute, to get good concentration data recording is done for 80 seconds. The next step, the recorded data is filtered so that the data taken is data after the first ten seconds of recording. Recording conditions lack concentration is done for one minute by not giving any stimulation. Each

respondent made four recordings by the time specified, in this study the concentration conditions were seen with increasing beta waves of 14-30 Hz and gamma 30-50 Hz, while the less real conditions were seen with increasing alpha waves of 9-12 Hz. Testing is done by extraction and filters using Wavelet. The test results show that the use of Adaptive Backpropagation can accelerate the learning process with an accuracy rate of 75% and testing with Wavelet extraction gets an accuracy value of 95% for the tested training data and 45% for the newly tested test data while using a filter gets 100% accuracy for training data tested and 40% for new test data.

3. Method

3.1. Brainwave Data and Expert Judgement

EEG data is retrieved using an EEG tool, the NeuroSky mindwave, by providing a stimulus in the form of a basic cognitive activity that is carrying out the SPM test. Electrode placement on the scalp is in the position of FP1 (frontal lobe), based on the 10-20 system. The sampling frequency used is 512 Hz per second. The use of EEG data in this study focused on beta waves with a frequency of 12-30 Hz, based on on the EEG band on Neurosky Mindwave [5]–[7]. EEG band frequency comparison data can be seen in Figure 3.

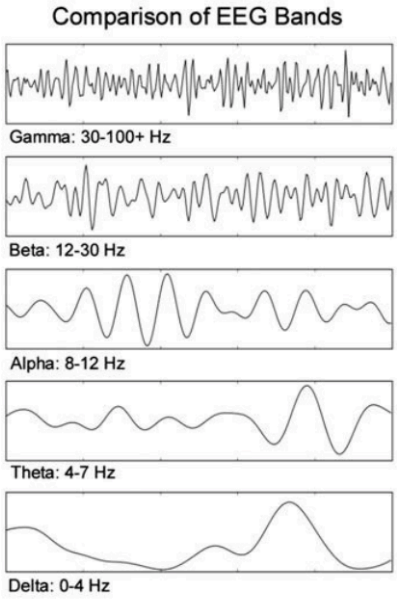

Fig. 3.EEG band frequency comparison data

The object of this study is the early adult phase according to periodization by Robert J. Havighurst, namely the age of 18-30 years based on the characteristics of people who are growing up according to Jeffrey Arnett [8]. Data collection involved ten respondents and was carried out in three different times, and the minimum data collection interval was two weeks.

Expert judgment was conducted by a psychologist named Amalia S.J. Kahar, S.Psi., M.Psi., Psychologists to find out whether a person's concentration can be known by conducting tests or observations. The results of interviews with psychologists, concentration can be known by conducting basic cognitive activities such as those found on the SPM test and observations by psychologists when respondents take the test.

3.2. Proposed Method

The method proposed in this study is illustrated in a flowchart which can be seen in Figure 4.

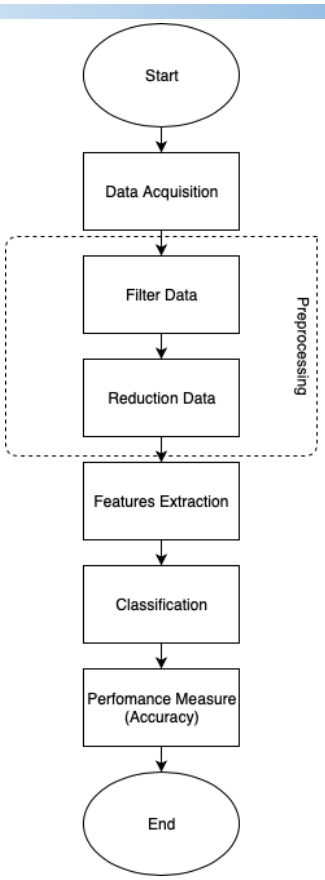

Fig. 4. The proposed method of this research

Figure 4 explains the proposed method in this research. The proposal is in the form of stages. The first stage, EEG data were acquired using an EEG tool, Neurosky Mindwave, with a sampling frequency of 512 Hz per second by placing electrodes in the frontal lobe, Fp1. Data acquisition involved ten respondents with cognitive stimuli of the brain used were psychological tests with the type of SPM. The processing time is 30 minutes. In the second stage, EEG data is filtered to separate beta signals from other EEG signals (alpha, gamma, theta, and delta) with the frequency bandpass signal set according to the beta range (13-30 Hz) with Fs = 512, Fstop1 = 12.9, Fspass1 = 13, Fstop2 = 30, Fpass2 = 30.1. The third stage, Reduction using principal component analysis (PCA) in order to minimize data or cut data by not eliminating important data. The fourth step is taking some features to use first-order feature extraction methods, mean, standard deviation, skewness, and kurtosis, to determine the characteristics of each respondent's data collection. The fifth stage, the classification uses the kNN method by determining the k-value in observation in order to get a good accuracy value of the k value, the training data and test data used must also be good. In this kNN calculation uses the Euclidean distance. The last stage, the evaluation phase of testing in this study uses accuracy testing using Confusion Matrix.

3.3. Standard Progressive Matrices (SPM)

The SPM consists of 60 questions with five groups A, B, C, D, and E. This test can be used for normal people aged 6-65 years. This test was designed by J.C Raven and was last published by H.K Lewis & Co.Ltd. London in 1960. This test can be done individually or classically because of instructions given orally. The preparation of this test is based on the concept of Spearman's intelligence, which refers to its conception of "education of relations and education of correlates". Raven also believes that this test is for clarity of observation and thinking [9], [10].

The results of SPM are not IQ numbers but are expressed in the form of intellectual level in several categories, according to the magnitude of the subjects tested are:

1. Grade I: Superior intellectuals
2. Grade II: Intellectuals above average

3. Grade III: Average intellectual property
4. Grade IV: Intellectuals below average
5. Grade V: Intellectual hampered

3.4. Feature Extraction

Feature extraction is used to get a pattern from an image to be tested. There are three feature extraction methods, one of which is statistical image extraction. This method uses the gray-level distribution statistics calculation technique by measuring the level of contrast, granularity, roughness, and roughness. The statistical feature extraction used in this study is the first-order statistical approach. First-order feature extraction depends on the histogram value, the histogram value that can be calculated is mean, skewness, standard deviation, and kurtosis [11], [12].

1. Mean ($\bar{x}$)

   The mean is used to measure the average from data distribution. The mean also shows the dispersion size of an image, can be seen in equation 1.

$$\bar{x} = \frac{x_1+x_2+x_3+\cdots+x_n}{n} \quad (1)$$

   With n representing the amount of data, the data to n is represented by x_1, x_2,...,x_n.

2. Standard Deviation (s)

   Measuring the standard deviation of data distribution, by looking for the value of s squared first or the value of variance. Can be seen in equation 2.

$$s^2 = \frac{(x_1 + \bar{x})^2 + \cdots + (x_n + \bar{x})^2}{n} \quad (2)$$

$$s = \sqrt{s^2}$$

   $x - \bar{x}$ is the frequency range of the value x with $\bar{x}$

3. Skewness ()

   Skewness is used to measure the slope level of data distribution, can be seen in equation 3.

$$\alpha_3 = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{(\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2})^3} \quad (3)$$

4. Kurtosis

   Kurtosis is used to measure the height of data distribution, can be seen in equation 4.

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

3.5. k-Nearest Neighbor (kNN)

The kNN method is one of Lazy Learner, including a very simple method without performing target functions on training data but directly applied to the target. This method works by finding the pattern k value (among all training data patterns in each label) closest to the pattern then determining

the decision class based on the highest number of patterns between the patterns (also called voting) [13].

The basic concept (algorithm) of KNN according to Pulung Nurtantio Andono in the book Digital Image Processing is: [14]

1. Determine the value of k (number of closest neighbors to be chosen).
2. Calculate the distance between the data to be classified with all training data using Euclidean distance.
3. Sort the distance formed (ascending sequence).
4. Determine the closest distance to a number of k.
5. Pair the corresponding class.
6. Find the number of classes from the most neighbors and set the class as the data class to be evaluated.

The kNN training process produces k values that can provide accuracy but to determine the pattern k cannot be determined mathematically. So, to get the optimal k value for accuracy, an experiment or observation must be made of a value of k.

3.6. Cognitive Activities

Cognitive activity is an individual behavior that has an impact on gaining knowledge. In addition, cognitive is also a mental condition because of indirect observations of cognition, hence cognition cannot be measured directly but through observable behavior [15]. According to Mayers, Cognition refers to all mental activities associated with thinking, knowing, and remembering. Kuper & Kuper also explained that cognition is a general term that involves many modes of understanding, such as perception, imagination, reasoning, observation, response, memory, thinking, and judgment in the Drever's Dictionary of Psychology. Cognition also involves forms of recognition, such as observing, seeing, watching, imagining, giving, guessing, and judging. Cognition is also contrasted with a will and with affection (feeling) in Chaplin's Dictionary of Psychology. Cognitive is always the main thing to determine someone in responding, thinking, processing information, storing information to get a pattern from a new environment. [15].

3.7. Performance Evaluation

Evaluating a classification model requires a set of test data that is not used in Training Data. Evaluation can use a certain size where:

- TP (true positive) defines a positive tuple number with label is correct by classification model.
- TN (true negative) defines the number of negative tuples correctly labeled by the classification model.
- FP (false negative) defines the wrong number of negative tuples is labeled by the classification model.
- FN (false negative) defines the wrong number of positive tuples is labeled by the classification model

An explanation of the above points can be explained as in Table 1. Evaluation Measurement.

Table 1. 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)

The four terms are described as confusion matrices, such as Table 2 Confusion Matrix.

Table 2. Confussion Matrix

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

1) Accuracy

Accuracy is the level of recognition that states the percentage of tuples in the test data that are correctly classified by the classification model [13]. The accuracy formula is shown in equation 5.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} * 100\% \quad (5)$$

2) Precision

Precision is the level of accuracy between the information requested by the user and the answer given by the system [13]. The precision formula is shown in equation 6.

$$Precision = \frac{TP}{TP + FP} * 100\% \quad (6)$$

3) Recall

Recall is the system's success rate in rediscovering information [13]. The recall formula is shown in equation 7.

$$Recall = \frac{TP}{TP + FN} * 100\% \quad (7)$$

4. Results and Discussion

Discussion of the results of this study will include several discussions related to data acquisition, preprocessing, feature extraction, implementation and classification, and performance evaluation tests.

4.1. Data Acquisition

Data acquisition in this study uses the EEG tool by giving stimulus to respondents. Data retrieval in this study was carried out up to 3 times with a time span of taking 14 days of 10 respondents who were willing to take brainwave data using SPM tests and paired EEG devices when doing the test. The recording time with an EEG device is 10 minutes which results in 15,3600 EEG signal points. The resulting brain wave point is the result of calculation of the frequency of the samples used in Neurosky, which is 128 every 0.5 seconds. The number of retrieval and test results from experts on each respondent can be seen in Table 3 Results of Expert Grouping on brainwave data.

Table 3. Expert Grouping Results on brainwave data

Subject	**Intake 1**	**Intake 2**	**Intake 3**
Resp. 1	Grade I	Grade II	Grade II+
Resp. 2	Grade II	Grade II	Grade II
Resp. 3	Grade I	Grade I	Grade I
Resp. 4	Grade II	Grade I	Grade I
Resp. 5	Grade III+	Grade II	Grade II
Resp. 6	Grade I	Grade I	Grade I
Resp. 7	Grade I +	Grade I +	Grade I +
Resp. 8	Grade I	Grade I +	Grade I +
Resp. 9	Grade I	Grade I +	Grade I

Resp. 10	Grade III+	Grade III+	Grade III+

4.2. Preprocessing

The data processing stage to obtain the frequency of the beta wave is 12-30 Hz. There are two stages to get these frequencies, the Filter and Reduction stages.

1. Filters

Filter is done to separate the waves with beta frequencies 18-30 Hz. In this signal separation using a Bandpass filter with the aim of only getting beta frequencies and rejecting data at other frequencies. When using a bandpass filter, the sample frequency and frequency range are described as Frequncy sample (Fs) = 512, Frequency stop 1 (Fstop1) = 12.9, Frequency pass 1 (Fpass) = 13, Frequency stop 2 (Fstop2) = 30, Frequency pass 2 (Fpass2) = 30.1.

2. Reduction

Reduction is done to minimize data or discard data that is not needed. Before disposing of data is normalized so that the range of numbers in the data is not so far away, normalization is done from the range -1 to 1.

4.3. Features Extraction

Feature extraction is used to find out statistical information available on EEG data. The results of first order feature extraction calculations can be seen in Table 4 Feature Extraction of brainwave data.

Table 4. Feature extraction of brainwave data

Intake	First-Order Feature Extraction			
	Mean	***Standard Deviation***	***Skewness***	***Kurtosis***
*Intake **1***	-0.1571	0.3467	0.4325	2.9523
	0.1175	0.7374	-0.2341	5.1889
	-0.0528	0.2300	0.1865	2.6940
	-0.2033	1.3150	0.3155	6.1181
	-0.0145	0.3973	-0.3123	2.9422
	0.0154	0.3257	0.2799	3.1173
	-0.0573	0.7513	-0.3382	3.3386
	-0.1101	0.8364	-1.0724	5.4697
	-0.0179	0.5261	-0.3266	2.7655
	0.0190	0.2098	-0.5626	6.1676
*Intake **2***	0.2268	0.2987	0.1814	2.9547
	0.1150	1.3902	1.6532	12.8987
	0.1134	0.4357	0.1571	2.2688
	0.0675	0.3538	-0.9314	12.4392
	0.3633	0.3839	-0.4369	4.1043
	0.0005	0.1790	-0.5748	5.0524
	-0.1539	0.9530	0.3788	12.4208
	0.0929	0.7807	-0.3398	3.4398
	0.0022	1.1751	-0.3742	1.9699
	0.0277	0.7012	-0.0945	2.4703
*Intake **3***	0.3073	1.5681	-0.8313	4.6139
	0.0096	0.6995	0.0150	3.0626
	-0.3259	1.0286	0.3122	3.7964
	-0.0179	0.6555	0.2528	2.8629
	0.0300	0.7592	-0.7291	7.7490
	-0.1142	1.0400	-0.2563	2.8146
	0.3713	2.2295	0.2316	2.9572
	-0.0178	1.0165	-0.3925	5.2838
	-0.0148	1.2957	0.3862	3.9052
	0.0323	0.9912	0.2900	2.1597

4.4. Implementation

At the implementation stage, the system is designed to meet all stages, from acquisition to classification and evaluation. The implementation interface can be seen in Figure 5.

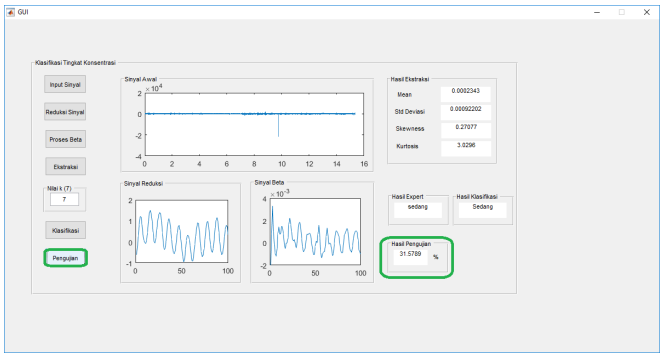

Fig. 5. Implementation of the EEG data classification interface

The results of the data classification of the system will be matched with the results of grouping by the experts (Expert). The results of the classification by experts can be seen in Table 5 Results of Grouping by Expert.

Table 5. Results of Grouping by Expert

Intake Data	First-order Features Extraction				Category (*Expert*)
	Mean	***Standard Deviation***	***Skewness***	***Kurtosis***	
1	-0.1571	0.3467	0.4325	2.9523	Low
	0.1175	0.7374	-0.2341	5.1889	
	-0.0528	0.2300	0.1865	2.6940	Medium
	-0.2033	1.3150	0.3155	6.1181	
	-0.0145	0.3973	-0.3123	2.9422	High
	0.0154	0.3257	0.2799	3.1173	
	-0.0573	0.7513	-0.3382	3.3386	
	-0.1101	0.8364	-1.0724	5.4697	
	-0.0179	0.5261	-0.3266	2.7655	
	0.0190	0.2098	-0.5626	6.1676	
2	0.2268	0.2987	0.1814	2.9547	Low
	0.1150	1.3902	1.6532	12.8987	Medium
	0.1134	0.4357	0.1571	2.2688	
	0.0675	0.3538	-0.9314	12.4392	
	0.3633	0.3839	-0.4369	4.1043	High
	0.0005	0.1790	-0.5748	5.0524	
	-0.1539	0.9530	0.3788	12.4208	
	0.0929	0.7807	-0.3398	3.4398	
	0.0022	1.1751	-0.3742	1.9699	
	0.0277	0.7012	-0.0945	2.4703	
3	0.3073	1.5681	-0.8313	4.6139	Low
	0.0096	0.6995	0.0150	3.0626	Medium
	-0.3259	1.0286	0.3122	3.7964	
	-0.0179	0.6555	0.2528	2.8629	
	0.0300	0.7592	-0.7291	7.7490	High
	-0.1142	1.0400	-0.2563	2.8146	
	0.3713	2.2295	0.2316	2.9572	
	-0.0178	1.0165	-0.3925	5.2838	
	-0.0148	1.2957	0.3862	3.9052	
	0.0323	0.9912	0.2900	2.1597	

System testing is done to test the system that has been made by matching directly using classification data from experts. The data used are 30 data for each of the high, medium and low categories. The results of the test data in the system can be seen in Table 6.

Table 6. Evaluation result

k-value	Low	Medium	High	Result
3	0	1	6	Matched
	1	2	0	Not Matched
5	0	1	5	Matched
	1	2	1	Not Matched
7	0	1	6	Matched
	1	2	0	Not Matched

Determination of the value of performance using the calculation of Accuracy, Precision, and Recall of the confusion matrix. By calculating the difference between each result of the k-value that has been tested is 3, 5, and 7. The results of the calculation can be seen in Table 7. The results of the calculation of Accuracy, Precision, and Recall.

Table 7. Performance evaluation result

k-value	**k-1**	**k-2**	**k-3**
TP	7	6	7
FP	0	0	0
FN	3	4	3
TN	0	0	0
Accuracy	70%	60%	70%
Precision	100%	100%	100%
Recall	70%	60%	70%

5. Conclusion

The purpose of this research is to look at the level of concentration in the adult-early phase with stimulus in the form of cognitive activity using an IQ test with a type of Standard Progressive Matrices (SPM). Based on research conducted, data obtained from 30 respondents' data showed the results of grouping the concentration level using the k-Nearest Neighbor (k-NN) method with an accuracy percentage of 70%. The application of the k-NN method into the system created can group data based on the given category and is able to provide information about the category.

This research provides simulation results related to the recording of IQ test results, this research succeeded in forming individual patterns related to the cognitive concentration of the respondents. The use of patterns in training data can accelerate the computational results from assessing IQ test results.

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