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Study on the classification and the relationship with brain function regions of multiple intelligences

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ABSTRACT

The researchers collect the 19-lead EEG signals corresponding to visual-spatial intelligence, logical-mathematical intelligence and bodily-kinesthetic intelligence in the multiple intelligences, extract the frequency characteristics of the δ、θ、α、ß bands as the features of classifier to study the classification performance based on SVM, and then analyze the corresponding relationship between multiple intelligences and brain function regions by ranking the contribution of the lead features to the classification. The result shows that: (1) The identify rate of various intelligences reaches 61% or better, while the classification result of α, β bands is better than θ, δ band, among which α band is the best; (2) Experiment result shows that there is a significant intelligence difference between the people of different professions, it also shows that professional education and training can make changes in the structure of a person's multiple intelligences; (3) From the contribution of the lead-features to the classification we can find that leads Cz, T4, C4, Pz respond more to visual-spatial intelligence, while leads P3, O1, T5, T3 respond more to logical-mathematical intelligence. This conclusion is important to the further development of cognitive science and the analysis of brain function.

KEYWORDS

Multiple intelligences; SVM; Classification; Features ranking; Brain function regions.

INTRODUCTION

According to the theory of multiple intelligences, each individual has relatively independent and specific cognition fields or multiple intelligences of related knowledge categories, i.e. linguistic intelligence, logical-mathematical intelligence, visual-spatial intelligence, bodily-kinesthetic intelligence, musical intelligence, interpersonal intelligence, intrapersonal intelligence and naturalistic intelligence[1]. The combination of these intelligences in each individual in different ways and different levels makes each individual's intelligences distinctive, and such intelligence can be developed and strengthened, or may be neglected or weakened[2-4]. The present studies on Multiple Intelligences mainly focus on theoretical research and applications to education. Based on the quantitative analysis of classification characteristics of multiple intelligences and the relationship between multiple intelligences and brain function regions through EEG Intelligence Modeling, this article intends to provide Multiple Intelligences with the basis of biology[5].

EEG records the signals of neurons' electrical activity through cerebral cortex and obvious characteristics and non-invasiveness feature the EEG analysis. The study shows that both different physiological states and mental condition can make EEG show different patterns. The present studies on EEG mainly focus on prevention and diagnosis of mental illnesses, the areas of human-computer interaction, etc, and some fruits have been obtained[6-8]. But researches on multiple intelligences by EEG intelligent modeling have not been reported.

EEG is rich in frequency components, whose frequency changes in the range of 1-30 times per second. Generally it can be divided into four bands, namely δ (1-3Hz), θ (4-7Hz), α (8-13Hz), β (14-30Hz). Some bands' energy distribution in different regions of the scalp may change in different physiological and psychological states. So we can extract the energy in different bands of EEG as a characteristic parameter, and then conduct in-depth study by using intelligence modeling and methods of pattern recognition. In this article, the authors first design psychological imagination tasks for different intelligences, then test the corresponding EEG (19 leads) to typical professional college students, and finally carry out researches on multiple intelligence categories and the relationship between multiple intelligences and brain function regions by means of Support Vector Machine (SVM), a pattern recognition tool, which helps to solve some practical problems characterized by small samples, nonlinear, high dimension and local minimum point etc.

SVM Classification and Features Ranking

SVM Classification

SVM is a new machine learning method put forward by Vapnik et al, and mainly aims at two types of classifications based on the principle of structural risk minimization of statistical learning theory. Its basic principle is to find a hyper plane as the division of two types of classification in high-dimensional space in order to ensure the minimum classification error rate. It has been successful in solving a series of practical problems[9-10].

Taking two types of classification as example, it is assumed that $((x_1, y_1)\cdots(x_n, y_n))$ is the training data set, x_i is the representative of the data, and $y_i \in(-1,+1)$ is the classification label. Through this data set, SVM is based on a linear discriminate in a high-dimensional feature space. By maximizing the border distance to distinguish the two types of classification, it corresponds to the following quadratic programming function:

$$\min \frac{1}{2} w.w^T + C\sum_{i=1}^{N} \xi_i \quad (1)$$

$$s.t.\begin{cases}\forall i y_i(w \bullet \Phi(x_i)+b) \geq 1-\xi_i \\ \forall i \xi_i \geq 0\end{cases} \quad \textbf{(2)}$$

In the function above, ξ_i is the slack variable to describe the wrong sub-level of the training sample set. It is converted to the dual problem by Lagrangian function.

$$W(a) \equiv \sum_{i=1}^{N} ai - \frac{1}{2}\sum_{i,j} a_i a_j y_i y_j K(x_i x_j) \quad \textbf{(3)}$$

$$s.t.\begin{cases}\forall i 0 \leq a_i \leq C \\ \sum_{1}^{n} a_i y_i = 0\end{cases} \quad \textbf{(4)}$$

Here $\Phi(.)$ is the mapping from input space to feature space, $K(x_i, x_j) = (\Phi(x_i), \Phi(x_j))$ is the kernel matrix, and the sample point corresponding to $a_i \neq 0$ is called support vector.

SVM Feature Ranking

Feature Ranking, also called Feature Elimination, first trains classifier, then calculates the weight of feature selection, and finally ranks features according to their weight to select the best feature. In the classification of different intelligences, as long as we can determine which location of the EEG signals is the most effective for classification, we can know the region which is the most sensitive to such intelligence and then can determine which brain function regions correspond to different intelligences. Based on Feature Ranking of support vector machine (SVM), the algorithm is as follows:

(1) Input: training sample

$$X_0 = [x_1, x_2, ...x_k, ...x_l]^T$$

Category label: $y = [y_1, y_2, ...y_k, ...y_l]^T$,

(2) Initialization：the remaining feature subset, $s = [1, 2, ...n]$,feature ranking table $r = [\ ]$,

(3) Training classifier:

$$\alpha = SVM - train(X, y) \quad \textbf{(5)}$$

(4) Calculating the weight vector of the length dimension:

$$w = \sum_k \alpha_k y_k x_k \quad \textbf{(6)}$$

(5) Calculating the ranking criteria: $c_i = (w_i)^2$, all *i*, find out the minimum features of the ranking criteria, $f = \arg\min(c)$,

(6) Updating feature ranking table:

$$r = \left[s(f), r \right] \tag{7}$$

(7) Eliminating the minimum features of ranking criteria：

$$s = \left(1 : f - 1, f + 1 : length(s)\right) \tag{8}$$

(8) Looping until the classification accuracy does not change,
(9) Output: feature ranking table: r.

EEG Signal Acquisition of Multiple Intelligences, Feature Parameter Selection

The experiment of this article is conducted in the Nanjing Brain Hospital by using 19-lead EEG signal sampling equipment. 19-lead EEG is placed in accordance with the international standard lead, 10-20 system, as is shown in Figure 1, the reference electrode is the left and right ear lobe, the sampling frequency is 512HZ. After 19 Road EEG signal is analyzed by spectral, each road obtains the four energy values corresponding δ、θ、α、β 4 frequency bands as the characteristic parameters. 19 Road EEG has 76 in total. The relationship between feature coding and leads correspondence is shown in TABLE 1 (the last coding 0-3 corresponds to δ、θ、α、β 4 frequency bands respectively).

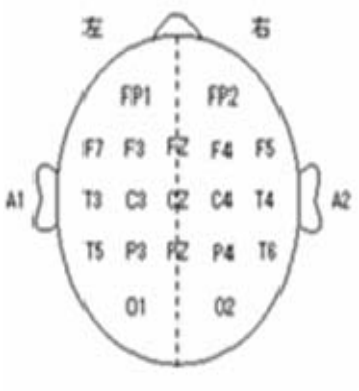

Figure 1 : 10-20 Corresponding figure of the international lead

TABLE 1 : The Characteristic Parameters Encoding and Brain Function Regions

Lead	FP1	FP2	F7	F3	FZ	F4	F5
Feature Encoding	f10	f20	f30	f40	f50	f60	f70
	f11	f21	f31	f41	f51	f61	f71
	f12	f22	f32	f42	f52	f62	f72
	f13	f23	f33	f43	f53	f63	f73

Lead	T3	C3	CZ	C4	T4	T5
Feature Encoding	f80	f90	f100	f110	f120	f130
	f81	f91	f101	f111	f121	f131
	f82	f92	f102	f112	f122	f132
	f83	f93	f103	f113	f123	f133

Lead	P3	PZ	P4	T6	O1	O2
Feature Encoding	f140	f150	f160	f170	f180	f190
	f141	f151	f161	f171	f181	f191
	f142	f152	f162	f172	f182	f192
	f143	f153	f163	f173	f183	f193

The experiment subjects in this article are college students who are prominent in some intelligence field, among whom, 10 are first-grade postgraduates majoring in art design (good at visual-spatial intelligence), 10 are freshmen from the Physical Education Department (good at bodily-kinesthetic intelligence), 10 are first-grade postgraduates majoring in educational technology (good at logical-mathematical intelligence), 8 psychological imagination tasks related to visual-spatial intelligence, logical-mathematical intelligence and bodily-kinesthetic intelligence are designed.

The steps of psychological tasks are as follows:

(1) Relax with eyes closed, without any imagination for two minutes.

(2) The subjects imagine designing a house for themselves, including the house structure, the shape, the color and the display location of furniture, etc. with eyes closed for 90 minutes. After that, the subjects self-regulate and relax without any imagination for one minute.

(3) The subjects imagine designing a sculpture on the plaza, including the shape and the color of the sculpture with eyes closed for 90 minutes. After that, the subjects self-regulate and relax without any imagination for one minute.

(4) The subjects do mental arithmetic on sum of all even or odd numbers from 1 to 100 with eyes closed; if mental arithmetic is over, they move their fingers to indicate their completion. After that, the testers record the answers and the subjects self-regulate and relax without any imagination for 1 minute.

(5) The subjects do mental arithmetic on the area of the regular hexagon with side length 6cm with eyes closed; if mental arithmetic is over, they move their fingers to indicate their completion. After that, the testers record the answers and the subjects self-regulate and relax without any imagination for 1 minute.

(6) The subjects do mental arithmetic on descend in sequence starting from 100; if mental arithmetic is over, they move their fingers to indicate their completion. After that, the testers record the answers and the subjects self-regulate and relax without any imagination for 1 minute.

(7) The subjects imagine themselves doing high jump action and repeat imagination with eyes closed for one minute. After that, the subjects self-regulate and relax without any imagination for 1 minute.

(8) The subjects imagine themselves doing swimming moves and repeat imagination with eyes closed for one minute.

Here, 2 and 3 are visual-spatial intelligence, 4, 5 and 6 are logical-mathematical intelligence, 7 and 8 are bodily-kinesthetic intelligence. After obtaining the EEG signals, the researchers remove some significant artifact signals caused by the subjects' physiological processes (such as swallowing, coughing, eye movements, drowsiness and other activities) under the doctor's guidance and then analyzed and processed.

Data Analysis

Comparison of classification accuracy of multiple intelligences under different frequency

First of all, using the power spectrum of different frequency bands δ, θ, α, β as characteristic parameters respectively, the researcher classifies different psychological imagination tasks between every two groups. In the experiment, 5 groups cross-validation of SVM is adopted. It was discovered

that the Classification accuracy between visual-spatial intelligence with bodily-kinesthetic intelligence is low; while the Classification accuracy between visual-spatial intelligence with logical-mathematical intelligence and bodily-kinesthetic intelligence with logical-mathematical intelligence is higher. TABLE 2 is the classification result of two kinds of visual-spatial intelligence and three kinds of logical-mathematical intelligence. The numbers of the Classification accuracy in the table are the average of the experiment individuals. From the table, we can see that the classification accuracy of α, β bands is higher. From the physiological perspective, it is viewed that this is mainly because the β band acts more intensively when the mind is sober, the eyes are open, and the brain is active; when the mind is sober, the eyes are closed, and the brain is quite, the α band acts more intensively.

TABLE 2 : Comparison of classification accuracy of task classification in different bands

State	2vs4	2vs5	2vs6	3vs4	3vs5	3vs6
δ	45%	56%	46%	59%	56%	57%
θ	52%	57%	44%	54%	70%	56%
α	73%	74%	61%	75%	76%	64%
β	56%	76%	59%	73%	75%	76%

Classification of Multiple Intelligences of students in different majors

Next, we observe the differences of different intelligences of students in different majors, and obtain the correspondence between intelligences and brain function regions in accordance with the aforementioned feature ranking. TABLE 3 is the classification results of the visual-spatial intelligence and the parameters ranking of its corresponding feature for the three kinds of students with specialty.

TABLE 3 : The classification results of the visual-spatial intelligence of students in different majors and its parameters ranking of the corresponding features

Majors	Art VS P.E	Art VS Educational	Educational VS P.E
Classification accuracy	81.25%	100.00%	82.14%
Characteristic parameters	f122 f103 f113	f153 f152 f123	f113 f122 F112
Corresponding Leads	T4 Cz C4	Pz Pz T4	C4 T4 C4

From TABLE 3, it can be seen that EEG signals of the visual-spatial intelligence of students from art department and educational technology department can be fully discriminated (100%), indicating that after years of professional training, there exist big differences in their brain functions of students from art department and educational technology department. From the corresponding lead-feature brain function region, the Cz, T4, C4, Pz electrodes of the lower right half of the brain play more important roles to the classification of the visual-spatial intelligence.

TABLE 4 : The classification results of the logical-mathematical intelligence of students in different majors and its parameters ranking of the corresponding features

Majors	Art VS P.E	Art VS Educational	Educational VS P.E
Classification accuracy	84.38%	89.29%	75.00%
Characteristic parameters	f142 f183 f132	F182	F132

		f133	f143
		f82	f142
		O1	T5
Corresponding Leads	P3 O1 T5	T5	P3
		T3	P3

TABLE 4 is the classification results of logical-mathematical intelligence and the parameters ranking of its corresponding features for the three kinds of students with specialty. From the table, it can been seen that the P3、 O1、T5、T3 etc electrodes of the lower left half of the brain play more important roles to the classification of the logical-mathematical intelligence.

TABLE 5 is the classification results of bodily-kinesthetic intelligence and the parameters ranking of its corresponding features for the three kinds of students with specialty. From the table, relatively speaking, we can see that the classification accuracy in bodily-kinesthetic intelligence is low for students majoring in art and physical education（68.75%）, indicating that it is not obvious in Classification accuracy of bodily-kinesthetic intelligence of students from art department and physical education department. In addition, the position of the leads which play a more important role to the classification is relatively dispersed.

TABLE 5 : The classification results of bodily-kinesthetic intelligence of students in different majors and its parameters ranking of the corresponding features

Majors	Art VS P.E	Art VS Educational	Educational VS P.E
Classification accuracy	68.75%	89.29%	78.57%
		f23	f173
Characteristic parameters	f112 f183 f22	f173	f193
		f122	f172
		FP2	T6
Corresponding Leads	C4 O1 FP2	T6	O2
		T4	T6

In the above-mentioned comparison among the three groups, the differences of EEG signals of students from art department and educational technology department are the biggest, and the average accuracy is 89.29%, followed by the differences of EEG signals of students from educational technology and physical education department, whose average accuracy is 78.57%; the least obvious ones are the differences of EEG signals of students from art department and physical education department, whose average accuracy is 68.75%.

CONCLUSIONS

Through the acquisition of EEG signals of psychological imagination tasks of students' different intelligences from typical majors, the quantitative research was conducted on the classification accuracy of multiple intelligences, the differences of multiple intelligences of students in different majors as well as the relationship between multiple intelligences and brain function regions with the help of intelligent information processing technology for the first time. The results indicate that, α, β bands are of more significance to multiple intelligences; there is a significant intelligence difference between strong intelligences and weak intelligences of students in different majors, it also shows that education can cultivate a person's specialty and professional education and training can make changes in the structure

of a person's multiple intelligences; the right lower half of the brain and the left lower half of the brain have more obvious influence on visual-spatial intelligence and logical-mathematical intelligence.

The conclusion of this article is basically consistent with the views of educational experts[7], which is of positive significance to carry out in-depth and quantitative researches on cognitive science and brain function. In the future research, we will further explore the relationship between other intelligences and the distribution rules in their brain.

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