Electroencephalographic Characteristic of Automatic Calibration of Finger Movements in Graphic Design

Jian Liu

ABSTRACT

With the development of the graphic design, the computers replace the traditional paper drawing process, which means the high requirement about the finger movement during normal work. In this paper, a experiment has been done to collect the electroencephalography signal of finger automatic correction under the situation of graphic design, which is highly relied on the finger movement to operate the computer. The research outcome presents that the half brain difference on bereits-chaft-spotential (BP) and event-related desynchronization (ERD) are two characteristics of electroencephalography signal when the automatic correction happens in the finger movement, which means that the opposite brain would be more active when the single side finger moved. The characteristic of electroencephalography signal would benefit the exploration and development of graphic design assist system to improve the efficiency of design process.

Key Words: Electroencephalographic Characteristic, Bereits-chaft-spotential, Event-related Desynchronization, Automatic Calibration, Graphic Design

DOI Number: 10.14704/nq.2018.16.5.1250 **NeuroQuantology 2018; 16(5):706-712**

Introduction

The automatic calibration of finger movements of human beings, as highly evolved primates, plays an important role in daily life. From daily activities such as dining and drinking, to cultural acts such as writing and typing, automatic calibration of finger movements plays a crucial role. When finger movements make changes beyond expectation, the brain will produce rapid response to the changes (Bobick and Davis, 2001). This response is beyond the control of the subjective awareness in a certain period of time, that is, the electroencephalogram (EEG) produced by habitual response can automatically correct the wrong finger movements before the formation of subjective consciousness. The part of brain involved in the automatic calibration of the left and right fingers is mainly in the cortex of the posterior parietal region. Its close practice in visual networks promotes the production of automatic calibration of EEG.

Traditional graphic design, such as advertisement design, is mainly two-dimensional graphic drawing which relies on pen, ruler and other drawing tools. Its requirements on practitioners in the industry are not only flexible and accurate finger movements, but the movements of wrists and elbows. With the development of electronic computers, computer graphics gradually replace freehand sketching and the graphic design is no longer limited to two-dimensional graphs but extends to three-dimensional animation or video clips. The reliance on electronic computers not only increases the efficiency of sketching, but also releases upper body joints such as wrists and elbows.

Corresponding author: Jian Liu
Address: Shandong University of arts, Jinan 250014, China
e-mail ✉ liujian6984@163.com
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 20 February 2018; **Accepted:** 22 March 2018

Thus, the physical requirement of graphic design industry on practitioners is only finger movements. By observing the working status of practitioners in the graphic design industry and analyzing the operating commands of the commonly used cartographic software, it is found that the requirements of graphic design on finger movements are mainly the left hand's control of keyboard keys and the right hand's control of mouse keys and wheels.

If the event-related EEG can be converted to the corresponding instruction to be input into the computer, then the hands of graphic designers to achieve brain-computer interaction design can be liberated, which will be another major technological innovation in the graphic design industry after the computer graphics. Brain-computer interaction establishes a communication path between the human brain and a computer or other electronic device so that people can generate commands through the brain and then make the computer or other electronic device execute (Liao *et al.,* 2007). The designer's imagination of specific movement steps can form event-related brain wave and the commands of specific finger movements are sent out in the form of EEG. When this information is captured and disposed by the computer, it can be converted into computer language through corresponding algorithm. The study on electroencephalographic characteristic of automatic calibration of finger movements can correct the wrong finger habits of the corresponding graphic designers in the process of graphic design and then it is taken as an auxiliary support system that can save events so as to improve the work efficiency of graphic designers. At the same time, this can relieve the pressure on the finger joints of graphic designers, reducing the work load and increasing the output.

In this paper, corresponding electroencephalographic signal of automatically corrected finger movements are collected under the corresponding scenario simulation of graphic design. Through the corresponding calculation steps, the electroencephalographic signal are decomposed and analyzed to obtain that readiness potential and hemi-brain difference of event-related desynchronization potential are the two most obvious electroencephalographic characteristic of automatic calibration of finger movements.

The Design of Experiment Procedure about Automatic Correction of Finger Movement under Graphic Design Situation

Screening of subjects

The subjects in the paper are graphic design practitioners who are finger-well and 25-40 years old. All subjects are right-handed with no history of mental illness and their strength is normal or reaches the normal level after calibration. In order to ensure the universality of experimental results, the selected subjects are five male graphic design practitioners and five female graphic design practitioners. During the experiment, the subjects should maintain the correct sitting position with the back of the spine being vertical, the feet falling to the ground, and the legs being perpendicular to the ground. And the head is upright and eyes shall watch computer screen, 450~500 mm away from the screen. The head should be kept motionless to reduce the impact of shaking on the EEG acquisition. Shoulder shall be relaxed and forearms are put on the desktop. The left hand is responsible for the operation of the keyboard and the right hand gently holds the mouse. This series of standardized sitting requirements is to reduce the impact of uncorrelated factors on EEG acquisition as much as possible, otherwise it will lead to experimental errors.

Selection and installation of experimental equipment

This experiment is the automatic calibration of finger movements in the graphic design. The experimental subjects should operate the most common graphic design device, namely mouse and keyboard, and complete the experiment according to the corresponding scenario simulation. EEG acquisition equipment is UE-16B model machine produced by Zhongke Xintuo Co., Ltd. Electrodes are placed on the head of the subjects in compliance with the International 10-20 Standard System, namely the standard electrode placement method stipulated by the International Society for EEG, with a sampling frequency of 100 Hz (Leocani *et al.,* 1997). For the experimental setting of obvious left and right hand cooperation and the expected semi-brain characteristic will be more obvious, focus will be put on EEG changes monitored on C3 and C4 electrodes because area near C3 and C4 electrodes represents the left and right sensorimotor area. In order to ensure the accuracy of the experimental results, the experiment shall be conducted in a shielding room dedicated to EEG experiments to shield the irrelevant sound and electromagnetic interference from outside so as to ensure the smooth operation of the experiment and the credibility of the results.

Scenario simulation of experiment stimulation

In the normal graphic design process, it is difficult to collect EEG data of automatic calibration of fingers. Therefore, there are mainly two kinds of scenario simulation of automatic calibration of fingers in the experiments of study on electroencephalographic characteristic of automatic calibration of finger movements in graphic design. That the right index finger presses the left mouse button to move can be considered the highest frequency of finger movements in the graphic design work. So the entire process should be as accurate as possible to control the mouse to

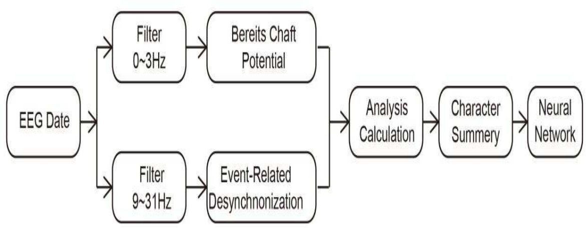


Figure 1. Diagram about Experiment Procedures and Following Analysis & Calculate Process

ensure the movement of finger joints. Another scenario is left-handed fingers' switch on the keyboard. Usually, graphic drawing should be compatible with shortcuts, so the choice of left-handed fingers on the keyboard is also high-frequency scenario in the graphic design. Diagram about Experiment Procedures and Following Analysis & Calculate Process as shown in figure 1.

Experimental Outcome Analysis and Two Main Electroencephalography Characteristics

Data collection

EEG of automatic calibration of finger movements is collected by UE-16B model machine produced by Zhongke Xintuo Co., Ltd. The electroencephalographic signal are processed subsequently to generate EEG and the event-related potential (ERP) is shown in the following table 1. ERP, namely cognitive potential, is the special potential recorded in the skull surface monitoring under the stimulation of specific external events, which is closely related to cerebral cortex nerve activity. It can be seen from the following data that significant ERP is generated during the right hand controls the mouse and left hand controls the keyboard, resulting in an increase of electroencephalographic power spectrum, namely event-related synchronization potential, or a decrease of electroencephalographic power spectrum, namely event-related desynchronization potential. For the activities of the left and right fingers, significant readiness potential is detected on the surface of the heads of subjects before the corrective movements while the event-related synchronization/ desynchronization potential occurs both before and after the event. The decrease of electroencephalographic power spectrum occurs before the event while the increase of electroencephalographic power spectrum occurs before the event.

The biggest difference between the readiness potential and the event-related synchronization/ desynchronization potential lies in frequency. Generally speaking, the frequency of readiness

Table 1. Experimental EEG Signal Presented Based on Gender Difference

Group		Male		Female	
The Component of EEG		N1 (SD)	P300 (SD)	N1 (SD)	ERS (SD)
Right Hand Click Mouse	Latent Period (ms)	145.13 (14.59)	326.75 (25.95)	147.58 (12.63)	323.42 (26.97)
	Amplitude (μV)	-12.10 (3.51)	17.98 (4.32)	-13.60 (4.01)	16.58 (5.82)
Left Hand Click Keyboard	Latent Period (ms)	146.17 (15.23)	322.43 (24.37)	149.46 (12.07)	321.15 (25.79)
	Amplitude (μV)	-13.34 (4.21)	16.88 (5.56)	-12.85 (5.57)	15.67 (5.56)
Without Automatic Correction	Latent Period (ms)	148.12 (12.34)	-	150.23 (11.95)	-
	Amplitude (μV)	-4.67 (2.73)	-	-5.03 (2.55)	-

potential is slightly lower, at 0~3Hz while the event-related synchronization/ desynchronization potential is at 9~31Hz (Adamovich *et al.,* 2009). Thus, when ERP of finger calibration movements is input to Butterworth band-pass filter whose screening range is 9~31Hz, readiness potential and the event-related synchronization/ desynchronization potential can be distinguished. After the EEG is filtered in the time domain to select the paragraph of the most obvious characteristic, the average value of EEG of 10 subjects can be calculated according to the following formula and characteristic extraction is conducted. Then the neural network is trained on the experimental subjects and the valid information is extracted and identified.

Electroencephalographic characteristic-readiness potential

The contralateral hemispheric dominance is the main characteristic of the readiness potential and the readiness potential is affected by the activity. Before the movements, the EEG of the sensory epidermis of the brain shows a downward trend in value, that is, the readiness potential generates (Gerloff *et al.,* 1998). According to the EEG shown in the following figure 2 and figure 3, the finger movements in the simulation scenario are automatically corrected. The readiness potential of left and right brain decreases regardless of whether the left or right hand clicks the mouse but the falling range is significantly different. When the right index finger clicks left key of mouse, the potential of the left brain recorded by C3 electrode decreases more rapidly than that of the right brain recorded by C4 electrode. In contrast, when the left finger clicks the keyboard, the potential at C4 electrode drops faster than that at the C3 electrode. Moreover, the difference in the rate of decrease of the potential is most obvious about 150 ms before the finger movements occur. Therefore, the semi-brain advantage of the readiness potential can be used as the first electroencephalographic characteristic of automatic calibration of finger movement.

Electroencephalographic characteristic-event-related synchronization/ desynchronization potential

The event-related synchronization/ desynchronization potentials reflect changes in electroencephalographic energy at a particular frequency band before and after the movements with significant temporal and spatial characteristics. After monitoring the relevant electroencephalographic signal generated during the process of automatic calibration of finger movements and calculating the energy changes produced before and after the movements, it is not difficult to find out the obvious energy weakens near the frequency of 10Hz before the movements occur, which is called the event-related desynchronization potential. Correspondingly, an energy rebound occurs near the frequency of 20Hz after the movements, which is the event-related synchronization

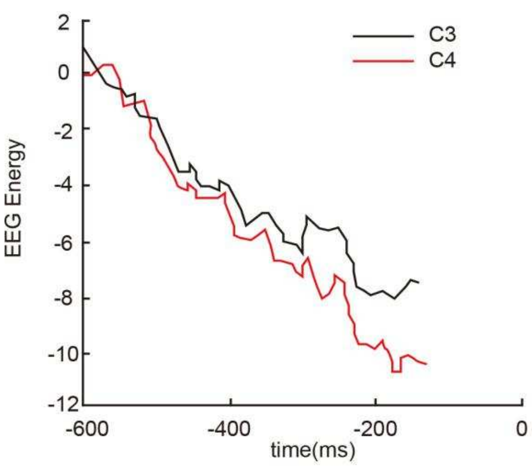


Figure 2. The Bereitschafts potential (BP) when left finger click the keyboard

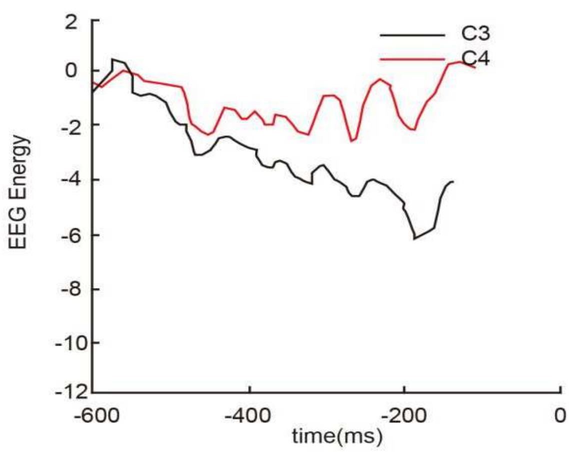
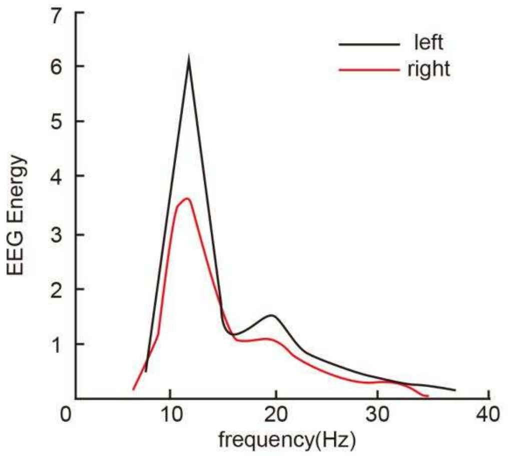


Figure 3. The Bereitschafts potential (BP) when right finger click the mouse



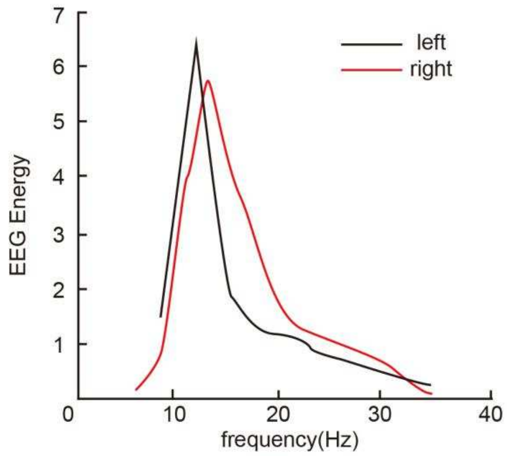


Figure 4 (left). The Electroencephalography Signal Collected by C3 Electrode on Left Brain
Figure 5 (right). The Electroencephalography Signal Collected by C4 Electrode on Right Brain

potential (Calmels *et al.,* 2006). In general, the event-related synchronization potential is considered as a rebound of the event-related desynchronization potential. This experiment is to study the automatic calibration of finger movements in graphic design. The calibration should occur before the finger movements. Therefore, it is more meaningful for this paper to study the event-related desynchronization potential. As mentioned before, the acquisition of the event-related synchronization potential of EEG of finger movements through Butterworth band-pass filter, so the frequency is 9~31Hz. Under the two experimental simulation scenarios, significant change in electroencephalographic energy occurs at about 10Hz before the movements regardless of whether the left hand clicks keyboard or the right hand clicks mouse. What is different is that the change amplitude of electroencephalographic energy is monitored by C3 and C4 electrodes, as shown in figure 4 and figure 5. As for the finger movements that left hand clicks keyboard, the falling range of electroencephalographic energy detected C4 by electrode is significantly greater than that of C3 electrode. On the contrary, when the right hand clicks mouse, electroencephalographic energy of left semi-brain release at C3 electrode is significantly greater than that of C4 electrode. Therefore, the same as the readiness potential, the event-related desynchronization potential also has obvious semi-brain differences, which can be used as the second electroencephalographic characteristic of automatic calibration of finger movements.

Specific Data Analysis and Calculation Process

Electroencephalographic energy

(1) Data preprocessing

Wavelet transform can convert electroencephalographic signal into superposition of mother wavelet as the preprocessing step of this experiment. Such multi-resolution method is widely used in the processing and analysis of non-stationary signal such as electroencephalographic signal. The superposition of mother wavelet has higher frequency resolution while time resolution is lower at a low frequency. On the contrary, frequency resolution is lower while time resolution is higher at a high frequency. Normally, wavelet decomposition is carried out on the signal of a larger scale, and then re-decomposed on a half scale of the original scale. The discrete wavelet transform and inverse transform of electroencephalographic signal can be calculated by the following formula (Buccino *et al.*, 2004):

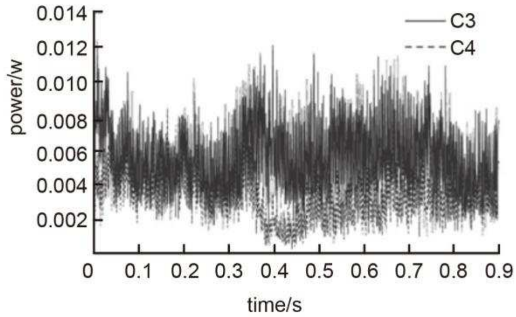
$$d_{ab} = 2^{-a/2} \sum_{n=-\infty}^{\infty} f(x)\bar{\phi}\left(2^{-a}x-b\right), ab \in Z \quad (1)$$

$$f(x) = \sum_{a=-\infty}^{\infty} \sum_{b=-\infty}^{\infty} d_{ab}\phi_{ab}(x), ab \in Z \quad (2)$$

Where, $f(x)$ is electroencephalographic signal to be processed; d_{ab} is wavelet coefficient; $\emptyset_{ab}(x)$ is mother wavelet; a is decomposition scale; b is the amount of time shift.

(2) Average energy of electroencephalographic signal

Since readiness potential and time-related desynchronization potential are two



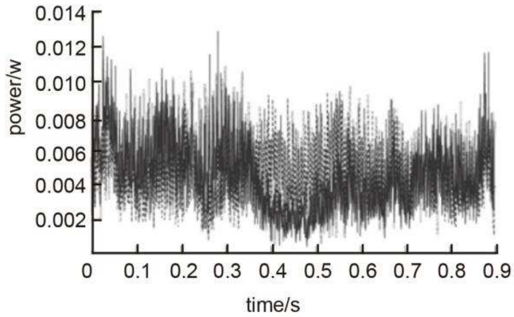


Figure 6 (left). The Electroencephalography Power Diagram When Left Finger Click Keyboard
Figure 7 (right). The Electroencephalography Power Diagram When Right Finger Click Mouse

electroencephalographic characteristics of automatic calibration of finger movements and both are changes of electroencephalographic signal, it is of important reference meaning to calculate the average energy of electroencephalographic signal according to the following formula.

$$E(b)=(1/n)\sum_{a=1}^{n}x^2(a,b) \quad (3)$$

Where, x(a,b) is the bth EEG data of the ath subject; n is the number of signal; and E is the average electroencephalographic energy (Formaggio *et al.,* 2008). There are 10 experimental subjects, two simulation scenarios, and 20 monitoring electrodes, so a=10;b=2;n=20..

(3) Average energy of event-related desynchronization potential
The calculation of event-related desynchronization potential shall take the value of electroencephalographic energy of 0.4~0.6s before automatic calibration of finger movements and the calculation formula is as follows (Li *et al.*, 2004):

$$ERD_{(b)}=\frac{R-E_{(b)}}{R}\times 100\% \quad (4)$$

Where, $R=\frac{1}{s}\sum_{a=0}^{a+s}E_{(b)}$is the average power of s EEG data within 0.4~0.6s before the calibration of finger movements occurs; x(a,b) is the bth EEG data of the ath subject.

Characteristic extraction

(1)Characteristic extraction of readiness potential

The two electroencephalographic characteristics discussed before have obvious hemispheric difference, so electroencephalographic activity is more significant in C3 and C4 electrodes. The average electroencephalographic energy of automatic calibration of finger movements at C3 and C4 electrodes is shown in the following figure 6 and figure 7. The left and right semi-brain electroencephalographic energy is significantly different 0.4 ~0.6s before automatic calibration of finger movements occurs whether the left hand clicks keyboard or the right hand clicks mouse. In the meantime, when left-handed fingers move, right semi-brain EEG decreases more monitored by C4 while the left semi-brain EEG declines more when the right hand clicks mouse.

The first electroencephalographic characteristic of automatic calibration of finger movements is that readiness potential of countermeasures brain for both the left and right finger movements drops faster. Through the screening of the 0-3 Hz filter and the locking of the period of 2S before the movements occur, the intercepted electroencephalographic signal should be extracted by independent component analysis (Pfurtscheller and Neuper, 1992). The analysis method can separate the independant source from electroencephalographic signal without knowing the source signal, and has strong spatial characteristic. The specific characteristics are defined as follows:

$$f(1)=\frac{ds(S_a)}{ds(S_a)+ds(S_b)} \quad (5)$$

Where, $S_a=F_aX$; $S_b=F_bX$ is the corresponding source of signal X obtained through the filter F_a; F_b, and ds corresponds to its variance.

(2)Characteristic extraction of event-related desynchronization potential

It can be seen from the above discussion that the event-related synchronization potential is the process of decrease in electroencephalographic energy before the automatic calibration of finger movements and also has obvious semi-brain differences. Therefore, the characteristic extraction of this characteristic can refer to the extraction method of readiness potential. However, the screening of electroencephalographic signal should use 9~31 Hz filter, and the time changes to 0.4~0.6s before the movements.

Conclusions

The study about the electroencephalography signal when automatic correction happens in finger movement plays an important role in graphic design, because the research outcome could promote the assist system development, which could improve the work efficiency. In terms of the graphic design, the finger movement mainly includes the left hand finger click the keyboard and right hand finger control the mouse. The character of electroencephalography signal could be summered into the half brain difference in the bereits-chaft-spotential (BP) and event-related desynchronization (ERD). The formal one is the electroencephalography power decrease happens in the movement preparation stage, and the latter one is the power disappear before the action. Meanwhile, those two phenomenons have half brain difference which means the opposite brain has more obvious decreasing when only one side finger movement corrected. However, those electroencephalography characters are not enough for the automatic correction of finger movement in the graphic design. The further research direction has been suggested to find out the electroencephalography difference between five different finger movement automatic correction in both left and right hand.

References

Adamovich SV, Fluet GG, Mathai A, Qiu Q, Lewis J, Merians AS. Design of a complex virtual reality simulation to train finger motion for persons with hemiparesis: a proof of concept study. Journal of Neuroengineering and Rehabilitation 2009; 6(1): 28-28.

Bobick AF, Davis JW. The recognition of human movement using temporal templates. IEEE Transactions on pattern analysis and machine intelligence 2001; 23(3): 257-267.

Buccino G, Binkofski F, Riggio L. The mirror neuron system and action recognition. Brain and Language 2004; 89(2): 370-76.

Calmels C, Holmes P, Jarry G, Hars M, Lopez E, Paillard A, Stam CJ. Variability of EEG synchronization prior to and during observation and execution of a sequential finger movement. Human Brain Mapping 2006; 27(3): 251-66.

Formaggio E, Storti SF, Avesani M, Cerini R, Milanese F, Gasparini A, Manganotti P. EEG and fMRI coregistration to investigate the cortical oscillatory activities during finger movement. Brain Topography 2008; 21(2): 100-11.

Gerloff C, Richard J, Hadley J, Schulman AE, Honda M, Hallett M. Functional coupling and regional activation of human cortical motor areas during simple, internally paced and externally paced finger movements. Brain: A Journal of Neurology 1998; 121(8): 1513-31.

Leocani L, Toro C, Manganotti P, Zhuang P, Hallett M. Event-related coherence and event-related desynchronization/synchronization in the 10 Hz and 20 Hz EEG during self-paced movements. Clinical Neurophysiology 1997; 104(3): 199-206.

Li Y, Gao X, Liu H, Gao S. Classification of single-trial electroencephalogram during finger movement. IEEE Transactions on Biomedical Engineering 2004; 51(6): 1019-25.

Liao X, Yao D, Wu D, Li C. Combining spatial filters for the classification of single-trial EEG in a finger movement task. IEEE Transactions on Biomedical Engineering 2007; 54(5): 821-31.

Pfurtscheller G, Neuper C. Simultaneous EEG 10 Hz desynchronization and 40 Hz synchronization during finger movements. Neuroreport 1992; 3(12): 1057-60.