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CyberPsychology Computation of online shopping behaviors based on EEG signal analysis*

Tian Wang** Fudan University

Chuncheng Wang*** Fudan University

Wenhui Han**** Fudan University

Jie Ren***** Fudan University

Weihui Dai****** Fudan University

Abstract

With the rapid development of e-commerce, customer's online shopping psychology and behavior analysis has become the important issue for making a successful marketing strategy. Existing researches are mainly based on the methods of external behavior analysis and questionnaire survey, which are lack of deep understanding of the intrinsic neural mechanism leading to the customer's psychology and behaviors, and are easily affected by all kinds of subjective factors. Therefore, the traditional methods have a lot of limitations to achieve the accurate and reliable analysis results. In this paper, we introduced the concept of CyberPsychology Computation(CPC), and designed an online shopping website to record the customers' behaviors and their self-reported psychological states as well as the relevant EEG signals. On this basis, we explored the neural mechanism for the CPC according to the AIDA consumer behavior analysis model, and indicated the features of EEG signals which can be used to evaluate the customer's psychological states in their online shopping behaviors. Research work of this paper provided a new method for analyzing the customers' online shopping behaviors as well as their psychology from the perspective of NeuroManagement.

Keywords: CyberPsychology Computation(CPC), online shopping behaviors, EEG analysis, NeuroManagement

1. Introduction

Online shopping has become a popular way in people's daily life in China owing to the rapid development of e-commerce (Meng, 2013). In order to make a successful marketing strategy, it's an important issue for the online sellers to understand customer's psychology and behavior precisely (Li, 2008). The common methods for the above psychology and behavior analysis are mainly based on the relationship between customers' self reports and their shopping behavior data, through a questionnaire survey or data mining techniques (Li, 2008;

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** Joint first author: wangtian14@fudan.edu.cn

*** Joint first author: 11307100104@fudan.edu.cn

**** 15307090148@fudan.edu.cn

***** 15307100071@fudan.edu.cn

****** Corresponding author: whdai@fudan.edu.cn

Wang and Lv, 2015). However, it's difficult to achieve an accurate and reliable result in the dynamic online shopping process due to a lot of limitations, such as affecting by all kinds of subjective factors in the survey and customers' self reports (Wang et al., 2017). With the development of advanced neuroscience and modern experimental technology, NeuroManagement, a new interdisciplinary concept proposed by a Chinese scholar in 2006, has attracted worldwide attentions of academia, and provided the new research paradigm as well as methodology for the study of management issues (Wang et al., 2017). The online shopping analysis will be based on a deep understanding of the intrinsic neural mechanism underlying customers' psychology and behaviors from the perspective of NeuroManagement.

Customer's online shopping psychology and behavior analysis belongs to the scope of CyberPsychology Computation(CPC) which aims to compute the online users' psychological states from their behavioral data, as one part of the CPP(CyberPsychosocial and Physical Computation) framework proposed by Professor Weihui Dai in 2014(Zhou et al., 2015). In order to perform the CyberPsychology Computation of online shopping behaviors, we designed an online shopping website to record the customer's behaviors and their self-reported psychological states as well as the relevant EEG (Electroencephalogram) signals. The features of EEG signals can be used to evaluate the customer's psychological states as objective evidences, and furthermore, to establish the relationship between physiological and psychological states by quantitative analysis. AIDA model summarized by Heinz M. Goldmann(Goldmann, 1958) stands for the acronyms of Attention, Interest, Desire (or decision), and Action. It provides the founding principles of psychological analysis in different periods of online shopping, and offers the dynamic development stages of customer's psychology and behaviors. Therefore, CyberPsychology Computation is a more sustainable method in this case with the ability to cope with dynamic changes in each stages of the AIDA model (Wang et al., 2017).

This paper is divided into six parts. In the second section, the related works will be introduced. In the third section, the research scheme and methods used by this paper will be explained. The details of EEG experiment process, data acquisition and data analysis will be shown in the fourth section. After that, the experimental results will be analyzed combined with AIDA model in the fifth section. Finally, the sixth section will make the conclusion and discussion of this paper, and indicate the possible development directions.

2. Related works

2.1 Online shopping behavior analysis

Through a literature review, we can find that most researches on customer's online shopping psychology and behaviors adopted the common analytical method, which is obtaining customers' survey data and online behavioral data, and building a model to analyze their characteristics as well as the relationships between different factors. In recent years, various data mining techniques have also been applied to this issue under the big data environment. Wang and Lv used data mining and K-means clustering algorithm to analyze the different consumers' preferences for commodity (Wang and Lv, 2015). Based on the mining of complex networks, Zhang and Li, etc. proposed a novel scheme of user behavior perception (UBP-CN) to perceive the user's behaviors (Zhang et al., 2014). UBP-CN constructed a host complex graph by abstracting every node and edge from the identifier IP, port, and communications between different users. In addition, some scholars started to build behavior prediction model from the user emotional information. For example, Cui, Hong and Zhao studied the consumer satisfaction and trust computation through the online review extraction and semantic analysis of emotional words (Cui, Hong and Zhao, 2015).

Undoubtedly, data mining is already a mature method which is widely adopted in user analysis. The above researchers have put forward many valuable and innovative analysis methods on this aspect. However, it is not hard to find that the data sources used by most of the above researchers to support their models are from online browsing records or customer's surveys. The intrinsic mechanism affecting customer's online browsing behaviors is still to be explored. On the other aspect, self-reports from customer's surveys have a lot of defects due to all kinds of subjective factors, such as the inconsistency in understanding and inaccuracy of descriptions.

2.2 CyberPsychology Computation(CPC)

Dr. John Suler launched the original conceptual framework of CyberPsychology in his hypertext book "*The Psychology of Cyberspace*" in January of 1996 (Suler, 1996). In this work, CyberPsychology can be defined as the research on psychological phenomena and related laws in order to understand people's online behaviors. In modern networked society, people are increasingly connected in physical space and cyber space, which are also closely related to their activities in psychological space. In order to better understand people's psychology and behaviors systematically, Prof. Dai put forward the concept of CPP (CyberPsychosocial and Physical Computation) in his study of the evolutionary mechanism of social public emergency (Dai, 2014). On this basis, as one part of the CPP framework, CyberPsychology Computation (CPC) is to study the quantitative relationship between the cyber behaviors of online users and their psychological states, and seeks to establish a computation model for the above relationship (Zhou et al., 2015).

Currently, CPC has been studied and applied in many aspects. One aspect is to explore the cognitive interpretation of human behaviors in cyber space. For example, psychological cognitive computation is to explain the observed phenomena and thoughts where the mathematical principles can be applied (Wang et al., 2011). A common application of CPC is related to the identification and analysis of emotions from people's online behaviors. Picard put forward the concept of affective computing, and claimed that machine can identify the emotional states of human beings (Picard, 1997). In addition, Wu et al. applied CPC to e-learning system, and established an evaluation model for the learning system's accessibility according to users' psychological experience (Wu et al., 2012). Zhou et al. studied the CPC on social community of ubiquitous learning, and presented a BP-GA neural network which achieved nearly the accuracy of 78% for the computation of the learners' attention, interest, emotion, and satisfaction states (Zhou et al., 2015). Moreover, Dai defined the concept of "smart" in smart education, smart health and medical service, and smart city, etc. as that machine should possess not only rational intelligence but also the emotional intelligence to perceive and understand human's emotions, and in which CPC plays the important role to provide online service with emotional intelligence (Dai, 2012).

2.3 Electroencephalogram (EEG) technology

EEG is an electrophysiological detecting method to record electrical activities of the brain, and plays a crucial role in clinical diagnosis and cognitive studies (Hornero et al., 1999). In the cognitive study, EEG signals are widely used because they contain rich and dynamic information of neural activities in the cerebral cortex, which can reflect the emotional, spiritual states and psychological activities. EEG signals have high time resolution, and the detecting method is noninvasive. Thus, EEG signals have become the popular choice to carry out cognitive analysis. Hu et al. classified mentally demanding tasks of the subjects by extracting their EEG signals and using the AR model to obtain the relevant characteristics based on a BP neural network (Hu, 2007). Fang carried out a simulated motor vehicle driving experiment, extracted the brain waves of subjects,

investigated the frequency of brain waves changes on different frequency bands to detect the driver's fatigue (Fang, 2009). Li and Liu, by extracting EEG signals and using event-related potential (ERP) methods, analyzed the EEG characteristics of movements of left and right fingers and used them as identification criteria (Li and Liu, 2006).

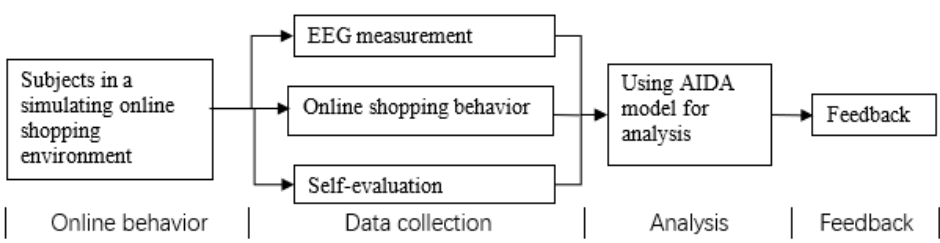
The analysis method of using EEG signals has great application prospects and large potential values. Its biggest advantage is that EEG signals can reflect the brain activities of users authentically. At present, most researchers focus on the identification of physiological state of users, which plays a more significant role in the clinical diagnosis, psychological treatment and other field rather than commercial fields. Few researchers applied EEG signals to the field of emotional recognition and behavior analysis of users in electronic commerce, which is a gap in the fields of the future research.

3. Research scheme and methods

3.1 Research scheme

Traditional CyberPsychology Computation is divided into four stages, namely, the generation of cyber behaviors of users, the collection of behavioral data, the behavioral data analysis for psychological characteristics and the generation of feedback on psychological characteristics of users according to the analysis. In this paper, the experiment is conducted through the corresponding four stages to establish the CyberPsychology Computation. The research scheme is illustrated in Figure 1.

Figure 1. Research scheme of CyberPsychology Computation



By collecting the EEG signals of online shopping users, we later decompose the waveforms in the way of wavelet transforms and superimpose them according to different frequencies. The subjects' waveforms of different frequencies will be attained, and then the corresponding relationships between the physiological signal and the psychological state will be explored. After that, subjects' different psychological states corresponding to different online shopping behaviors will be obtained, combined with the interface of the subjects and subjective self-evaluation. Finally, the relationships between them will be established through the mathematical model so that the EEG signals of online shopping behaviors can be graphically displayed. This process of user data acquisition and analysis measures the users' psychological state with higher accuracy and objectiveness compared with the onsite analysis and questionnaire survey. It instead reflects the users' shopping behavior and establishes the relationship between physiological and psychological states by quantitative analysis, in which the EEG signals provide sufficient objective evidence and the AIDA consumer behavior model provides the

psychological analysis in different periods of online shopping (Wang et al., 2017). Therefore, CyberPsychology Computation is a more sustainable method in this case with the ability to cope with dynamic changes.

3.2 Method of EEG analysis

EEG analysis of multiple analysis methods is mainly classified as three categories: time domain analysis, frequency domain analysis and time-frequency analysis.

According to different frequency bands, EEG is mainly classified by the following categories as shown in Table1.

Table 1. Categories of brain waves

δ wave	0.4 ~ 4Hz	20 ~ 200μV	Common in adults, deep sleep or extreme fatigue status
θ wave	5 ~ 8Hz	10 ~ 50μV	Common in adults in frustration and depression
α wave	9 ~ 13Hz	20 ~ 100μV	Basic rhythm of normal brain waves; frequency is constant; Common in the sober, quiet and eyes closed time.
β wave	14~ 30Hz	5 ~ 20μV	When adults are nervous or excited

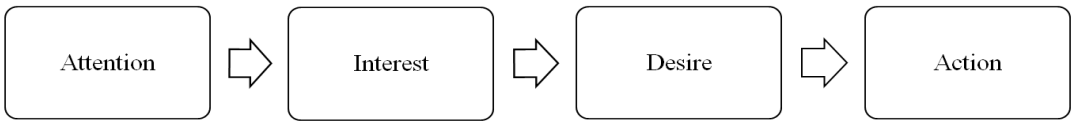
As the EEG signal is a non-stationary random continuous signal, it is necessary to do time-frequency analysis. Time-frequency analysis is a combination of time and frequency to comprehensively analyze the changes of EEG signals, including Fourier transform analysis and wavelet transform analysis (Hornero et al.,1999; Xue et al., 2003; Yuan et al., 2009).

Since brain waves are non-stationary signals, it is very important to ensure the accurate display of local detailed information. The wavelet packet transform can provide a relatively precise decomposition of the high frequency component, and the time-frequency localization analysis can be carried out for the signals contain a large amount of medium and high frequency information. Besides, Wavelet packet decomposition can conduct multi-level frequency band division and adaptive selection of the corresponding frequency band to match the spectrum according to the signal characteristics. As a result, the time-frequency resolution is well improved. Therefore, in this paper, wavelet packet decomposition method will be used.

3.3 AIDA consumer behavior analysis model

During the analysis stage of CyberPsychology Computation, AIDA consumer behavior analysis model is used. AIDA model is a model of consumer behavior analysis, which is summarized by Heinz M. Goldmann. Its specific meaning is that the effect of the sales staff's persuasion to consumers is hierarchical. When the sales staff do the consumer analysis, the impact can be divided level by level into Attention, Interest, Desire and Action (Gharibi et al., 2012). With the AIDA consumer behavior analysis model to decompose the subjects of the shopping behavior, more accurate explanation of the psychological state and its relationship with the EEG signal will be available.

Figure 2. AIDA consumer behavior analysis model



In the stage of Attention, businesses usually consider strategies like fancy packaging and novelty advertising to arouse the attention of consumers. In the stage of Interest, businesses will make exquisite user interface, considered text introduction, pictures and video to dig needs of consumers and stimulate consumer interest to purchase. In the stage of Desire, businesses will employ various means to arouse the desire of consumers to buy. When customers believe that the benefits are greater than the payment, they will desire to purchase. In the stage of Action, businesses focus on enhancing of consumer confidence, such as providing perfect after-sales service, express insurance, and quality insurance, so that consumers believe that their consumption action is worthy.

In summary, when designing consumer interface within market campaigns, businesses are not only for artistic creation purposes, but also for business purposes. Thus, the principle of AIDA analysis is applied widely to maximize influence on consumers.

4. Experiment and data processing

4.1 Experiment preparation

The experiment was in the nerve electrophysiological examination room. The environment was well ventilated, quiet with low interference. We used Z2N-F-20-C EEG recorder. The international standard of 10-20 dual-lead 8-channel EEG information collection was satisfied and the machine worked normally. Therefore, the environment and equipment met the experimental requirements.

This experiment selected thirteen subjects. Three of them completed all the experiment sections and others were doing a single section of the experiments for comparison. The basic information of three subjects is listed in Table 2.

Table 2. Basic information of subjects

	Gender	Age	Degree of Education	Online Shopping Experience
Subject 1	Female	20-29	Bachelor	>5 years
Subject 2	Male	20-29	Master	>5 years
Subject 3	Male	<20	Bachelor	1-5 years

4.2 Experimental process

This experiment selected three subjects. In our own virtual shopping website, subjects played the role of consumers. They could browse and buy the goods shown on the website freely. Subjects were wearing an EEG headset recorder which could collect the EEG signals during the experiment, and the subjects' behavior on the user interface was all recorded by our screen recording software. They were asked to open the product link to

fill out the first impression on the merchandise interface and fill out their preferences for the goods after they got the information on the website. In the end of all operations, we immediately interviewed the subjects, the psychological changes in the operation and so on.

Then we matched the operation of the EEG signal and the subjects, and combined the subjects' subjective assessment of their behavior experience as a reference to observe the subjects in different shopping psychological state to prepare for the display of EEG Signal characteristics.

Our virtual shopping site simulated shopping website interface, including a total of four kinds of goods, where a brand kitchenware flagship store provided non-stick pan, a South Korea purchasing shop provided women' s fashion clothing, a private digital store provided the iPhone5 and a brand clothing store provided baby socks. The reason of the construction of virtual shopping site is that in the real shopping site environment, the interface content is more complex than our virtual site complex, including advertising, animation, plug-ins, etc. These factors will distract the attention of the subjects.

4.3 The preliminary processing

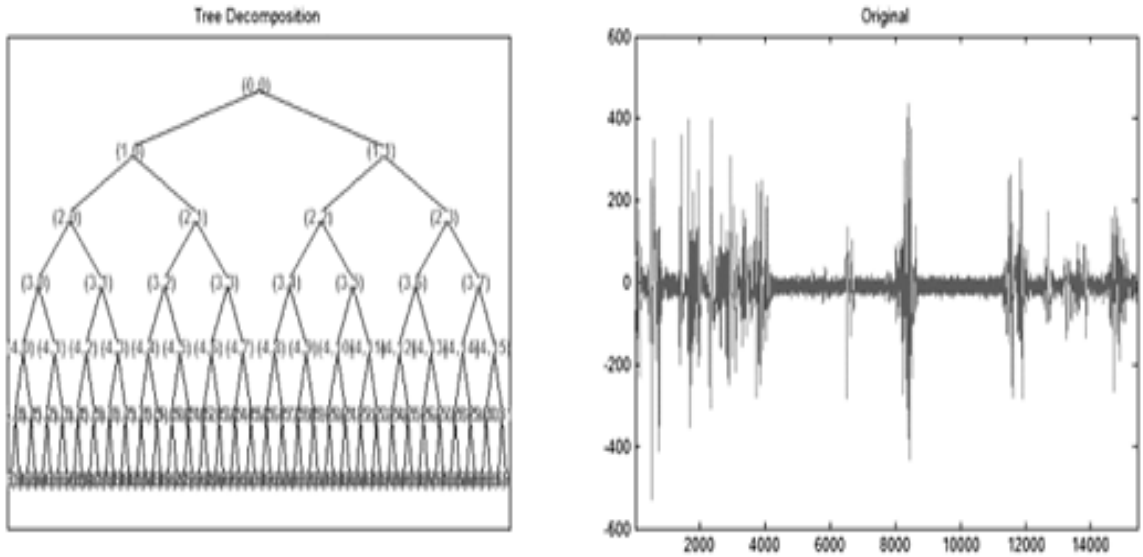
EEG artifacts usually exist because of the head shake or electrode loosening and other reasons. In order to remove such artifacts, we proceeded to take the average reference electrode, that is to say, the voltage values measured at the eight electrode positions were averaged. The reason is that the entire head is approximately spherical, and we think that the sum potential of the positive and negative electrodes is equal to zero.

Since the sampling frequency of this experimental data is 128Hz, the Nyquist frequency is 64Hz, so we can calculate the frequency of each band is about 1Hz. So in this experiment, we will use db10 wavelet packet. The signal is decomposed by six layers, and 64 wavelet packets can be obtained in the sixth layer. Then according to the previous definition of the frequency band for different waveforms, we can decompose the various types of rhythm wave waveform, as follows

δ : S1 = S6, 0 + S6, 1 + S6, 2 + S6, 3, [0 - 4Hz]
θ : S2 = S6, 4 + S6, 5 + S6, 6 + S6, 7, [5 - 8Hz]
α : S3 = S6, 8 + S6, 9 + … + S6, 12, [9 - 13Hz]
β : S4 = S6, 13 + S6, 14+ … + S6, 29, [14 - 30Hz]

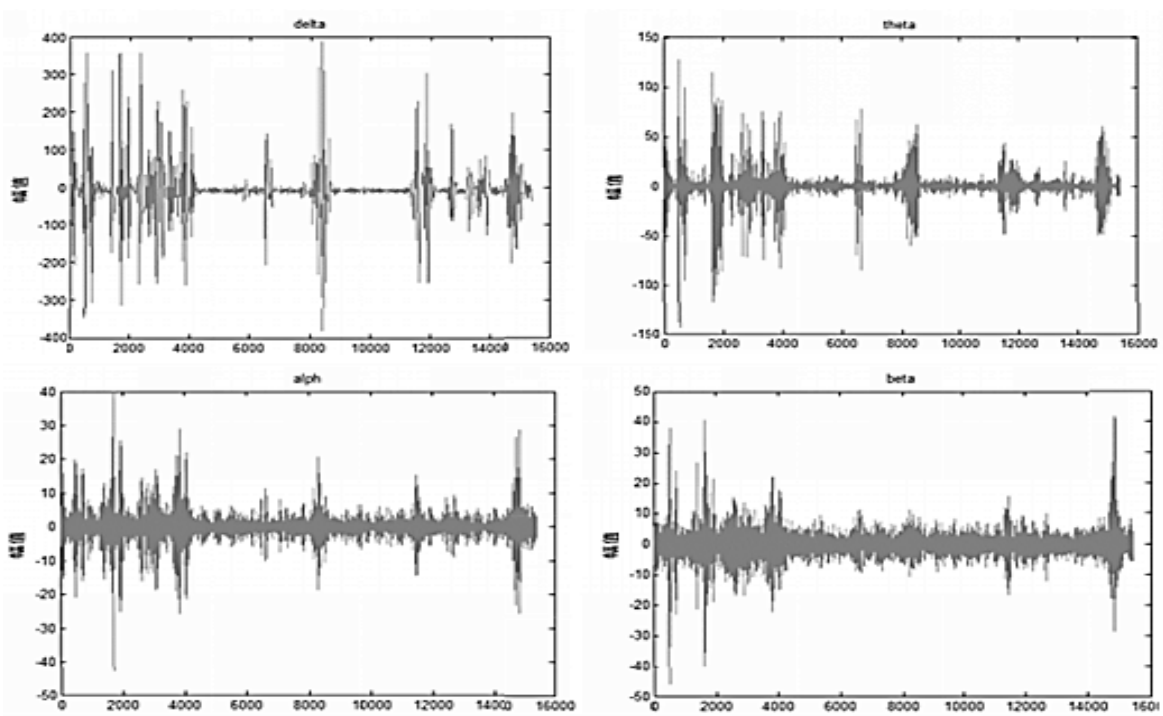
We use Matlab to do wavelet packet decomposition and reconstruction. Take Subject 1 for example. We get the wavelet packet tree and the original signal waveform as shown in Figure 3.

Figure 3. Subject 1 wavelet analysis tree with original waveform



Waveforms of δ, θ, α and β wave for Subject 1 are shown in Figure 4.

Figure 4. Waveforms of δ, θ, α and β wave (From left to right, from top to bottom) for Subject 1



4.4 Records of online shopping behaviors

We recorded each subject's behavior through the screen record software, and divided their operation procedure into seven classes, which could be seen in Table 3. We will use this classification approach in the subsequent waveform display.

Table 3. Decomposition and classification of subjects' operation procedure

Begin the experiment	Class 0
Visit the product link	Class 1
Grade the first impression of the product The grade is x	Class 2 -x
Click next step after glance over the product	Class 3
Grade the browsing process of the product The grade is y and buy/not buy is 0/1	Class 4 -y-0/1
Start to browse the product detail	Class 5
Staring over the product detail	Class 6

We use the five-grade marking system. The degree of preference is rated from bottom to top, as 1 for hate and 5 for adore, recording the subjects' first impression and browsing process towards the online stores. The results are listed in the subsequent tables.

Table 4 and Table 5 are from Subject 1.

Table 4. Browsing and operating information of Subject 1

Browsing Order	First impression	Degree of preference during browsing process	Whether or not will she buy it immediately
Supor non-stick pan	3	3	No
iPhone	4	4	No
Baby socks	5	5	Yes

Table 5. The record of browsing process from Subject 1

Video Length(Seconds)	Behavior Record	Behavior Classification
65	Visit the online store	0
76	Click the non-stick pan	1
87	Grade the first impression (3)	2-3
96	Click next step	3
103	Click 'temporarily not to buy' and grade (3)	4-3-0
108	Click the iPhone	1
114	Grade the first impression (4)	2-4
123	Click next step	3

Video Length(Seconds)	Behavior Record	Behavior Classification
130	Click 'temporarily not to buy' and grade (4)	4-4-0
135	Click the booties	1
142	Grade the first impression (5)	2-5
153	View the product detail	5
169	Click next step	3
174	Buy immediately and grade (5)	4-5-1

Table 6 and Table 7 are from Subject 2.

Table 6. Browsing and operating information of Subject 2

Browsing Order	First impression	Degree of preference during browsing process	Whether or not will he buy it immediately
Supor non-stick pan	4	5	Yes
iPhone	5	4	No
Korean Panty	3	3	No

Table 7. The record of browsing process from Subject 2

Video Length(Seconds)	Behavior Record	Behavior Classification
101	Visit the online store	0
113	Click the iPhone	1
125	Grade the first impression (5)	2-4
129	View the product detail	5
140	Staring at freebie information	6
168	Go to the bottom of the page	Not satisfied
180	Click next step	3
187	Grade the preference (4) There is hesitationbefore click "to buy"	4-5-1
194	Click 'temporarily not to buy' and grade (4)	4-5-1
206	Click the non-stick pan	1
215	Grade the first impression (4)	2-5
219	View the product detail	5
222	Staring at the information: market price 199, now sale for 179.	6
236	Move up before hit the bottom of the page	Not satisfied
240	Click next step	3
243	Click "temporarily not to buy" and grade	4-4-0

Table 8 and Table 9 are from Subject 3.

Table 8. Browsing and operating information of Subject 3

Browsing order	First impression	Degree of preference during browsing process	Whether or not will he buy it immediately
iPhone	2	3	No
Supor non-stick pan	3	4	Yes

Table 9. The record of browsing process from Subject 3

Video Length(Seconds)	Behavior Record	Behavior Classification
97	Visit the online store	0
107	Click the iPhone	1
118	Grade the first impression (2)	2-2
121	View the product detail	5
133	Staring at the information: verify authenticity	6
138	Moving up from the "verify authenticity"	Not satisfied
142	Moving down slowly	Not satisfied
159	Staring at the information: Instruction for seal off activate	6
183	Fling to the bottom of the page	Not satisfied
224	Click next step (Before this move subject 3 fail to visit "Other" page)	3
232	Click "temporarily not to buy" and grade (3)	4-3-0
250	Click the non-stick pan	1
259	Grade the first impression	2-3
264	View the product detail	5
276	Staring at the information: on sale information	6
309	Move to the bottom of the page	Not satisfied
317	Click next step	3
321	Buy immediately and grade (4)	4-4-1

5. Analysis and results

We mentioned earlier that the β wave appears in people in a state of mental stress or excitement. When the human brain is in a state of excitement, it will produce a large amount of β waves. The β wave waveforms of the subjects in different mental states are shown in Figure 5. Figure 5(a) is the first appearance of class 1 waveform from the three subjects. Class 1 waveforms of each subject refer to Figure 5(b)(c) and (d). Class 4-3-0 and class 4-4-0 waveforms of each subject refer to Figure 5(e) and Figure 5(f). Class 4-5-1 waveforms of Subject 1 and Subject 2 refer to Figure 5(g). Class 5 waveforms of the three subjects refer to Figure 5(h), Figure 5(i) and Figure 5(j), respectively. We have recorded the change of EEG for the whole purchasing process of Subject 1 and Subject 2, which can be referred to in Figure 5(k) and Figure 5(l).

Figure 5. Waveforms of subjects in different mental states

(a) From left to right: Subject 1, Subject 2, Subject 3

(b) Three Class 1 waveforms from Subject 1

(c) Three Class 1 waveforms from Subject 2

(d) Two Class 1 waveforms from Subject 3

(e) From left to right is Class 4-3-0 waveforms of Subject 1, Subject 2 and Subject 3

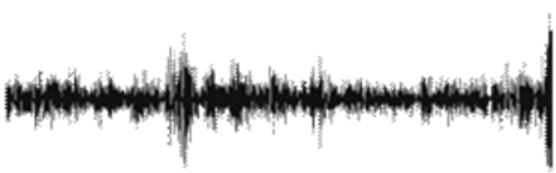
(f) From left to right is Class 4-4-0 waveforms of Subject 1, Subject 2 and Subject 3

(g) Class 4-5-1 waveforms of Subject 1 and Subject 2

(h) First appearance of Class 5 waveform from Subject 1

(i) Three Class 5 waveforms from Subject 2

(j) Two Class 5 waveforms from Subject 3



(k) The whole waveform from Subject 1 in purchasing booties

(l) The whole waveform from Subject 2 in purchasing iPhone

Combined with the above experimental results, we use the AIDA consumer behavior model to make the following analysis:

- *Attention stage*: When the three subjects took actions which repeated each time entering a new product interface, such as clicking on the product link, entering the purchase interface, etc., only the first time a great increase in β waves appeared.
- *Interest stage*: we found that all subjects performed operations like sliding slider or rolling the mouse wheel for page browsing. At last, Subject 1 and Subject 2, respectively, made the final purchase decision. Meanwhile, we can clearly find a significant fluctuation of β waves when Subject 1 and Subject 2 started to glance over the products.
- *Desire stage*: in this stage, the business will usually take several means such as discounts to induce consumers to think that the products are worth buying. A specific example is that the interface showing a discount on the non-stick pan attracted Subjects 2 and Subjects 3 simultaneously, which made them keep reading the contents. We can see that the discount contents are prominent, with bigger font size and striking colors.
- *Action stage*: Subject 1 and Subject 2 had a purchase behavior. When Subject 1 clicked to buy the baby socks, his β wave changes greatly, while Subject 2 who purchased an iPhone had a more significant β wave increase.

6. Discussion and conclusion

In this paper, we complete a thorough process of CyberPsychology Computation, and establish the relationship between cyber behaviors and psychological characteristics of online shopping customers. According to the experimental results above, we got the following findings:

(1) When the three subjects in the first time clicked on the product link and gave same scores to the non-purchased goods, we can see similar EEG signals to some extent, and this similarity is different from other psychological process. Although EEG signals are heavily influenced by individual differences, when customers performed the same behavior and were in a similar mental state, they were able to exhibit similar EEG patterns. This means that EEG analysis is an effective way and we can establish the relationship between users' online shopping behaviors and psychological behaviors according to their EEG signal. EEG signal can accurately record the psychological changes of consumers, giving psychological and physiological explanation about online shopping behaviors. This provides a reliable reference for future research.

(2) Each time the three subjects opened the product web page, their β wave gradually decreased. The reason is that when a consumer gets exposed to something in the first time, the brain is more likely in a state of excitement due to his/her curiosity.

(3) When consumers browse the content of their interest, their brains are also in a β wave dominant excitement. Moreover, faced with the final choice to buy the goods, the customers' brains all have produced a significant change in the β wave.

(4) After consumers purchase the goods, their EEG will also show a state of brain excitement according to the experiment's results.

(5) By studying the waveforms of Subject 1 and 2 when they purchased the goods, we found that the factors contributing to the final purchase of consumers were multiple. The purchase finally came after an increase in β waves. Therefore, this result implies that the product description, interface experience and other factors play multiple roles in the excitement of the subjects.

Based on our findings above, some useful strategies can be proposed for the business. First of all, the first impression is crucial to attract consumers and thus shiny web interface and persuasive advertisements are the key point to draw customers' attention at the beginning. Besides, business focus should also be placed on how to use clever marketing strategies to extend customers' first impression so as to transform their shopping interests into shopping desire and actions. To go further, since the customers will keep excited after their purchase, if the business can take action to provide further attraction to consumers at this time, the business will greatly increase the probability of consumers' following purchase.

Due to the limitation of the experiment time and some unresolved technique problems, there are still some limitations in this paper:

(1) The number of samples needs to be improved. There are only three subjects in our research. Our future research will focus on when different people produce the same behavior, the differences of their psychological characteristics, to provide more accurate and more detailed conclusions for our experiments.

(2) β wave is not only in the positive state of excitement. Fear will also result in a great increase in β waves. In our experiment, we found that some behaviors of the consumer reflected that some goods were unpleasant and this would sometimes promote the brain's excited state to produce β wave. Sometimes, it is difficult to distinguish between these two β waves. Thus, one of the future researches can study how to distinguish consumers' affection and disgust.

(3) Considering that the EEG signal is a non-stationary random signal, there are slight differences between individuals. Thus, it is difficult to establish an accurate mathematical model to match the user's psychological state and brain wave signal.

Through several individual experiments, the main contribution of this paper is to provide a research means that uses EEG signal to find the similarity between the user behavior and their psychological state. In the future, multi-level repeated experiments will be conducted. Furthermore, combined with neurobiology and mathematical knowledge, we hope to establish a more comprehensive prediction model in order to further clarify the relationship between users' psychological state and their cyber behavior.

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