Study on Event-Related Potential of Information Alarm in Monitoring Interface

Jiang Shao[1], Chengqi Xue[1(✉)], Haiyan Wang[1,2], Wencheng Tang[1], and Yafeng Niu[1]

[1] School of Mechanical Engineering, Southeast University, Nanjing 211189, China
ipd_xcq@seu.edu.cn
[2] Science and Technology on Electro-Optic Control Laboratory, Luoyang 471000, China

Abstract. Conduct research on the problems caused by the improper design of alarm modes in the digital interface of monitoring system. Based on the behavior data and physiological data obtained by the event-related potential brain electrical experiment, compare the influences of the two alarm modes of interface elements size change and color change on the visual cognition of users, analyze the key elements that cause these reasons and lay the foundation for the improvement of alarm modes of monitoring interface. In the brain electrical components of color change and size change, N100, P200 and P300 are more obvious, and they are focused on the top region, the central left top region and the central right top region. As for the present of digital interface alarm information, in the present method with the same channel, participants is more sensitive to the color code change, although the activation degree of size change on human brain is higher. The data analysis and conclusion of this thesis can provide reference for the design of the digital interface alarm mode in the future, so as to effectively avoid the users' misjudgment and omission on the interface information and improve the use efficiency of system in reality.

Keywords: Information identification · ERP · Human computer interaction

1 Introduction

Monitoring interface is one of the digital interfaces for complex systems, which are characterized by an enormous stockpile of information, intricate information structures and dynamic changes in dimensions of information. The information presented by the monitoring interface is usually part of the real-time information. In terms of the

Biographies: Shao Jiang (1988-), male, graduate; Xue Chengqi (corresponding author), male, doctor, professor, ipd_xcq@seu.edu.cn;Wang Haiyan, female, doctor, professor, the guest researcher of Science and Technology on Electro-optic Control Laboratory.
Foundation items: The National Natural Science Foundation of China (No. 71271053, 71471037), Aeronautical Science Foundation of China (No. 20135169016), The Scientific Innovation Research of College Graduates in Jiangsu Province (No. CXLX13_082).

D. Harris (Ed.): EPCE 2015, LNAI 9174, pp. 54–65, 2015.
DOI: 10.1007/978-3-319-20373-7_6

information theory, real-time information refers to a kind of specific information that can be transmitted to a sink within an expected time range by the timeliness of information, thus achieving timeliness to some extent [1]. In the human-interactive processes of these real-time interfaces, users generally bear enormous cognitive loads, and unreasonable and inaccurate interface information feedback modes will have effects on users' efficiency of interface information acquisition and their further task decision-making. Therefore, research on alarm modes of these interfaces can effectively improve such problems as users' misreading and misjudging the interface information, and increase the system efficiency of monitoring interface.

In cognitive load and working memory of visual information processing, researchers have conducted the following studies: Findings of the behavioral study by Posner [2] as early as 1980 showed that reaction times (RTs) for invalid, neutral and valid cues exhibited a slow-to-fast trend, and that the RT was significantly faster in expecting where the stimulus was oriented than in invalid or no-cue conditions. This experiment has been a classical paradigm for studying visual attention. Girelli and Luck (1997) determined the hypothesis whether a common attentional mechanism was used during visual search tasks with color, orientation, and motion targets, and confirmed this hypothesis by singletons [3]. A study of updating of working memory in a running memory task by Kusak et al. (2000) found that both series length and interferences had marked effects on recalls but there was no interaction between them [4]. This paradigm has been widely used for studying the central executive of working memory. Missonnier et al. (2007) made a distinction between patients with progressive and mild and stable cognitive impairment by studying EEG parameters for working memory [5]. Rader et al. (2008) investigated auditory event-related potentials during a spatial working memory task and concluded that their findings were in good agreement with a previous study of a contribution of auditory cortex to working memory [6]. Yi et al. (2011) used event-related potential (ERP) measures to reveal the timing of memory selection processes and proactive interference resolution in working memory [7]. Krigolson et al. concluded the amplitude of the feedback error-related negativity (fERN) was reduced in the high load condition through experiments manipulating the cognitive load of the feedback stimuli (low load versus high load), and evaluated the functional efficacy of participants in the high load condition through behavioral experiments [8].

In terms of P300 event-related potential (ERP), a study of conformance of air traffic control by Isreal et al. (1980) found that there was a continuous decline in amplitude of tone-evoked P300 ERP with the increase of workload of air traffic control [9]. Luck (1998), by means of electrophysiological evidence of sources of dual-task interference, used the delay period of the P3 wave to verify whether a given experimental operation had effects on categorization process or response selection and execution processes [10]. A comprehensive comparative study of P3 amplitude by Kok (2001) presented the utility of the P3 amplitude as a measure of processing capacity and mental workload, which reflected activation of elements in an event-categorization network that was controlled by the joint operation of attention and working memory [11]. Polich (2007) made generalization and summary to P3a and P3b that: P3a originated from stimulus-driven, bottom-up frontal attention mechanisms during task processing, whereas P3b originated from task-driven top-down temporal-parietal activity associated with attention and appears related to subsequent memory processing [12]. In terms of

P200, Luck and Hillyard (1994) proposed electrophysiological correlates of feature analysis during visual search and found that an enhanced P2 wave was elicited when target pop-out stimuli were relatively rare [13]. A study of inferior anterior P2a and posterior N2b by Potts and Tucker (2001) found different mechanisms between them: N2b was usually related to both task and stimulus frequency, but P2a just reflected task-relevant processing [14]. Zhao and Li (2006) investigated the visual mismatch negativity elicited by facial expressions under non-attentional condition, and found that the latency of the P2 in the posterior part of the scalp tended to start from around 250 ms, and that this component had a different mechanism from the P2 in the anterior part of the scalp, probably being related to the early semantic processing of visual information [15].

Picon et al. proposed guidelines for using human event-related potentials to study cognition and established recording standards and publication criteria [16]. Smith et al. found effect of emotion valence could be distinguished early in 120 ms, reflecting the brain's selective attention processing of emotional stimuli [17]. Scott et al. (2006) investigated the ERP characterization of the expert object processing, and found that both basic- and subordinate-level training enhanced the early N170 component, but only subordinate-level training amplified the later N250 component [18]. The ERP study of attention by Hillyard et al. (1973) is representative among early ERP studies, in which they allowed subjects to listen selectively to a series of tone pips in one ear and ignore concurrent tone pips in the other ear, and found the N1 amplitude at Cz was markedly higher in the attentional ear than in the non-attentional ear; they also observed this phenomenon in the subsequent study of a combination of visual and auditory pathways [19]. Donchin, according to experiments, presented the fact that the latency of the P300 component, reflecting the assessment of stimuli or the required time for classification, increased with task difficulty [20]. Miltner et al. found that, when subjects received negative feedbacks of their performance, a negative ERP component was induced; the maximum amplitude occurred near Fcz of the middle of the frontal cortex, while the peak occurred at around 250 ms following feedbacks occurred, namely feedback negativity (FN) [21]. ERP includes P1, N1, P2, N2 and P3 (P300) components, as shown in Fig. 1 [22].

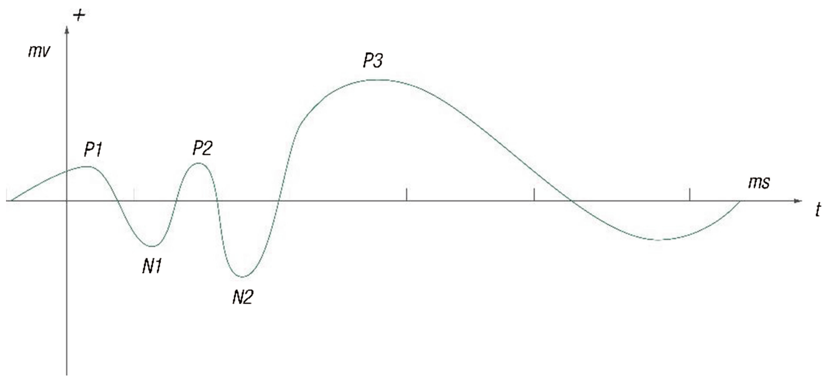

Fig. 1. ERP includes P1, N1, P2, N2 and P3 (P300)

2 Materials and Methods

2.1 Participants

Twenty-five subjects (13 males and 12 females) were present undergraduates (n = 7), postgraduate (n = 10) and doctoral candidates (n = 8) from Southeast University. They ranged in age from 20 to 35 years, with a mean age of 24 years. They had no color blindness or hypochromatopsia, with the corrected visual acuity over 1.0. They were required to practice and train to know the experimental procedure and operation requirements. Each participant put on electrode cap and sat in a comfortable chair in a soft light and soundproofed room, and eyes gazed at the center of the screen. A 17-in. CRT monitor with a 1024 × 768 pixel resolution was used in the experiment. The distance between participant eyes and the screen was approximately 60 cm, while the horizontal and vertical picture viewing angle was within 2.3° [23] (Fig. 2).

Fig. 2. The picture of experimental scene

2.2 Tasks and Procedures

The thesis adopts a system monitoring interface as the experimental interface. The reaction time and brain waves in the experiment are recorded. The reaction time and accuracy rate and conducted by variance method. All the tried brain waves' superposition average are conducted with the same brain wave to obtain the final brain wave form. Measure the peak and latency of each component, use SPSS to conduct the repeated measurement variance method with double factors and paired *t-test*. Subjects are tried as the monitoring personnel in the experiment, they need to find out the failure points in the interface and make responses by clicking the button. The normal state of the interface is shown in Fig. 3. The presentation forms of fault points are divided into two kinds: (a) the color change of site, blue site is normal, when failure appears, the "Beep" alarm will sound and the site changes into red, just as shown in Fig. 4; (b) the size change of site, when failure appears, the "Beep" alarm will sound and the site becomes larger, just as shown in Fig. 5. The experiment resents 80 times of fault samples in total (the color change alarm presents for 40 times and the size change alarm presents for 40 times), in each time, it presents a failure point randomly. The experiment is conducted through multi channels mode of visual sense and auditory sense.

This thesis compares the stimulus and response of difference interface alarm mode on human brain and then analyzes the inner connection.

Fig. 3. The normal state of the interface

Fig. 4. The site changes into red of the interface (Color figure online)

Fig. 5. The site becomes larger of the interface

A cross icon of 500 ms first occurred in the center of the screen, and then a normal 2000 ms monitoring interface occurred, followed by fault point. Each subject found the fault point and made a judgment. Pressed ‘A’ on the left interface and ‘L’ on the right interface, then a blank screen occurred; removed visual persistence and got access to the next test sample, then 80 samples were randomly presented. The experimental paradigm is shown in Fig. 6.

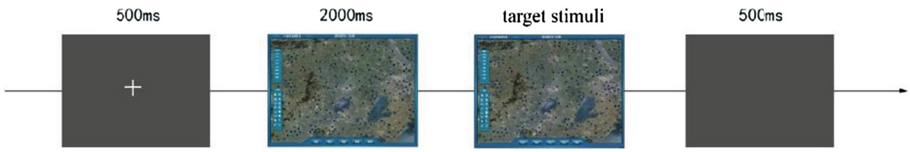

Fig. 6. The flow chart of experimental paradigm

3 Results

3.1 Behavioural Data Analysis

In terms of behavioral data in the present experiment, there were 25 subjects, but the data were available in only 21. Behavioral data included the accuracy of target stimulus identification and the reaction time. It was found by analyzing the experimental accuracy that the accuracy was over 99 % in either case, thus such data were not statistically significant. Therefore, the reaction time is analyzed for the behavioral data only, as shown in Fig. 7. In a manner of visual and auditory presentation, comparing the mean reaction times for target stimulus identification with changes in both information codes, size change was greater than color change (537.35 ms vs. 504.1 ms).

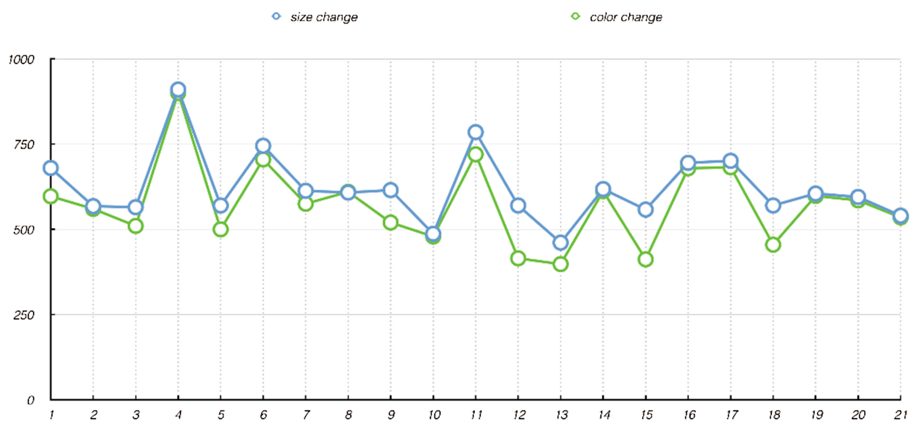

Fig. 7. RT data of 21 subjects in changing two information codes (color and size changes) (Color figure online)

3.2 Brain Electrical Data Analysis

In a manner of visual and auditory presentation, a segmental analysis was made of brain waves with color and size changes at the fault point. With the time quantum of the target stimulus starting to appear and ending at 1,000 ms as the split time for EEG, electrode-superimposed EEGs were obtained following Grand Average. In a manner of visual and auditory presentation, among EEG components with color and size changes, N100, P200 and P300 components were more significant, especially in the parietal, left and right central-parietal regions. Both types of EEGs are shown in Fig. 8.

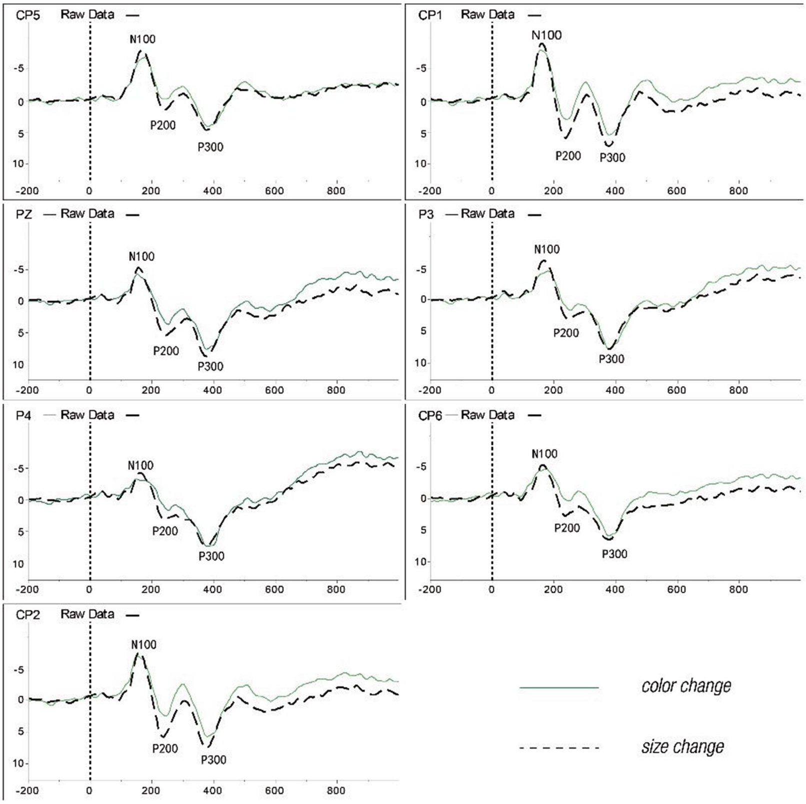

Fig. 8. Superposition of brain waves in changing two information codes

Seven electrodes in the parietal (P3, P4 and PZ), left (CP5 and CP1) and right central-parietal regions (CP6 and CP2) were selected for N100, P200 and P300 as analytical electrodes.

N100 Analysis. With respect to N100 component, repeated ANOVA of mean amplitudes for -200–1000 ms in 2 (changes in different codes: color and size changes) × 3 (regions: parietal, left and right central-parietal regions) was conducted, as shown in Table 1. From the analysis, regions had significant main effects ($F = 35.199$, P = 0.000 < 0.05); there was no significant difference between both stimulus encodings (F = 0.629, P = 0.629 > 0.05); there was no significant interaction effect between regions and stimulus encodings as well (F = 2.793, P = 0.085 > 0.05).

Table 1. Significant effects of regions and factors of N100

Effect	F	Sig.	Eta
Region	35.199	0.000	0.779
Stimulus encoding	0.240	0.629	0.011
Region* stimulus encoding	2.793	0.085	0.0218

In a manner of visual and auditory presentation, paired sample t test was conducted of different stimulus encodings in the parietal, left and right central-parietal regions. Results showed that, comparing stimuli elicited by color and size changes, the absolute value of the average was greater in the right central-parietal region than in the parietal and left central-parietal regions (for color change: 11.9115 uv > 11.0648 uv > 6.7692 uv, P < 0.05; for size changes: 2.3386 uv > 11.6397 uv > 6.8001 uv, P < 0.05), as shown in Table 2. In both cases, N100 was more significant in both left and right central-parietal regions than in the central-parietal region, while it was a bit more significant in the right central-parietal region than in the left parietal region.

Table 2. Significant effects of regions of N100

Color change	M	t	df	sig
Left central-parietal and right parietal regions	0.8467	2.966	21	0.007
Central-parietal and left parietal regions	4.29569	6.455	21	0.000
Right central-parietal and parietal regions	5.14239	8.537	21	0.000
Size change	M	t	df	sig
Left central-parietal and right parietal regions	0.69886	2.664	21	0.015
Central-parietal and left parietal regions	4.83961	6.289	21	0.000
Right central-parietal and parietal regions	5.53847	7.383	21	0.000

P200 Analysis. Based on ERP components related to numerous studies on working and short-term memory in prefrontal and parietal-occipital-temporal association cortex [24–29], P200 and P300 are especially important for icon memory. The peak latency of the P300 ERP component is approximately 300–600 ms. With respect to P200 component, repeated ANOVA of mean amplitudes for -200–1000 ms in 2 (changes in different codes: color and size changes) × 3 (regions: parietal, left and right central-parietal regions) was conducted, as shown in Table 3. From the analysis, regions had significant main effects (F = 5.024, P = 0.017 < 0.05); there was a significant difference between different stimulus encodings (F = 5.758, P = 0.026 < 0.05); there was a significant interaction effect between regions and stimulus encodings as well (F = 5.047, P = 0.017 < 0.05).

Table 3. Significant effects of regions and factors of P200

Effect	F	Sig.	Eta
Region	5.024	0.017	0.334
Stimulus encoding	5.758	0.026	0.215
Region* stimulus encoding	5.047	0.017	0.335

In a manner of visual and auditory presentation, paired sample t test was conducted of different stimulus encodings in the parietal, left and right central-parietal regions, as shown in the table. Results showed that: in the presence of visual and auditory presentation, comparing stimuli elicited by color and size changes, the absolute value of the average was greater in the right central-parietal region than in the parietal and left central-parietal regions (for color change: 5.5352 uv > 5.3333 uv > 3.1486 uv; for size change: 7.7961 uv > 7.4593 uv > 3.9533 uv), with P > 0.05 except that was not significant in left and right central-parietal regions; other comparisons were significant (P < 0.05), as shown in Table 4. In both cases, there was a significant difference in P200 between central-parietal and left central-parietal regions, as well as between central-parietal and right central-parietal regions, but there was no significant difference between right central-parietal and left parietal regions.

Table 4. Significant effects of regions of P200

Color change	M	t	df	sig
Left central-parietal and right parietal regions	0.20194	1.004	21	0.327
Central-parietal and left parietal regions	2.18473	2.259	21	0.035
Right central-parietal and parietal regions	2.38667	2.490	21	0.021
Size change	M	t	df	sig
Left central-parietal and right parietal regions	0.33685	1.592	21	0.126
Central-parietal and left parietal regions	3.50599	3.406	21	0.003
Right central-parietal and parietal regions	3.84284	3.584	21	0.002

In terms of stimulating factors, because of a significant difference between stimuli (F = 5.758, P = 0.026 < 0.05), namely, the significant difference between stimuli elicited by color and size changes, according to the analysis of means in the regional t test, averages of right central-parietal, left central-parietal and parietal regions were 5.5352 uv, 5.3333 uv and 3.1486 uv for color change, 7.7961 uv, 7.4593 uv and 3.9533 uv for size change, respectively, namely, M (color change) < M (size change). Thus, peaks were higher for size change, with higher brain activation.

P300 Analysis. With respect to P300 component, repeated ANOVA of mean amplitudes for -200–1000 ms in 2 (changes in different codes: color and size changes) × 3 (regions: parietal, left and right central-parietal regions) was conducted, as shown in Table 5. From the analysis, regions had no significant main effects (F = 1.394, P = 0.271 > 0.05); there was no significant difference between different stimulus encodings (F = 0.144, P = 0.708 > 0.05); there was no significant interaction effect between regions and stimulus encodings as well (F = 2.637, P = 0.096 > 0.05).

Table 5. Significant effects of regions and factors of P300

Effect	F	Sig.	Eta
Region	1.394	0.271	1.22
Stimulus encoding	0.144	0.708	0.007
Region* stimulus encoding	2.637	0.096	0.209

4 Discussion

1. Seen from the behavioral data (reaction time), in a manner of visual and auditory presentation, the alarm information of the interface was presented by changing color codes, with a mean reaction time of 504.1 ms; when presented by changing size, the mean reaction time was 537.35 ms, suggesting color change had more significant stimulating effect on human than size change.
2. EEG components: Comparing peaks of N100 component at seven electrodes in the parietal (P3, P4 and PZ), left (CP5 and CP1) and right central-parietal regions (CP6 and CP2), there were significant differences in peak among these three regions. The N100 component elicits higher brain activation in the left central-parietal region than in the right one. There was a significant difference in P200 between central-parietal (P3, P4 and PZ) and left central-parietal regions (CP5 and CP1), as well as between central-parietal (P3, P4 and PZ) and left central-parietal regions (CP6 and CP2), but there was no significant difference between left (CP5 and CP1) and right central-parietal regions (CP6 and CP2). The P300 component was not significant in electrode regions and presentation factors, as well as the difference in activation among parietal, left and right central-parietal regions of the human brain.
3. Latency: Seen from EEGs in Fig. 8, in a manner of visual and auditory presentation, for three components elicited by color and size changes, N100, P200 and P300, there was little difference in latency among them, suggesting that these two stimulus encodings were close to the degree of human stimulation.
4. Peak: Seen from EEGs, in a manner of visual and auditory presentation, a slightly higher peak was obtained by size change compared with color change, suggesting size change elicited higher human brain activation.

5 Conclusion

Seen from above analysis of experimental results, for presentation of digital interface alarm information, the mode of visual and auditory presentation has better cueing effects on human stimuli. Moreover, when popping out the fault information, both sensitivity and activity are also related to changes in information encoding. This thesis aims at the comparison research on two kinds of interface alarm modes of element size change and the color change under particular circumstances. But there are also many other kinds of interface alarm modes. The layout form of interface, the amount of interface element, coding method, time pressures, users' cognitive load ability and other factors will influence the effect of interface alarm. The data analysis and conclusion of this thesis can provide reference for the design of the digital interface alarm mode in the future, so as to effectively avoid the users' misjudgment and omission on the interface information and improve the use efficiency of system in reality.

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