Brain Mechanism Research on Visual Information Cognition of Digital Human Computer Interface

Chengqi Xue[1(✉)], Xiaoli Wu[1,2], Yafeng Niu[1], Lei Zhou[1], Jiang Shao[1], and Zhangfan Shen[1]

[1] School of Mechanical Engineering, Southeast University, Nanjing 211189, China
ipd_xcq@seu.edu.cn
[2] College of Mechanical and Electrical Engineering, Hohai University, Changzhou 213022, China

Abstract. With the improvement of the degree of informatization, digital human-computer interface (hereinafter referred to as DHCI) has been gradually replacing the traditional display and control interface, which plays an essential role in the efficient and precise operation of complex informative system. In recent years, unreasonable visual information design of DHCI has been proved to be one of the main reasons that cause a lot of serious accidents, which leads to users' mistakes in cognitive understanding and decision-making periods. Complex system has a great amount of information and a complicated information structure, which is easy to result in the imbalance between visual information design and cognitive mechanism. This poster is planning to start from the brain mechanism research of visual information cognition, and carrying out visual information design research through a perspective that close to the origin attribute of human cognition, making the research on visual information analysis of the information structure and encoding method in DHCI.

Keywords: Digital human-computer interface · Cognitive brain mechanisms · Design · Visual information cognition

1 Introduction

Human brain is the most complex existence in the universe we have ever known, and the nervous system, especially the degree of the brain evolution is the main indicator that distinguishes animals' (including humans') evolution extent. The brains' mysteries are always the most challenging issues of the natural science. Visual system has received extensive attention because of its extreme importance in animal and human life, the brain mechanism of visual cognition has evolved into a relatively independent branch in neuroscience. Visual cognition has a typical "black box" property, information processing of which is difficult to directly detect. The existing methods are developed according to "sensor" and "reactor", such as eye-tracking, reaction time etc. Although behavioral studies can objectively reflect human visual cognitive process,

C. Stephanidis (Ed.): HCII 2015 Posters, Part I, CCIS 528, pp. 144–149, 2015.
DOI: 10.1007/978-3-319-21380-4_26

they are based on speculation, which cannot truly hit the brain mechanism of visual cognition.

Cerebral cortices are related to visual cognition include occipital lobe, temporal lobe and part of the frontal lobe, which constitute 25 of the 52 Brodmann areas. With another 7 visual association areas added, the surface area of these cortices sum up to around 55 % of all the neocortices. The technology of Event-Related Potentials (ERPs), applied in the high-temporal resolution analysis of the potential response in cognitive processes, will be helpful in tracking, distinguishing and comparing many important cognitive process involving perception, attention, memory, decision, etc., which are hard to probe into by traditional research. It is more close to the original attributes of human cognition compared with the method of behavioral analysis, and it has a promoting effect on the research in the field of design and cognition. Figure 1 shows the visual cognition research in ERPs.

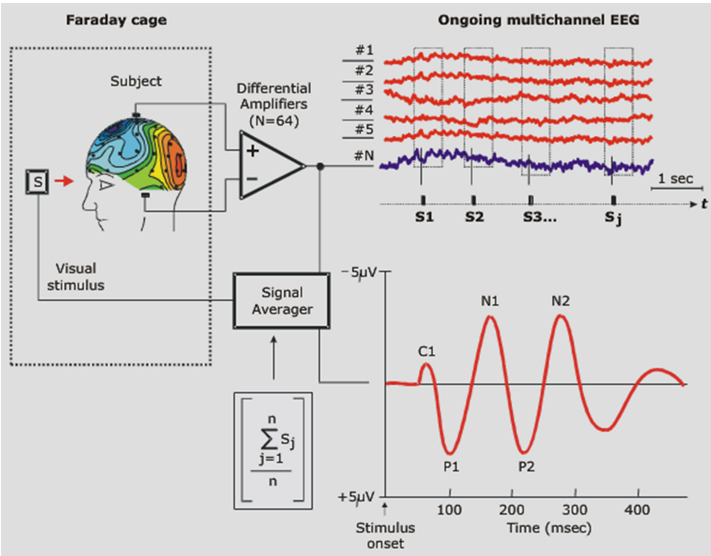

Fig. 1. Visual cognition research in ERPs

2 Method

Neuroscan SynamP2 Amplifier (Scan 4.3.1, Neurosoft Labs, Inc.) continuously records EEG (0.05–100 Hz band-pass; 500 Hz/channel sampling rate), using an electrode cap with a 64 Ag/AgCl electrode based on the extended international 10–20 system. Figure 2 shows the experiment environment in the ergonomic lab in Southeast University.

A total of 10 male and 10 female graduate students aged between 23 and 27 years (M = 25.2, SD = 2.1) who used computer almost everyday were recruited. All participants had normal or corrected vision without color blindness or color weakness.

3 Results

3.1 Study 1: Icon Memory ERP Research

In order to obtain related brain electrical components and neural basis of physiology assessment of icon elements in digital human-computer interface, the modified sample-delay matching task experimental paradigm is used under different time pressures (4000 and 2000 ms) and icon quantities (three, five and ten icons) on icon memory based on event-related potential (ERP) technology. Results demonstrate that P300 has significant volatility changes and maximum amplitude around the middle line of parietal area (PZ) and P200 has obvious volatility changes around the middle line of frontal and central area (FCZ) during icon cognition. P300 and P200 amplitudes increase as tasks become more difficult. Thus, P300 latency is positive correlated with the difficulty of the task. ERP research on icon memory characteristics will be an important reference standard in guiding users' neurocognitive behavior and physiology assessment on interface usability. Figure 2 shows the PZ electrode potential oscillogram of three icons under 2000 and 4000 ms and Fig. 3 shows the FCZ electrode potential oscillogram of five icons under 2000 and 4000 ms time pressure.

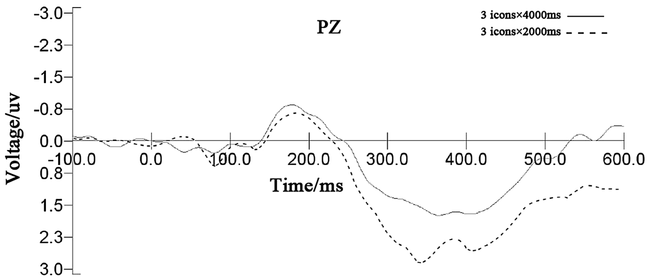

Fig. 2. PZ electrode potential oscillogram of three icons

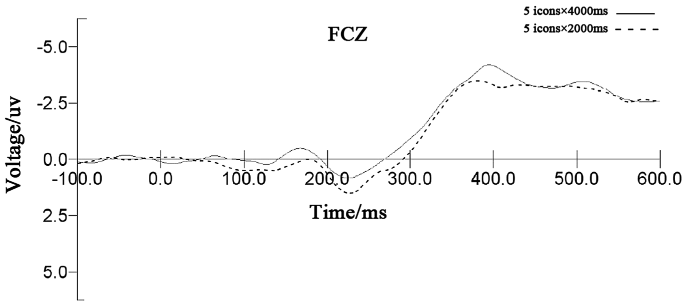

Fig. 3. FCZ electrode potential oscillogram of five icons

3.2 Study 2: Navigation Bar Visual Selective Attention ERP Research

In order to investigate the user cognitive processing of visual selective attention to icon navigation bar in the digital interface, 20 subjects were required to notice and remember the activated icons in the navigation bar selectively and judge whether or not target icon had presented in the navigation bar and if so press the button quickly. Their behavior and ERP data were collected. Experimental results demonstrate that P200 and N400 components of navigation bar selective attention exist obvious differences in amplitude and latency under different activated icon quantities. In the recognition process of target stimulus icon, accuracy rate and reaction time both exist regular changes with the activated icon quantities, and target stimulus recognition N200 component distributing in different brain areas exists obvious differences. Figure 4 shows the topographic maps of maximum amplitudes in different situations.

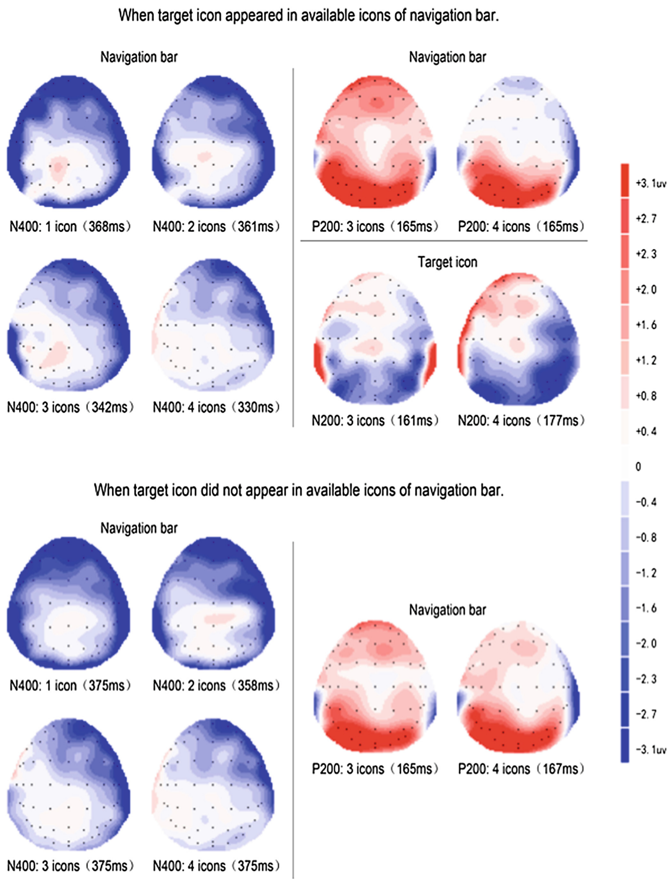

Fig. 4. Topographic maps of maximum amplitudes in different situations

3.3 Study 3: Interface Colour Matching ERP Research

By conducting interface colour matching ERP research, we can find N100 and P200 have more significant changes in colour matching and latency is around 100–200 ms. These results can be used for testing the design quality of interface and evaluated the usability of interface colour matching. Figure 5 shows the P3 electrode potential oscillogram under different colour matching situations.

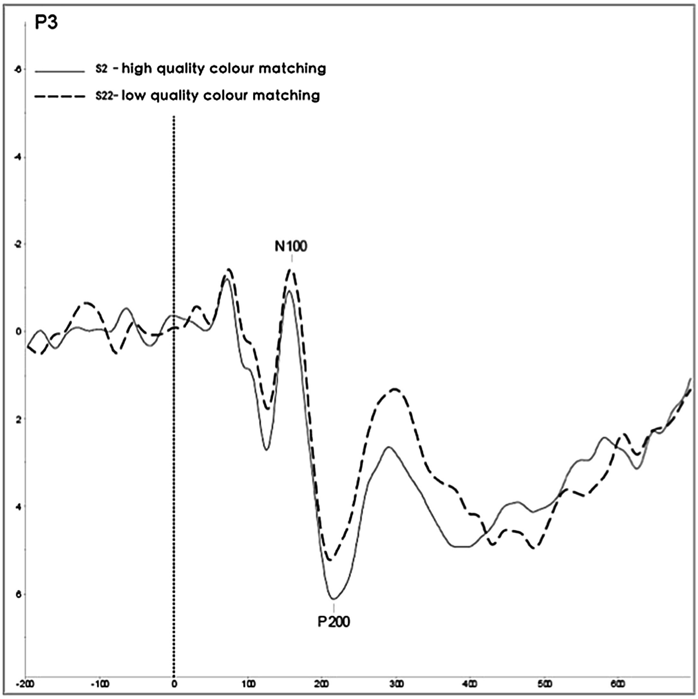

Fig. 5. P3 electrode potential oscillogram under different colour matching situations

4 Conclusion

According to brain electric experiments, the ERP evaluation indexes of digital interface elements were summarized, and interface element and EEG signal threshold values analysis was conducted. Based on these results, recommendation form of interface design was displayed. Besides, the overall and local ERP evaluation methods of digital interface were proposed. Table 1 shows the ERP physiological index and evaluation principle of digital interface elements.

Table 1. ERP physiological index and evaluation principle of digital interface elements

Interface element experiment	Experimental paradigm	ERP element	Max amplitude	Area	Evaluation principle
Icon memory	Modified sample-delayed matching task paradigm	P300	PZ P3	Parietal lobe	The higher amplitude of P300 of PZ and P3, the more difficult icon memory task
		P200	FCZ FZ	Central of frontal lobe	The later latency of P200 of FCZ and FZ, the more difficult icon memory task
Navigation bar selective attention	Serial mismatch experimental paradigm	P200	PO3	Right side of occipitoparietal	The higher amplitude of P200 of PO3, the wider selective range
		N400	FT8	Right side of frontotemporal	The earlier latency of N400 of FT8, the more interface number
Color matching	Go-Nogo	N100	P3	Left side of parietal lobe	The more positive amplitude of N100 of P3, the better interface
		P200	O_2	Right side of occipital lobe	The higher amplitude of P200 of O_2, the better interface

References

1. Girelli, M., Luck, S.J.: Are the same attentional mechanism used to detect visual search targets defined by color, orientation, and motion. Cogn. Neurosci. **9**, 238–258 (1997)
2. Kusak, G., Grune, K., Hagendorf, H., et al.: Updating of working memory in a running memory task : an event-related potential study. Int. Psychophysiol. **39**, 51–65 (2000)
3. Missonnier, P., Deiber, M.P., Gold, G., Herrmann, F.R., Millet, P.: Working memory load–related electroencephalographic parameters can differentiate progressive from stable mild cognitive impairment. Neuroscience **150**(2), 346–356 (2007)
4. Rader, S.K., Holmes, J.L., Golob, E.J.: Auditory event-related potentials during a spatial working memory task. Clin. Neurophysiol. **119**(5), 1176–1189 (2008)
5. Yi, Y., Friedman, D.: Event-related potential (ERP) measures reveal the timing of memory selection processes and proactive interference resolution in working memory. Brain Res. **1411**, 41–56 (2011)