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Human-computer Interaction Research on Alarm Signal in the Digital Interface Based on Fixed Coherent

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Abstract: Digital interface is an important medium in human-computer interaction, the operator electrophysiological index of alarm signal in the digital interface is one of the important basis of human-computer interaction research. Firstly, the brain automatic processing mechanisms and the pre-attentive change detection in human-computer interaction are analyzed, and the visual mismatch negativity which is cognitive neuroscience experiment measurement index was drawn out. Secondly, by using software E-prime, the visual mismatch negativity of operator was measured through the alarm signal in the digital interface stimulation. Finally, based on fixed coherent EEG inverse method, the source of brain signal on the alarm signal was found. The experimental results show that visual mismatch negativity exists in human-computer interaction of alarm signal. The perception ability for different types of alarm signals is different, and brain signal sources are also different. The results provide theoretical basis for ability improvement in human-computer interaction.

Key words: Human-computer interaction, digital interface, alarm signal, fixed coherent

INTRODUCTION

Human-computer interaction is one of important research content in industrial engineering on human factors. In today's highly modern production, the operators need to monitor a large number of equipments, perceive and analyze various types of data information. The alarm signals of various equipments bring the operators' attention for the alarm signals from the past classical focus attention to dispersible attention.

In an actual human computer interaction environment, operators pay attention to the change of the parameters of the equipment during normal operation at most of the time, and adopt the brain unconscious automatic processing for abnormal alarm signal perception. In the brain automatic processing, the pre-attention in the front of the human information processing model is used to percept and perform the signals of irrelevant task.

So far, a large number of researches have shown that the Event Related Potential (ERP) can be used to research the pre-attention, and the important index of the pre-attentive change detection is mismatch negativity (Naatanen *et al*., 2001; Naatanen *et al*., 2007).

The various types of stimulation materials of visual mismatch negativity can be chose. In the researches so far, the types of stimulus material mainly are: color (Czigler *et al*., 2004), duration (Khodanovich *et al*., 2010), orientation (Sulykos and Czigler, 2011), shape (Bubrovszky and Thomas, 2011), size (Kimura *et al*., 2008). In the numerous types of stimuli, visual mismatch negativity can be observed. This laid a theoretical foundation for this experiment on testing various types of visual mismatch negativity of alarm signals.

This study introduced the visual mismatch negativity in cognitive neuroscience to human-computer interaction research on alarm signal in digital interface. Referring to the auditory multi-feature MMN paradigm (Naatanen *et al*., 2004), five types of stimulations, such as color, duration, orientation, shape, size, are integrated into a complete oddball paradigm in the experiment. At the same experimental condition, participants' visual mismatch negativity was tested through five types alarm signal changes to directly reveal the reaction mechanism in human-computer interaction from the brain source when operators monitor alarm signal.

METHODS

Participants: Twelve volunteers (6 females, all right-handed) with normal or corrected-to-normal visual acuity served as participants (the average age = 25.5 years, age range = 24–30 years). All participants received payments for their participation. This research was

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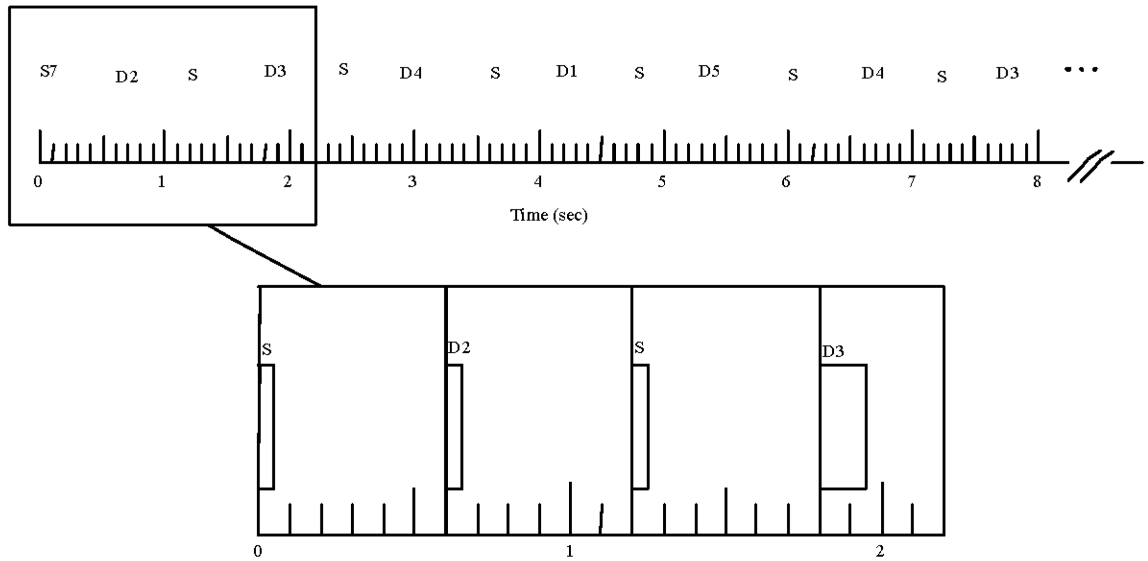

Fig. 1: Experimental paradigm, Schematic illustration of the stimulus condition used. S denotes standard stimulus and D_X stimuli of different deviant types (D_1- color deviant, D_2 - orientation deviant, D_3 - duration deviant, D_4 - shape deviant, D_5 - size deviant).

approved by the Ethical Committee in accordance with Declaration of Helsinki and all participants gave their written informed consents before the experiment.

Stimuli and procedure: The stimulation adopts digital interface of the tower winch, it was run via E-Prime 2.0 (http:// www.pstnet.com). During the experimental session, participants were seated in an acoustically and electrically shielded chamber. Participants watched the sequences of visual stimuli that were presented on a computer monitor from a distance of 1 m.

In the center of digital interface, a black number was displayed throughout the stimulus blocks. The black number is 7.5 which represent the rotating speed of tower winch drum. From time to time, the number became bigger (7.9) or smaller (7.1) unpredictably. The participants were requested to ignore the peripheral stimuli and press the left or the right button as quickly and accurately as possible when the black number became bigger or smaller.

In peripheral sides of the field, two same visual stimuli were simultaneously presented with the Stimulus Onset Asynchrony (SOA) of 600 ms. The visual stimuli represented the alarm signals of the tower winch. The alarm signals were green under the normal state. The concurrently presented peripheral stimuli occurred on the left and right of the black number (4.5° distance from center of number to center of the peripheral stimulus). The solid green rectangles (30 mm in length and 10 mm in width) were as standard stimuli, with the presentation of 50 ms. Five types of deviant stimuli were included: Two solid red rectangles (color deviant), two shifted 90° solid red rectangles to the standard stimuli (orientation deviant), two red rectangles with 150 duration (duration deviant), two solid red circle (shape deviant) and two wide red rectangles (size deviant).

In line with the method proposed by Naatanen *et al.* (2004), all the 5 deviants (P = 0.1; each) were presented in the same sequence so that every other visual stimulus was a standard stimulus (P = 0.5). The rationale of this paradigm was that the other deviants can strengthen the memory trace of the standard with respect to those levels of stimulus attributes they had in common. In each sequence, the first 15 stimuli were standards. The deviants were presented so that in an array of 5 deviants, each deviant category was presented once and 2 deviants of the same category never followed each other (Fig. 1). The stimuli were presented at a Stimulus-onset-asynchrony (SOA) of 600 ms in three 3 min sequences (900 stimuli in total), with the total recording time for the 5 types of deviants thus being 18 min.

EEG recording and analysis: The electroencephalogram (EEG) was continuously recorded with Neuroscan Synamps 2 Amplifier, using Quick Cap with 64-channel Ag/AgCl electrodes according to the extended international 10-20 system. The reference electrode was placed on the nose tip. Vertical EOG was recorded with two electrodes above and below the right eye. Horizontal EOG was recorded with two electrodes at the right and left outer canthusi of the eyes. The impedances of the

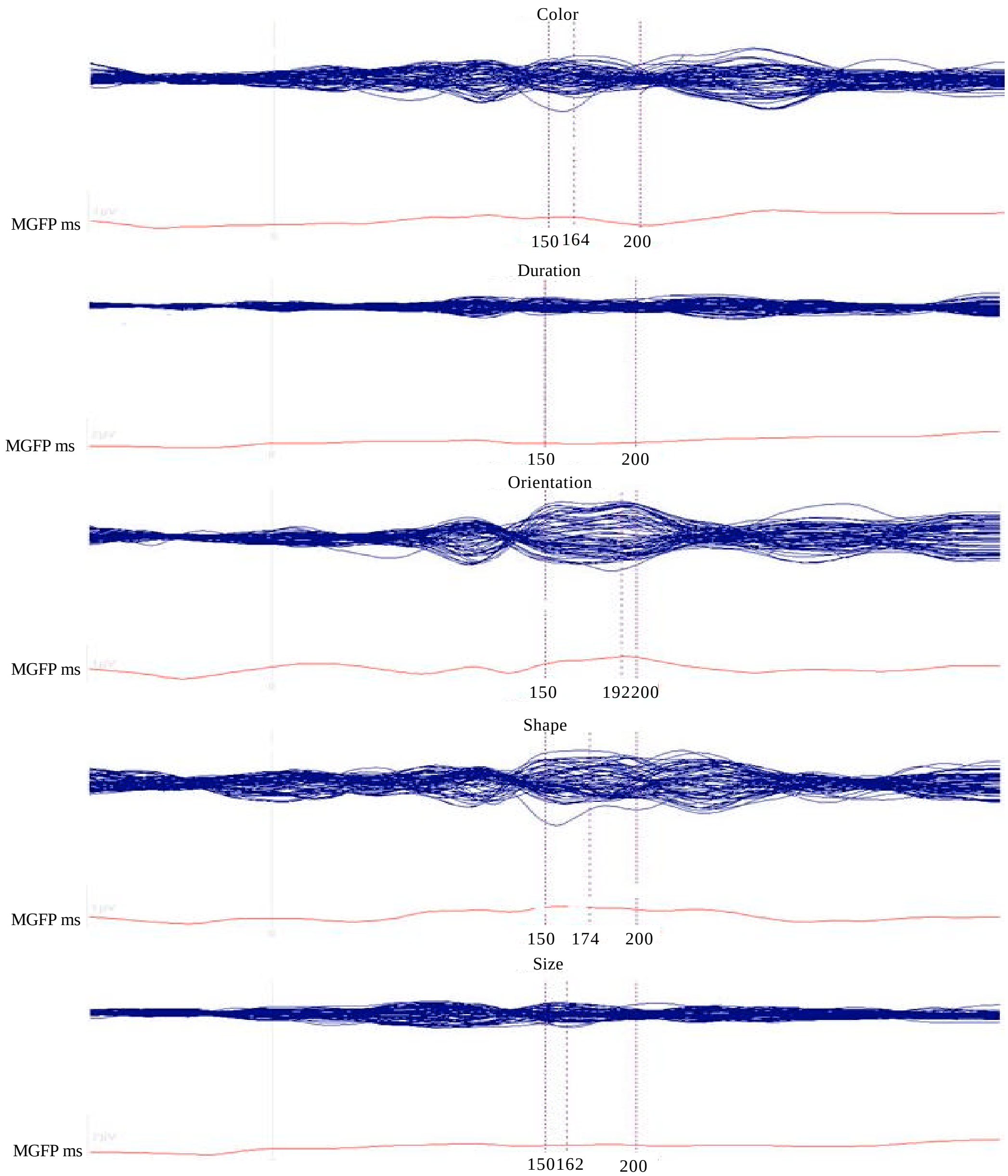

Fig. 2: Butterfly Plot and MGFP from visual MMN

electrodes were kept below 5 kΩ throughout the experiment. EEG and EOG signals were amplified with a band pass of 0.1-100 Hz at a sampling rate of 500 Hz.

After EOG artifact correction, the EEG was segmented into the epoch from 100 ms pre-stimulus to 400 ms post-stimulus. The trails contaminated with artifacts greater than±100 μV were rejected before averaging. The trails with targets when participants' responses occurred were rejected from averaging. The EEG segments were averaged separately for standard and deviant stimuli in different conditions. The visual mismatch negativity was obtained by subtracting ERP to standard stimuli from ERP to deviant stimuli for each visual feature, respectively.

The butterfly plot and Mean Global Field Power (MGFP) were drawn by the visual mismatch negativity data (Fig. 2). The brain sources of visual mismatch negativity were analyzed within the 150-200 ms time windows post stimulus onset by fixed coherent EEG inverse method.

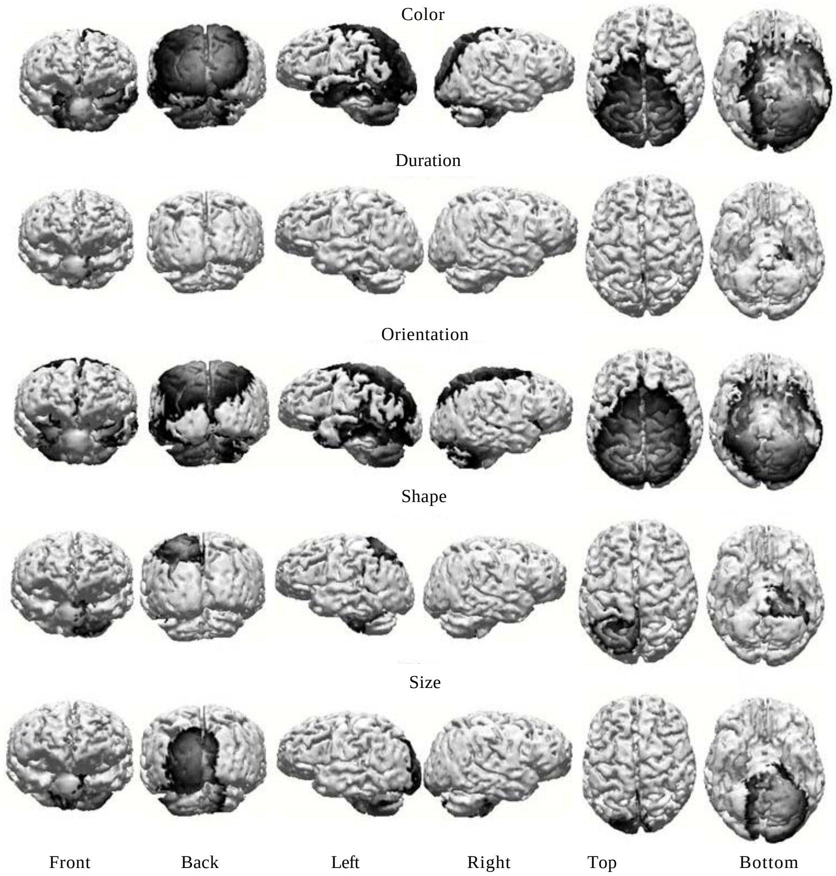

Fig. 3: ERP localization results of visual mismatch negativity

EXPERIMENTAL RESULTS

Behavioral data: Responses for detecting number changes in the center of the digital interface were scored as hit if the correct button was pressed within 150 to 1000 ms after targets onset. Mean accuracy rate was 97.22%. Referring to Czigler (2007), it can determine that participants' attention focused on the monitoring tasks of tower winch drum speed and participants for the alarm signal on either side of the digital interface belong to the state of unattended. These meet non-attentional requirement of irrelevant task for visual mismatch negativity.

Source analysis: The brain signal sources for different types of alarm signals are different by fixed coherent EEG inverse method. The Table 1 shows the current source locations of the visual mismatch negativity in the time window between 150 and 200 ms post stimuli onset, as estimated by using fixed coherent. The Fig. 3 illustrates the ERP localization results of the visual mismatch negativity.

Table 1: Source location of visual mismatch negativity

vMMN type	Time (ms)	X	Y	Z	Variance (%)
Color	164.0	-5.8	-38.2	-6.6	93.78
Duration	152.0	-12.4	-36.2	-5.9	86.76
Orientation	192.0	-4.9	-31.2	2.0	93.86
Shape	174.0	-21.7	-44.0	11.5	88.79
Size	162.0	-8.9	-60.6	-21.9	88.36

CONCLUSION

Through human-computer interaction research on alarm signal in the digital interface based on fixed coherent. The experimental results show that a variety of changes of alarm signals successfully induced the visual mismatch negativity. This is proof that humans can form the brain automatic processing for alarm signal in the digital interface when humans perform multiple tasks. When the operators are responsible for several tasks at the same time, the operators can use conscious control processing mode for real-time monitoring tasks. They will allocate the main focus resources on this kind of work tasks, such as monitoring equipment drum speed in experiment. The operators can use unconscious automation processing mode for alarm signal. The operators can directly turn to emergency response after perception for alarm signal by automatic processing ability at the pre-attentive stage.

Through experimental research, the emergency response capability for alarm signal in the digital interface environment was fully revealed. The mechanism of brain signals sources for alarm signals provide theoretical basis for operators' monitoring ability improvement in human-computer interaction.

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