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The Pre-attentive Processing under Background of Industrial Automatic Control: Evidence from the vMMN

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ABSTRACT
Safety education is a kind of effective means by which people can improve safety consciousness, can master the safety theory, regulations and technology standard.The most important reason of work-safety accident is human factor and the level of safety behaviors and emergency capability of production people is the focus of human factors. From the cognitive perspective, the article analyzes the pre-attentive processing features of human under the industrial auto-control background through people's information processing. Therefore article propose a cognitive neural experiment approach based HCI. Article used the auto-control interface of the towing vessels of ocean engineering vessels to simulate that of the real operating room. The figures on the central interface presented that the regular winding drum speed of the towing machine was 7.5m/min and the graphic symbols on the both sides of the interface presented the system pressure safety alerting signals of the towing machine. Normally, the safety alerting signals on the two sides of the interface were green rectangles, but abnormally they would be red vertical rectangles, red horizontal rectangles or red hexagons. Namely, the task-related stimuli appeared in the center of people's view but the task-unrelated stimuli appeared on the sides. The subjects were informed to concentrate on the winding drum speed on the center of the interface and ignore the pressure safety alerting signals on the sides. If the winding drum speed changes, the subjects should react as soon as possible. The experiment adopted Oddball and Equiprobable paradigms, using Event-related Potential (ERP) technology to verify. The results show that all of the 3 kinds of safety alerting signals can cause Visual Mismatch Negativity (vMMN) negative wave but the strength values are different. The pressure safety alerting signals of red horizontal rectangle are easier to cause the operator's attention.

Keywords: human factor (HF), visual mismatch negativity (vMMN), human-computer interaction (HCI), safety production (SP), pre-attentive (PA), event-related potentials (ERP)

INTRODUCTION

Although large-scale and modern HCI is more reliable and roboticized, safety accidents still cannot be avoided. People as the main body of man-machine system, the integrated monitoring and control functions of HCI requires people perceive and discern visual signals, auditory signals and tactile signals rapidly and accurately. This can increases people`s cognitive load. ISO has issued many international standards in field of HCI, including ISO10075 about term of ergonomics and mental load and ISO13407 about people-centric interactive system design process

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State of the literature

- Article point out although large-scale and modern HCI is more reliable and roboticized, safety accidents still cannot be avoided. Human factor is the most important reason of work-safety accident and the level of safety behaviors and emergency capability of production people is the focus of human factors.
- Article observed production people respond to the different safety alarm signals in the automated interface. Using the ERP experiment explored evoked potentials of different safety alerting signals and the pre-attentive processing exists in brain.
- Article proposed a cognitive neural experiment approach based HCI, and then used the auto-control interface of the towing vessels of ocean engineering vessels to simulate that of the real operating room. People as the main body of HCI system, the integrated monitoring and control functions of HCI requires people perceive and discern visual signals rapidly and accurately.

Contribution of this paper to the literature

- Article explored the pre-attentive processing under the combination of neuroergonomics and human-computer interface theory. It represents a typical feature of today's industrial automation.
- Describe the actual pattern of brain waves with the ERP experiment when safety production people perform multiple tasks. It can also make the results more realistic and reliable. Safety technology education is a kind of effective means by which people can improve safety consciousness, can master the safety theory, regulations and technology standard.
- It simulates the real automation safety production situation and it has rather strong practical applicability. It can provide reference for the real production and help workers enhance their level of safety behavior and emergency capability

(ISO, 2017). Parasurama (2007) study found that in a highly automated system, the reduced individual tasks and increase cognitive load make person become a passive monitoring rather than active participants. The transition from perform tasks to monitoring tasks inhibits people`s ability that people detect the key signal and perceive warning signal (Parasuraman& Rizzo, 2007). Better HCI will make the safety interface easier to identify and use. It can also make the safety supervisor more enjoyable and proactive, and then improve the level of individual safe behavior, reduce the accident rate of safe production and improve safety production performance. At present, the techniques such as vision, touch and biological characteristics have been applied to the HCI. It can help the safety workers acquire Multi- Modal Interaction (MMI) (Vertegaal, 2003; Shi-Yai, Jian, &Guo-Zhong, 1999). If equipment explosion or dangerous substance leakage causes casualty, property loss and environmental damage, there must be certain operator(s) making mistakes in certain step(s). The person may be the researcher, verifier, installer, operator or manager etc. of the equipment. The genuine source of accidental disaster lies in human factor. International Ergonomics Association (IEA) defined “Human factor” as a research on people’s psychological, physiological and anatomical factors in certain working environment, interaction of people, machine and environment, and how to comprehensively weigh their working efficiency, health, safety and comfort in their working, living and relaxing (Mark & Ernest, 1993). Parasuraman (2007) first put forward the “Neuroergonomics” which is a science researching human brain and behavior at work. It links research with practices, combining neuroscience and ergonomics (or human factor) to exert the greatest advantages of the two disciplines (Parasuraman & Rizzo, 2007; Parasuraman, Christensen, & Grafton, 2012). So far, the researches on human factor mainly concentrate on physiologic level, cognitive level and organizational level. Neuroergonomics and HCI provides a new view for people’s cognitive process to alerting signal. Safety technology education can help the production workers improve their own safety behavior level. And then safety technology education apply safety technology, skill, safety system control and experience to meet the needs of safety production.

It’s worth noting that people’s reflection to signal is an information processing course. Primarily, the accident signal transits people’s perception, then it goes through the information processing of human brain and finally direct the limbs to reply to the accident threaten (Wickens, Hollands, Banbury, & Parasuraman, 2013). The analysis on the three signal processing steps was from the view of people’s information processing (Wickens, et al. 2013). A classic research “Human Information-processing Model” on human signal reaction was provided by

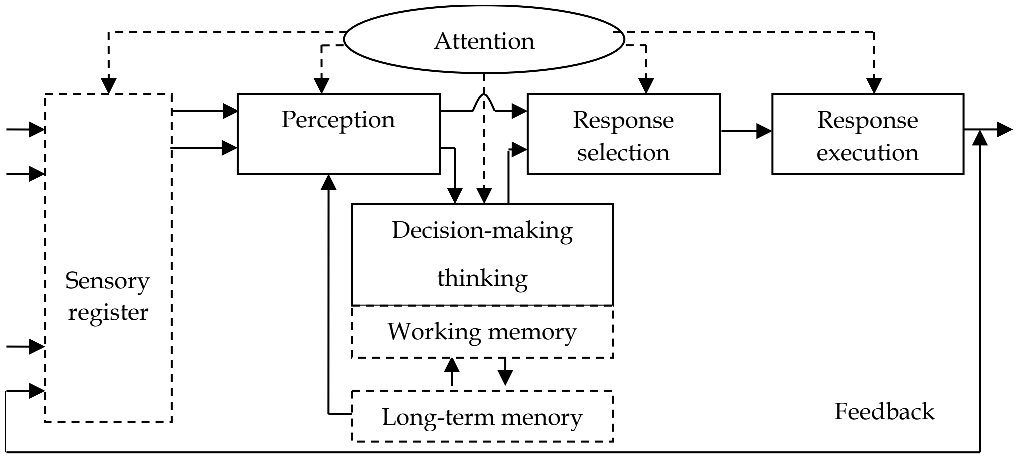


Figure 1. The model of information processing (Wicken, Lee, Liu, & Gordon-Becker, 2004)

ergonomic expert Wickens (Wickens, Lee, Liu, & Gordon-Becker, 2004). As psychological endeavor, attention exists along the whole information processing course (Wickens, et al. 2013). Human brain can receive different kinds of changing information from the outside, but the brain pays attention to certain selective information, namely this is the selectivity of attention (Parasuraman & Rizzo, 2007). It is because the brain has selectivity feature and it needs to make transient register before the attention and processing of information and it takes out the information to be processed. The psychological process analyzing that if it should be noticed is called pre-attention (Naatanen, Paavilainen, Rinne, & Alho, 2007; Liping & Jun, 2013). Pre-attention reflects the brain's automatic processing of information change. It needs not to consume excess attentive resources; people can concentrate their main attention on important tasks (Liping & Jun, 2013). Pre-attention is one of the important functions of people's highly automatic production, it perceives various task-unrelated information in the front end of information processing (Xiaosen, Yi, Bing, Li, Songlin, Lijie, Cuiping, & Lun, 2014). Some scholars believe that pre-attention processing can reflect people's sentience and memory capability (Naatanen, et al. 2007). Then, pre-attention is related to people's automatic detection of stimulus variation. It is a necessary psychological process of brain to perceive the regular change of environment (Hammar & Ardal, 2009). Pre-attention is an analyzing process to decide, before the sensory register, whether the signal should be noticed. Attention is conscious selection of signals accessing the cognitive system. For this selection, the brain must distinguish different signals that intend to access cognitive system before sensory register, making out the signals noticed and not noticed, and the next is to conduct a series of information processing of sense, consciousness, decision and reaction and automatic processing of signals that should not be noticed (Yuejia & Jinghan, 2009). The so-called automatic processing is the processing of non-attention object of human brain and also cognitive processing needs no attention or needs less attention; it is not controlled by consciousness (Arthur, Rhianon, & Emily, 2009). Automatic processing is psychological operation needs no consciousness, it is featured with high speed, high efficiency and less consumption, and it is not controlled by consciousness (Arthur, Rhianon, & Emily, 2009). Therefore, it is necessary to develop new ways to open the black box of people's reaction to alerting signal.

Being an important cognitive function of human highly automatic production (as referred **Figure 1**), the "pre-attention" in the front of information processing model can perceive and execute different task-unrelated signals in non-attentive status (Schroger, 1997). Therefore, through the pre-attention research, the researcher could reveal a mechanism that when the monitor is carrying out regular tasks, they can also do automatic processing of the alerting signal of other task-unrelated accidents under non-attention condition. So far, many researches show that measuring ERPs of the EEG can research the "pre-attention" directly and effectively (Naatanen, et al. 2007; Naatanen, Tervaniemi, Sussman, Paavilainen, & Winkler, 2001).

ERPs are used in researching Ergonomics-related problems, mainly including the researches on working cognitive load, mechanism evaluation of vigilance decline, fatigue monitoring in people-machine system, stressor assessment, the influence of on-line self-adaption auxiliary on operators' performance etc (Kato, Endo, & Kizuka, 2009; Belopolsky, Kramer, & Theeuwes, 2008). As an important cognitive function of human living, pre-attention changing detection happens in early phase of information processing. Some evidence shows that a component of ERP--vMMN is a reliable index of exploring pre-attention processing (Naatanen, et al. 2007; Liping & Jun, 2013; Naatanen, Paavilainen, Rinne, & Takegata, 2004). Mismatch negativity (MMN) refers to an EEG index observed by the subject when the subject receives repeated sequence with the same stimuli of non-attention status (standard stimuli of large probability) and mismatching stimuli happens accidentally (deviant stimuli of small probability) (Steven & Luck, 2005). MMN is a non-task-reliable experimental paradigm that is not influenced by cooperative degree. It even can be used in researches on loss of consciousness and disturbance of consciousness. Compared with other EPR component, the cognitive function referred by MMN is relatively definite and the MMN is not influenced by motivational factors as easy as P300. Currently, the MMN is already used in clinic researches of pre-attention processing of many diseases, such as schizophrenia, depression, hearing disorder, conscious disturbance and multiple sclerosis (Kujala, Tervaniemi, & Schroger, 2007; Naatanen & Kahkonen, 2009; Takei, Kumano, Hattori, Uehara, Kawakubo, Kasai, Fukuda, & Mikuni, 2009; Roggia & Colares, 2008; Qin, Di, Yan, Yu, laureys, & Weng, 2008; Xiaosen, Yi, Bing, Li, Songlin, Lijie, Cuiping, & Lun, 2014). Early MMN researches limited in auditory pathway. In recent years, visual MMN researches have been significantly developed. The researchers found that certain types of visual stimuli (color, shape, movement of subject and spatial frequency etc.) can also induce VMMN (Pazo-Alvarez, Amenedo, Lorenzo-Lopez, & Cadaveira, 2004; Cziger, 2007; Pazo-Alvarez, Cadaveira, & Amenedo, 2003). The EEG index measured in this experiment is VMMN. In real work, alerting signal in automation interface regularly appears as green symbols, but in alerting status, it is red. However, the VMMN factor induced in Oddball paradigm is disputed. In this paradigm, the VMMN may be induced by refractoriness or sensory memory mismatch negativity (Jacobsen, Schroger, Horenkamp, & Winkler, 2003; Kenemans, Jong, & Verbaten, 2003; Kimura, Katayama, & Murohashi, 2006). Sometimes, they can be simultaneously induced (Kimura, Katayama, & Murohashi, 2008). Cziger (2007) experimented with Oddball sequence and equal probability Control sequence; he found that real VMMN should be the difference element that equals the deviant stimuli ERPs in Oddball minus the equal probability stimuli ERPs in Control sequence. He called it Control-MMN. Recently, a subtle experimental design reveals that vMMN in Oddball paradigm is composed by refractoriness and sensory memory matching effect (Kimura, Katayama, & Murohashi, 2008; Kimura, Katayama, Ohira, & Schroeger, 2009). The temporal region under Oddball paradigm includes two negative components, one is early Oddball-MMN at 100ms-150ms, it reflects the difference of refractory effects between deviant stimulus and standard stimulus; the other is Control-MMN negative components at 200ms-250ms, it is the vMMN based on real sensory memory (Kimura, et al. 2008). The most reliable way to acquire the real VMMN is to use Control sequence and Oddball sequence simultaneously, using deviant stimuli in Oddball sequence minus the ERPs equal probability stimuli in Control sequence to eliminate the refractory effect so as to research the subject's pre-attention automatic processing (Kimura, et al. 2008).

LITERATURES REVIEWING

Referring to the past theses on visual mismatch negativity (Xiaosen, et al. 2014; Sulykos & Czigler, 2011; Kimura, Schroeger, & Czigler, 2010; Maekawa, Tobimatsu, Ogata, Onitsuka, & Kanba, 2009; Czigler, Winkler, Pato, Varnagy, Weisz, & Balazs, 2006; Kimura, Widmann, & Schroeger, 2010; Czigler, Weisz, Winkler, 2006), the number of subjects was from 8 to 12 people. In this experiment, article chose 12 healthy common subjects (6 males and 6 females) aged between 18 to 28 years old. Their average age was 22.5. They were all right-handed. Each subject was stimulated 3240 times so that the data was reliable. The subjects did not use any sedative and hypnotic drugs and psychoactive drug substance within 24 hours before the experiment. In addition, all the subjects had normal color distinguishing ability and visual acuity, their naked eyesight or corrected vision was above 1.0. The experiment obeyed the Declaration of Helsinki, the subjects all signed informed consent before the experiment. The experiment was conducted after the subjects fully understood the experimental content and fully practiced.

The stimulation materials of the experiment were wrote and presented with the software Eprime2.0. Article used some automatic control interfaces of the towing engines of ocean engineering vessel as the stimulus materials (shows in the pictures). They were presented in the center of 19 inch LCD (liquid crystal display). The standard stimuli were shown as green rectangles, but the deviant stimuli were shown as different rectangles with

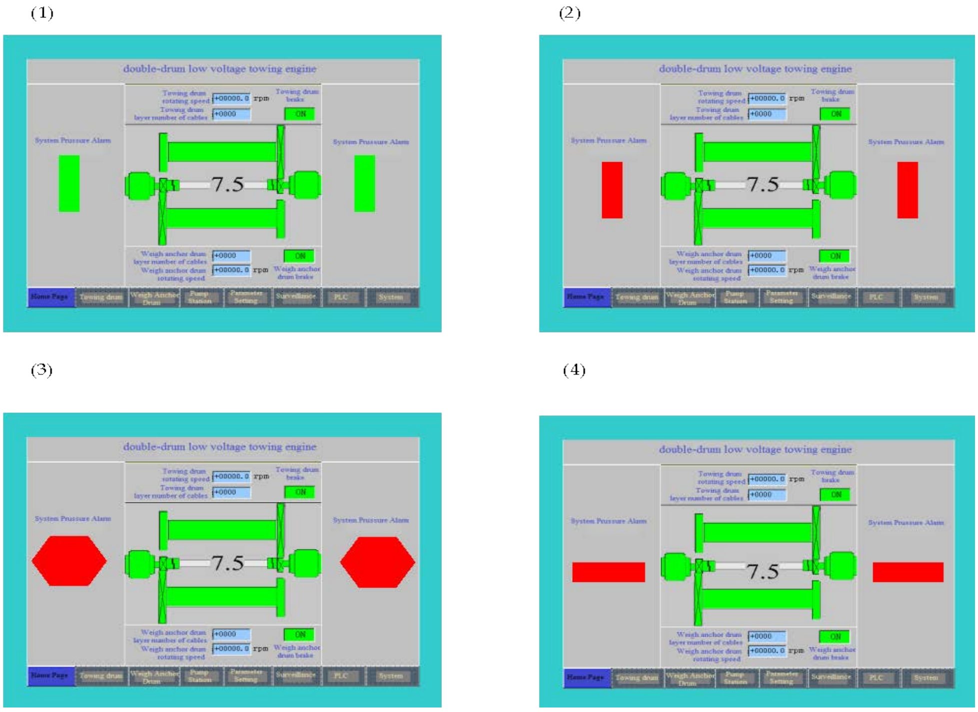


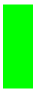
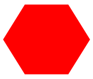
Figure 2. Experimental stimuli

different color, orientation and shape. All the stimulus materials were with the same size, brightness, contrast ratio and spatial frequency after the software process. In the stimulus materials, the figures in the central interface presents that the winding drum speed in regular work is 7.5m/min and the graphic symbol on the two sides of the interface represents systematic pressure safety alerting signals (the visual angle from the central interface to the center of one side alerting signal is 45°) of the towing machine. The interface arrangement conformed to the ideal vMMN experimental paradigm, namely the task-related stimuli appeared in the center of view but the task-unrelated stimuli appeared on the margin of view, they are separated (Kimura, Katayama, Ohira, & Schroeger, 2009). Under regular condition, the safety alerting signals on the both side of the interface were green; and they would be red when meeting abnormal alerting (according to the international norms and conformity GB2682). As the pictures show, (1) represents the standard stimuli of VMMN as green rectangles on the sides of the interface (30mm long, 10mm wide); (2) represents the deviant stimuli of the color change of VMMN as red rectangles on the both sides of the interface; (3) represents the deviant stimuli of the orientation change of VMMN as the red rectangles rotated 90° on the sides of the interface; (4) represents the deviant stimuli of the shape change of VMMN as the red hexagons on the sides of the interface (conform with the IEC60073 standard) (as referred **Figure 2**). In order to control the task fineness, the task-related stimuli should be concentrated on the center of the view, but task-unrelated stimuli are arrayed on the margin of the view. And they are separated (Wickens, Holiands, Banbury, & Parasuraman, 2013). The screen shows non-target stimuli and target stimuli. The non-target stimuli are task-unrelated standard stimuli and deviant stimuli, but the target stimuli are task-related stimuli. They are not related and arranged as pseudorandom.

RESEARCH DESIGN

The experiment was carried out in a quiet electrophysiology laboratory with comfort light. The subjects were seated comfortably 1m before the screen. The subjects were asked to concentrate on the winding drum speed on the central interface. In regular status, winding drum speed should be 7.5（m/min）. If it changed, the subjects were asked to react correctly as soon as possible. The principle was that when the winding drum speed increased

Table 1. Stimuli and their probabilities(times/block)in the oddball and equiprobable sequences

Stimuli					**Total**
Oddball	450	90	90	90	720
Equiprobable	90	90	90	90	360

to 7.9, the subjects should press the button "Z" on the keyboard; when the speed decreased to 7.1, they should press the button "/". The subjects could adjust the winding drum speed at any time. In addition, the researchers emphasized that the subjects should focus on the monitoring and adjustment of the winding drum speed and ignoring the alerting signal change on the sides of the interface. At the same time, the subjects were informed that the change of the winding drum speed on the central interface had no relation with the alerting signal on the sides. This experimental design enables the subjects to form the task-unrelated safety alerting signals into non-attention status to satisfy the test requirements of VMMN.

The experimental process has 6 Blocks, including 3 Blocks of Oddball paradigm and 3 Blocks of Equiprobable paradigm. In this research, the Oddball paradigm was corrected after those one used in the Tales researches (Tales, Newton, Troscianko, & Butler, 1999). Each Block in the Oddball paradigm included 720 trails. In the Equiprobable paradigm, each Block included 360 trails. There was breaking time between two adjacent Blocks; the length of breaking was controlled by the subjects (as referred **Table 1**).

(1) In the Oddball paradigm, the standard stimuli and deviant stimuli appeared alternately. The occurrence rate of standard stimuli was 50% and that of the other three kinds of deviant stimuli was 16.7%. Each standard stimulus was followed by a deviant stimulus at random. The target stimuli and non-target stimuli were presented in different sequences. Deviant stimuli of the same type should not appear one after another, namely the target stimuli in case that the subjects assembly the target and non-target stimuli together. In this research, each stimulus of the Oddball paradigm was presented for 50ms and the breaking time (SOA) was 600ms.

(2) In Equiprobable paradigm, to evaluate deviant-minus-control and control-minus-standard difference waves, 4 equal-probability stimuli substituted the standard and deviant stimuli in the Oddball paradigm. Therein, the physical property and presenting mode of the equal-probability stimuli were all the same with the standard and deviant stimuli in the Oddball paradigm. The probability of all the stimuli was 25%. Each stimulus appeared at random and stimuli of the same type could not be presented continuously. The presenting time of each stimulus was 50 ms and the breaking time (SOA) was 600ms.

Before starting the experiment, the subjects needed to do 15 trail exercises and the experimenter gave them detailed instruction to enable the subjects to fully understand the engineering environment and meaning of the experiment.

EVALUATED MEASUREMENTS

Article use the Scan4.5 software to do offline analysis on the recorded consecutive EEG data. The detailed operation included: (1) doing DC correction and removal of obvious drifting or disordered EEG data, (2) removing the influence of electrooculogram (HEOG) and (VEOG) on other lead-data according to the eye movement, (3) segmenting the EEG, choosing the 400ms after stimulation as the time history and the 100ms before stimulation as the baseline, and then doing the baseline correction and removing the artifact of amplitude greater than ±100μV, (4) classifying, overlaying and averaging the EEG data, (5) classifying, overlaying and averaging the deviant stimuli (in Oddball) and equal probability stimuli (in Equiprobable) of the 7 electrodes M1, P5, P7, PO5, PO7, CB1, O1 on the left and the 7 electrodes M2, P6, P8, PO6, PO8, CB2, O2 on the right, (6) using the deviant stimuli in the Oddball-MMN to minus the equal probability stimuli in the Equiprobable to get the Control-MMN (removing

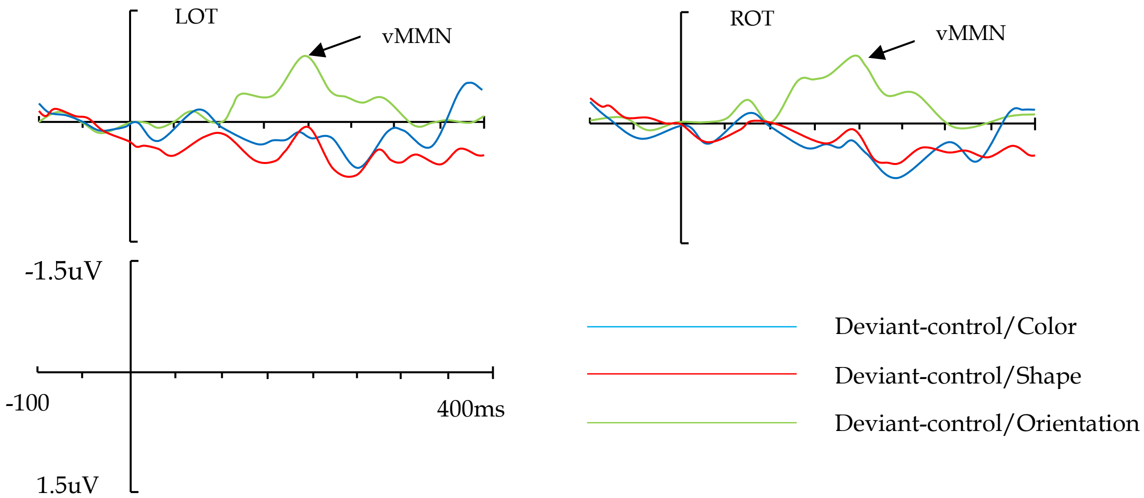


Figure 3. Brain Oscillograms of different types of VMMN

the refractoriness to avoid the P1, N1, P2 component confusion [33]), and (7) getting the peak value in a 50ms window and getting the result at 175-225ms. Based on the past literatures, the VMMN appeared at 100-300ms after the stimulation.

Article analyzed the processed behavior and EEG data with the software SPSS19.0, including (1) behavior data. Article analyzed the reaction time and accuracy of the subjects when their winding drum speed values out of range. (2) EEG data. Article did descriptive analysis on the type (color, shape, orientation) of the vMMN; the vMMN amplitude values were analyzed with repeated measurement and variance analysis, respectively. The factors were type (color, shape, orientation) of the vMMN × cerebral hemisphere (left LOT, right ROT), and used Greenhouse-Geisser to correct the degree of freedom. Research get the result that from the behavior data analysis, the accuracy of the subjects' reaction to the winding drum speed change (out of range) in 1S is 96.34%. The accuracy shows that the subjects' attention mainly concentrated on the task of monitoring the winding drum speed change so that they got a non-attentive status that forms the unrelated non-attention demand of the VMMN (Cziger, 2007).

The combined EEG data of LOT and ROT, namely the Control-MMN EEG brain electrical activity mapping getting from the deviant stimuli in Oddball minus equal probability stimuli in Equiprobable, getting the peak values at the 175-225ms time window. The peak values were orientation, shape and color, from large to small (as referred **Figure 3**).

It shows the brain electrical activity mapping of different types of vMMN safety alerting signals at the 175-225ms time window. The VMMN induced by safety alerting signals of the color type were more significant in the prefrontal lobe; that of the shape type were more significant in frontal lobe and superior frontal gyrus; that of the orientation type were more significant in the parietal lobe and posterior central gyrus (as referred **Figure 4**).

Based on the statistics result of sphericity test, Mauchly's W=0.451 and Sig=0.752, the spherical hypothesis can be accepted. The results show that the vMMN EEG data has significant difference (F=4.106, P<0.05); the hemispheres have no significant difference (F=0.531, P>0.05); the interaction between the vMMN type and the hemispheres factors have no significant difference (F=0.123, P>0.05). The descriptive statistical result shows that the sequence of vMMN amplitudes from small to large is respectively the vMMN induced by orientation, shape and color.

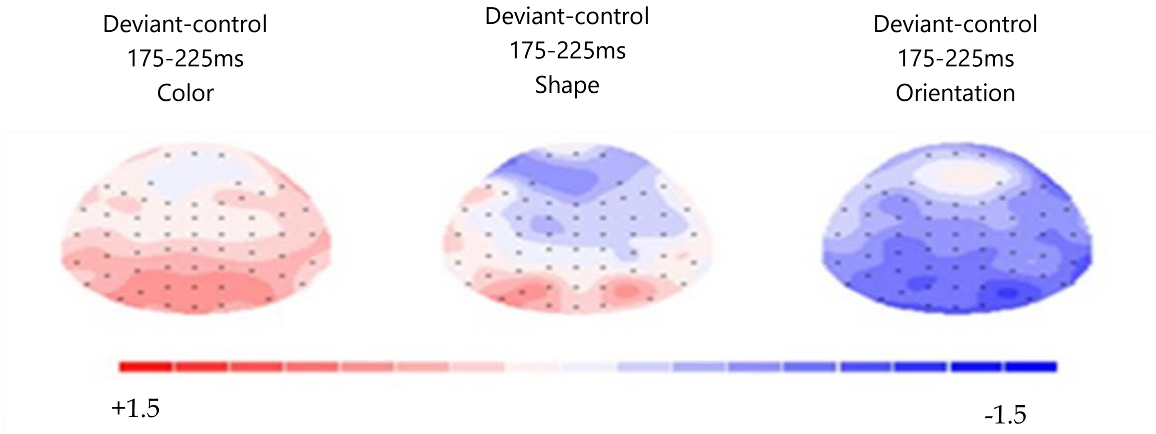


Figure 4. Brain Electrical Activity Mapping of VMMN

CONCLUSION AND RECOMMENDATION

The purpose of this experiment is to use the neuroergonomics and HCI theories and measures to explore the mechanism of people's reaction to the safety alerting signals of automatic interface. Research used the interactive model and design approach based on cognitive science and the auto-control interface of the towing vessels of ocean engineering vessels to simulate that of the real operating room. It makes production people identify and response safety alerting signals rapidly in HCI. It can improve the level of individual safe behavior, reduce the accident rate of safe production and improve safety production performance. In the experiment, it used the most reliable (Oddball and Control paradigms) to exclude the refractoriness to verify the existence of people's reaction to safety alerting signals in the pre-attention course and if the safety alerting signals of different stimulus can induce different strength of VMMN. The experiment verifies that when people monitor and operate the automatic interface, the brain can really form automatic processing on task-unrelated visual signal stimuli (safety alerting signals), namely people's reaction to safety alerting signals really exists in the pre-attention phase; when the monitoring are responsible for multiple tasks at the same time, they can adapt conscious controlling and processing mode to the tasks needing real-time monitoring and they must concentrate mainly on this kind of tasks, for example, monitoring of the winding drum speed of the towing machine; to the perception of abnormal accident signals, automatic processing mode can be used that the monitor are demanded to exert their reaction to the pre-attention automatic processing capability and turn to react and execute after accident signal perception; meanwhile, the experiment verifies that the safety alerting signals of different types of stimuli induce different strength of VMMN.

People's reaction to the safety alerting signals exists in pre-attentive process. When the subjects are monitoring and operating the automatic interface, the safety alerting signals can be attributed to physical stimuli. The change of it induces the oddball-vMMN and control-vMMN. Peak value getting from the equation that deviant stimulus ERP of the Oddball minus the equal probability ERP of the Control within a 50ms time window, as a result, the peak value was got at 175-225ms, namely the real pre-attention automatic processing course. It verifies that people's reaction to the safety alerting signals definitely exists in the pre-attention phase. It shows that brain can do automatic processing for the signals that not related to the task when human perform multiple tasks. At the moment, they can do controlled processing for the signals that important and real time monitoring tasks and they can focus the major attention resources on these tasks. For example, people use controlled processing for the winding drum speed of the towing machine and use automatic processing for the abnormal accident signal. Let the monitor be able to use the automatic processing capability of the pre-attention stage, and then transform to the emergency response directly.

The safety alerting signals of different types of stimuli induce different strength of VMMN. The experiment verifies that safety alerting signals of the orientation type cause the greatest strength of VMMN, followed by the pure VMMN induced by the safety alerting signals of the shape type and color type. The reason of this result may be because: the VMMNs induced by safety alerting signals of the orientation type and the shape type, are greater than the pure VMMN induced by that of the single-color type. This result conforms to the visual information coding principle that the property information coding of multi-dimensional visual stimulant decreases people's reaction time and increase people's reaction strength, compared with that of single-dimensional visual stimulant. It is noteworthy that the IEC60073 Standards stipulate that in dangerous status, the safety alerting signals will change into red hexagons from the green rectangles in safe status so that the operators should immediately process the danger. This experiment explicitly shows that the orientation type of the safety alerting signals can induce stronger VMMN that people's reaction is more significant to it that it provides reference value to the design of safety alerting signals. Some scholars may doubt that the space of automatic controlling interface is limited, the orientation type of safety alerting signals (red rectangle rotating 90°) may occupy large space so that it does not fit to be used in automatic controlling interface. But in complicated people-machine system, there exists numerous safety alerting signals, so the designer usually put the most important safety alerting signals on the most obvious place, displaying the main signal and secondary signal. The function of main signal is to reminder the operator of abnormal condition and the secondary signal can help the operator to confirm the errors of the system. In view of that, in this thesis it provide that the orientation alerting signal can be considered as main signal so that the operators can rapidly perceive the change of the main signal in order to make other control reaction as soon as possible.

DISSCUSSION

Human-centered, natural and efficient pattern is the main objective of the new HCI. ISO13407 point out that the Ergonomics apply to the HCI can help users improve the effectiveness and efficiency of the work, improve working condition and reduce the harmful effect of user`s health, safety and performance in the process of using (ISO, 2017). Meanwhile, skills training and safety education should be reinforced to buildup vocational technique ability and consciousness for safety, ensuring safe running of production. In recent years, the usability engineering in industry design has now been recognized in the world. Microsoft, Siemens and Nokia all set up the usability lab. The experiment of this thesis adapts a real automatic control interface used in industrial production, under the background of ship automation. It has the typical characters of the present industrial automation, approaching the real safety production environment. By using this interface, it is enabled to test the reaction capability of the monitor and operator in order to reveal the mechanism of the workers' reaction to the safety signals in the present automatic production. It contributes to select, deploy and improve the workers' ability so that it improves the safety production of enterprise from the perspective of human factor.

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