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Research on Emergency Personnel Capability Classification Standard: A Perspective of Biofeedback Experiment

[1]Liping Shi and [1,2]Zewen Du
[1]School of Economics and Management, Harbin Engineering University, Harbin, Heilongjiang 150001, China
[2]School of Management, Harbin University of Commerce, Harbin, Heilongjiang 150028, China

Abstract: Enhancing emergency personnel capability is a fundamental policy to respond all types of emergencies effectively. Emergency personnel capability classification is the precondition for selection of high quality emergency personnel. Classification standards and scales of emergency personnel capability lack an objective basis. Therefore, based on theory of cognitive neuroscience, this study adopts biofeedback experiment to measure physiological changes under stress. According to differences of emergency personnel physiological indicators, emergency personnel capability is classified. The results indicate that low capability of emergency personnel changed are obviously compared with high capability of emergency personnel before and after stress in skin temperature, finger blood volume amplitude, heart rate variability and EEG. Besides, reference standard for emergency personnel capability classification is developed. Theoretical guidance and practical basis for optimization of emergency personnel structures are given.

Key words: Emergency personnel, capability classification standard, physiological indexes, biofeedback experiment

INTRODUCTION

Currently, economy enters a new era of rapid development and society also enters the "frequent incidence of emergencies" in China. All types of emergencies every year cause significant losses to the economy and society which become an important risk to build a harmonious society and sustainable development. Major factors of serious consequences on unexpected events are inadequate investment in government emergency, emergency command system failure, information network barriers and emergency management system deficiencies. However, few people for emergency personnel selection and the ability to enhance the proposed targeted recommendations. However, few people propose recommendations for emergency personnel selection and capacity building. Major prerequisites for an effective response to emergencies are reasonable classification of emergency personnel, emergency personnel structure optimization, establishment of efficient emergency response team.

Emergency response capability classification research focused on organization emergency response capacity and individual emergency response capacity. In the level of organizational emergency response capability (Valdmanis *et al*., 2010; Davies *et al*., 2010; Cheng *et al*., 2011), the United States proposes classification criteria for emergency response capabilities of different categories. Japanese government set up disaster prevention capability evaluation projects of local public bodies. In the level of individual emergency response capability (Fedak, 2011; Lamhaut *et al*., 2010), emergency response capacity is measured and classified by way of examination in the United States. Existing research on ability classification criteria of emergency personnel is relative lack. In these theoretical and practical guide, emergency personnel capabilities are classified by biofeedback experiments means.

EXPERIMENTAL THEORY AND HYPOTHESIS

Principle of biofeedback experiments: Biofeedback experiment is a means which can measure people's skin temperature, blood volume means finger amplitude, heart rate variability and EEG and other physiological indicators by biofeedback. This study measures skin temperature, physiological index finger blood volume amplitude, heart rate variability and EEG by biofeedback experiments. Based on differences of physiological indicators under different stress state, emergency personnel ability is classified.

Corresponding Author: Liping Shi, School of Economics and Management, Harbin Engineering University, Harbin, Heilongjiang 150001, China

Experimental assumptions: Feng *et al.* (2005) measured heart rate, blood pressure and skin temperature and other physiological indicators by electrophysiological experiments and found that people of different psychological characteristics were under psychological stress conditions and their changes of heart rate, blood pressure and skin temperature were different. Under emergency situations, personnel of different emergency ability will have different level of tension and there are differences mood changes. These differences can be reflected by physiological index. And following hypothesis are proposed.

Hypothesis H1: Skin temperature is obviously different for personnel of different emergency ability under stress response of emergency situations.

Hypothesis H2: Finger blood volume is obviously different for personnel of different emergency ability under stress response of emergency situations.

Hypothesis H3: HRV is obviously different for personnel of different emergency ability under stress response of emergency situations.

Hypothesis H4: EEG (fatigue wave, relaxation wave, attention wave and excitement wave) is obviously different for personnel of different emergency ability under stress response of emergency situations.

EXPERIMENTAL METHODS

Experimental design: This experiment uses a hybrid experimental design. Independent variable: Psychological states of participants include level of tension, anxiety and fear degree; Three stages includes baseline, stress and recovery. Dependent variable: It includes skin temperature, finger blood volume amplitude, heart rate variability and EEG, etc.; Reaction time and correct answer rate. Control variables: It includes relevant factors such as age, experimental environment, temperature, circadian rhythm, etc., eliminate noise interference factors, cell phone signals.

Materials: In this experiment, based on existing research results, characteristics of emergency situations and ideas of emotional stroop effect paradigm, starting stimulus is the negative emotion pictures and target stimulus is mental arithmetic problems in different colors.

Negative emotion pictures. Negative emotion pictures are selected from the International Affective Picture Storeroom and China Affective Picture Storeroom. Negative emotions pictures describe the different types of emergencies. Its purpose is to induce participants to enter the emergency situation and trigger negative emotions of participants and it will produce impact of different degrees on speed and accuracy of judgment.

Mental arithmetic material. It consists of mental arithmetic questions, including different color and font. Center of the screen will show two mental arithmetic questions with different colors around which are divided into "red-yellow", "red-blue", "blue-red" and "yellow-red". Participants are only required to calculate the red font for the title, ignoring other color topics. There are three answers on each mental arithmetic questions, including red mental arithmetic questions, interference option and yellow (blue) mental arithmetic questions. Mental arithmetic questions are that 3-digit numbers subtract 2-digit numbers. All questions are randomly arranged through a combination of digital, non-repeating questions and each question is no digital of re-use. It is presented only once.

Participants and procedures: University students master certain emergency knowledge and skills, also participate in the relevant emergency drills. There are no significant difference on framework effects experiment of decision-making field between students and groups owning professional management experience. In electrophysiological experiments of Event Rrelated Potentials (ERP), minimum numbers of participants on each condition are 12. According to above requirements, 32 college students were recruited, whose physical and mental condition were normal. Before the experiment, participants read experimental guidance and wrote informed consent. They obtained corresponding reward after the experiment.

Experimental stages include baseline, stress and recovery and the experiment is about 15 min. Specific procedures are as follows: In baseline, physiological indicators data of participants are recorded under natural, quiet, eyes closed state in five minutes. In stress period, participants realized "start stimulation" which evoked negative emotions. And reaction rate of the target stimuli is affected, recording physiological indicators in five minutes. Stress of the process: First, in the middle of the computer, screen will pop up a "+" sign fixation point , reminding participants start the experiment. After 500 ms, the "+" disappears and then it will show a negative picture stimuli. After 400 ms, the picture disappears, then it will present two different colors of mental arithmetic questions which place three answers randomly from left to right below the title and in turn correspond to the "1", "2" and "3" key on the keyboard. Showing pictures and

reaction time can not be more than 10 seconds, or by miscalculation. In recovery, participants are required to choose a comfortable sitting position, naturally relax, keep quiet, close eyes. Various physiological indicators of participants are recorded under natural state in 5 minutes. After the experiment, participants are asked to fill in the subjective experience report form and tell their feelings in the experiment and get the appropriate compensation.

Equipment and data acquisition: Experimental physiological indicators include skin temperature, finger blood volume amplitude , heart rate variability and EEG. Skin temperature is a common indicator to measure autonomic responses. Finger blood volume amplitude is a sensitivity index to reflect the degree of emotional wake. Heart rate variability is a common indicator to reflect autonomic sensitivity. And it includes low frequency power frequency domain index which reflects the level of activity of the sympathetic nervous system; frequency power which reflects the extent of the parasympathetic nervous system activity; frequency correction value which reflects the relative strengths of the degree of sympathetic activity; high frequency correction value which reflects the degree of comparative advantage parasympathetic activity. In study about EEG feedback, brain waves are more from the central area , the target wave-band are fatigue wave, relaxation wave, attention wave, excited waves. Therefore, this study measures physiological indicators by Spirit-10 type biofeedback instrument from Netherlands and recordes participants' reaction time and accuracy by E-Prime software. the initial processing of data is used by Biotrace+ software of biofeedback and the average value is calculated, then the reaction time and the correct data rate is input to SPSS17.0 package for statistical analysis.

EXPERIMENTAL RESULTS

Cluster analysis of emergency personnel ability: Skin temperature, finger blood volume amplitude, heart rate variability and EEG are measured by biofeedback experiments to reflect the ability of emergency response personnel. Changes in physiological data will be compared between baseline and stress periods for statistical analysis (change value = stress value-baseline value). 6 invalid participants were excluded and 26 valid participants were reserved in this experiment. According to characteristics of human physiological changes in stress, skin temperature, heart rate variability (high frequency power and high frequency correction), EEG (relaxation wave and attention wave) are considered as positive indicators, finger blood volume amplitude, HRV (low frequency power and low frequency correction), fatigue wave and excitement wave are considered as reverse indicators. In baseline and stress phase, change value of physiological data on 26 participants will be computed to be dimensionless for cluster analysis. Therefore, classification results of emergency personnel ability are shown in Table 1.

From Table 1, emergency personnel capacity will be divided into low, medium and high classes by experimental results of biofeedback. Based on classification results of experiment, this study selects high and low emergency personnel with significant differences in ability as a comparison for further analysis of classification results.

Baseline data comparison with stress: Skin temperature of high and low response capacity personnel will be calculated on paired "t" test in the baseline period and the stress period. The results are shown in Table 2.

From Table 2, skin temperature of high and low response capacity personnel is no significant difference in the baseline period and the stress period. Because of stimulation, skin temperature of high and low response capacity personnel declined and skin temperature of low response capacity personnel declined greatly.

Finger blood volume of high and low response capacity personnel will be calculated on paired "t" test in the baseline period and the stress period. The results are shown in Table 3.

From Table 3, finger blood volume of high and low response capacity personnel is no significant difference in the baseline period and the stress period. Because of stimulation, absolute value of finger blood volume rised and absolute value of low response capacity personnel rised greatly.

HRV of high and low response capacity personnel will be calculated on paired "t" test in the baseline period and the stress period. The results are shown in Table 4.

From Table 4, HRV of high and low response capacity personnel is no significant difference in the baseline

Table 1: Classification results

Participants	Low	Medium	High
Number	13	7	6

Table 2: Comparing on skin temperature

Personnel	Baseline	Stress
High	26.3533±3.3755	26.1650±3.5193
Low	25.5946±3.7708	25.3076±3.9572

Data are mean and standard deviation.

Table 3: Comparing on finger blood volume amplitude

Personnel	Baseline	Stress
High	-98.1883±51.2494	-99.8983±37.7362
Low	-108.0023±3.77080	-110.1584±49.7675

Table 4: Comparing on HRV

Indicators	Baseline	Stress
Low	H: 21966.58±12573.15	34643.33±12583.20
frequency power	L: 25018.78±29856.61	24478.01±24218.64
Low	H: 47.0166±11.2663	57.1666±8.5537
frequency correction	L: 46.9461±6.2729	42.8769±10.2731
High frequency power	H: 12075.13±9269.95	17827.80±9877.38
	L: 16180.53±13373.64	15346.52±11688.77
High frequency	H: 26.2833±14.1113	28.0500±5.4202
correction	L: 37.4692±9.8106	30.3615±15.1418

Table 5: Comparing on EEG

Indicators	Baseline	Stress
Fatigue wave	H: 11.1066±3.3555	27.2166±9.4248
	L: 13.9223±4.9699	17.5300±4.4781
Relaxation wave	H: 12.7950±4.5602	14.0916±3.4969
	L: 13.7130±5.4253	9.9192±1.8236
Attention wave	H: 4.8350±0.7644	9.2833±1.7180
	L: 5.3569±1.4936	6.5569±1.1642
Excitement wave	H: 4.2400±0.7624	8.5633±1.8336
	L: 4.6792±1.2542	5.9346±1.2011

period and the stress period. Because of stimulation, heart rate variability (low frequency power, high frequency power, low frequency correction and high frequency correction) of high response capacity personnel rised and heart rate variability (low frequency power, high frequency power, low frequency and high frequency correction correction) of low response capacity personnel declined.

EEG of high and low response capacity personnel will be calculated on paired "t" test in the baseline period and the stress period. The results are shown in Table 5.

From Table 5, in the baseline period and the stress period, EEG (fatigue wave, attention wave and excitement wave) of high response capacity personnel is significant difference; EEG (fatigue wave, relaxation wave, attention wave and excitement wave) of low response capacity personnel is significant difference. Relaxation wave of high response capacity personnel rised and relaxation wave of low response capacity personnel declined. Attention wave of high response capacity personnel rised higher than low response capacity personnel.

DISCUSSION

Physiological indicators is an important basis to reflect anxiety conditions. Through skin temperature, finger blood volume amplitude, heart rate variability and EEG, this study compares high emergency ability personnel with low emergency ability personnel on physiological indicators in baseline and stress phase. Experimental results show that there are differences of physiological indicators in different emergency personnel under stress.

Skin temperature is positive indicator that reflects tension and relax level of body. Under stress stimuli, sympathetic activity will be caused and finger temperature is reduced. From Table 2, skin temperature of high and low response capacity personnel is no significant difference in the baseline period and the stress period. Because of stimulation, skin temperature of high and low response capacity personnel declined and skin temperature of low response capacity personnel declined greatly. It shows that tension level of low response capacity personnel is higher than high response capacity personnel. Thus, hypothesis H1is partially validated.

Finger blood volume amplitude is reverse indicator that reflects the degree of change in autonomic nervous system function. In the negative emotion materials stimulation, sympathetic is dominant. Finger blood volume amplitude increases and there are anxiety, stress and other psychological conditions. From Table 3, in the state of tension, low response capacity personnel is higher than high response capacity personnel on change magnitude of finger blood volume amplitude. Thus, hypothesis H2 is partially validated.

HRV includes low frequency power, high frequency power, low frequency correction and high frequency correction and other indicators. Low frequency power belongs to the reverse indicator of sympathetic activity which value becomes higher and sympathetic becomes more active. When individuals face stress situations, the degree of sympathetic activity increases and tension and rapid heartbeat appear. High frequency power is positive indicator which reflects the degree of parasympathetic activity. When value of high frequency power becomes higher and parasympathetic becomes more active, then active parasympathetic makes the heartbeat slow. Low frequency correction is reverse indicator which is related with sympathetic activity. High frequency correction is positive indicator which is related with parasympathetic activity. From Table 4, the stress period compared with baseline, high frequency power of high emergency ability personnel increases the rate significantly greater than the low response capacity personnel. It indicates that level of parasympathetic activity of high emergency ability personnel is higher than the lower and high emergency ability personnel is lower the degree of tension. High frequency correction of high emergency ability personnel increased which indicated parasympathetic activity increased, heart rate slowed and stress level became lower; High frequency correction of low emergency ability personnel decreased which indicated parasympathetic activity decreased, heart rate rised and the level of tension became higher. In the negative emotional stimuli, high frequency correction value of low emergency ability personnel on magnitude of changes is greater than the high. Du *et al.* (2012) found that high frequency correction value of low mental quality group on change magnitude is significantly greater than the high. Thus, hypothesis H3 is partially validated.

Physiological indicators of EEG include fatigue waves, relaxation wave, attention wave and excitement wave. From Table 5, in the baseline period and the stress period, EEG (fatigue wave, attention wave and excitement wave) of high response capacity personnel is significant difference; EEG (fatigue wave, relaxation wave, attention wave and excitement wave) of low response capacity personnel is significant difference. Fatigue wave is reverse indicator which reflects the degree of fatigue. In the stress, the brain of participants increased energy consumption, fatigue increased and fatigue wave rised. Relaxation wave is positive indicator which reflects the degree of relaxation. Relaxation wave of high response capacity personnel rised and relaxation wave of low response capacity personnel declined. Attention wave is positive indicators that reflects the focus of attention. In the experimental stress process, Participants increased the degree of focus and attention wave rised. Attention wave of high response capacity personnel rised higher than the low. Excitement wave is reverse indicator which activities are related with mechanisms of stress and it will rise in the state of anxiety and alertness. excitement wave of high and low response capacity personnel are no significant difference. Thus, hypothesis H4 is partially validated.

CONCLUSION

This study measures human skin temperature, finger blood volume amplitude, heart rate variability and EEG and other electrophysiological indicators by biofeedback experimental means. Conditions of research results is to require testers with normal cognitive abilities. The scope of the field in addition to emergency response but also can be extended to the fields of the state of emergency work. Since the sample size of experiment is not big enough, further study is to determine ability norm classification of emergency personnel.

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