Greater Heart Rate Responses to Acute Stress is Correlated with Worse Performance of Visual Search in Special Police Cadets

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Abstract. Special police often need search targets under stress situation. In this study we investigated the relationship between the autonomic stress response and performance of visual search. Eighty-two male special police cadets were randomly assigned to walk on an aerial robe ladder to induce stress response or walk on a cushion on the ground as control condition. And then participants were asked to completed two visual search tasks including detecting targets (experiment 1) and detecting and identifying targets (expriment 2). We found a negative association between the heart rate of treatment stage and accuracy of the identification task for the participants who were under stress condition. This result suggested that greater autonomic stress response are related with worse performance of visual search in professional working crowed such as special police.

Keywords: Acute stress · Heart rate · Visual search · Special police cadets

1 Introduction

Visual search is a fundamental activity in our daily life. People might look for a car in a crowed parking lot, or search a name in a long list. In some special populations, people who work on public security, such as searching criminal suspects from surveillance video or picking up the target by radar, often do their works under high stress. These professional works require people to have both an appropriate physiological response and behavioral adjustment to meet the demands of emergencies.

1.1 Visual Search

Visual search is defined as the ability to find one item in a visual world filled with distracting items [1]. In the laboratory, the most common paradigm of visual search requires participants to detect whether the target is present or absent [2]. And some researchers argued that the more common visual search task in real world is to identify

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the target with specific feature in crowed distractors such as looking for your car in crowded parking lot. In this situation, people are required to detect the target and then determine its identification [3]. Both the two paradigms are used pervasively in attention research. But researchers had little agreement with that whether there are different cognitive processes under the two tasks [5]. Horowitz and Wolfe found that when people were asked to detect a target among distractors, their visual system did not accumulate the information of the target identity [4]. Cameron et al. found that accuracy of identification was higher compare to detection [9]. However, Saarinen et al. found that the reaction time in identification task was slower than the reaction time in detection task [10].

1.2 The Relationship Between Acute Stress and Cognitive Functions

Exposure to acute stress leads to both a rapid activation of the sympathetic nervous system (SNS) and a slow activation of the hypothalamic-pituitary-adrenal (HPA) axis [12]. The activation of SNS leads to rapidly increasing heart rate, and the physiological responses are intimately correlated to behaviors and brain under stress [8, 13].

Studies found that many cognitive functions including working memory and executive control were influenced by acute stress, some results found the facilitated effect [6–8], for example, Yao et al. found that in acute stress condition, the stronger autonomic physiological responses was positively related with better post-error adjustment [8]. However other studies found stress attenuated cognitive function [11, 12], Plessow et al. found that acute psychosocial stress attenuated cognitive flexibility [11].

1.3 The Relationship Between Stress and Visual Search

Some previous studies focused on the effect of stress related emotion such as anxiety on visual search. Murray and Janelle found that reaction time of visual search task reduced in the low-anxious group but increased in the high-anxious group, but in this study, participants were grouped based on trait anxious [14]. Williams et al. found that anxiety which was induced by competition and prize money impaired performance especially the task imposed a heavy demand of working memory [15]. But few studies researched about the direct effect of acute stress on visual search processing and performance.

The aim of present study was to investigate the relationship between the acute stress and the performance of visual search including the detection paradigm and identification paradigm. Participants were male special police cadets. They were induced stress and then completed two visual search tasks. To induce acute stress, the participants of stress group were asked to walk on an aerial rope ladder bridge. And the participants of control group were required to walk on a cushion on the floor for the same distance as the stress group. We used a wireless chest HR transmitter and wrist monitor to recorder heart rate of participants.

2 Method

2.1 Participants and the Exclusion Criteria

Eighty-two healthy special police students participated this study, they were all male and aged 20 to 27 (mean = 22.47, SD = 1.25). They were randomly assigned to stress condition or control condition, 59 participants were in stress condition and the rest 23 were in control condition.

The criteria for exclusion were as follows: (1) smoking more than 5 cigarettes a day or alcohol abuse, (2) presence of cardiovascular, endocrine, neurological, or psychiatric disease, and other chronic major diseases. (3) Irregular sleeping patterns, (4) took medicine or had a cold two weeks before the study. And all participants were asked to not to do strenuous exercise and rest properly the day before the experiments.

2.2 General Procedure

The study run in the afternoon from 14:30 to 18:30 in order to control for the circadian fluctuation. Participants were given a brief introduction to the experiment in group sessions. Then they were required to fill up forms and questionnaires including informed consent, demographic information and personality questionnaires. After completing these forms, participants were asked to seat and be relaxed for 30 min, and then baseline heart rate data were recorded by a wireless chest rate transmitter and wrist monitor recorder (Polar RSC800CX, Polar Electro, Finland). Then, the participants were randomly assigned to the stress or control condition, at that time, participants had known that he would experience stress condition (see below) or control condition, recorded their heart rate of expect. And then, participants were required to do the stress treatment or control condition, during which heart rate data were continuously recorded. After completing the treatment, they were asked to complete the visual search task immediately in computers. At last recorded the posttreatment heart rate after the cognitive tasks.

2.3 Stress Induction

In the stress condition, the participants in the stress group were required to walk on an aerial rope ladder bridge to induce acute stress. All the participants were experienced such training for the first time. The aerial rope ladder which bridged between two buildings was 18 m above ground, and 12 m in length. Participants in stress condition were asked to wear harness and then walk on the aerial for 8 m (there was a mark on the two-thirds of the ladder), and stayed here and looked down for 5 s, and then turned back (16 m in total).

For the control condition, participants were asked to walk on a cushion on the floor for the same distance in a straight line and to turn around at the midpoint.

2.4 Visual Search Tasks

Based on previous study [3], two experiments were conducted. Both two experiments included 8 practice trails and 64 experimental trials. Figure 1 illustrates the sequence of events in a single trial of experiment 1. The trial began with a premask that stayed on for 600 ms, and was followed by the presentation of the search array that terminated with a response, or remained on the screen for maximum of 5,010 ms. After the presentation of the search stimuli, a postmask was presented for 600 ms, followed by feedback presented at the centre of the screen for 900 ms. The intertrial interval was 550 ms, during which time the screen was blank. On each trial, stimuli were black L and T on a white background, the target was a T, and the distractors were Ls. Both targets and distractors were in for orientations (0°, 90°, 180° or 270°). And the set size

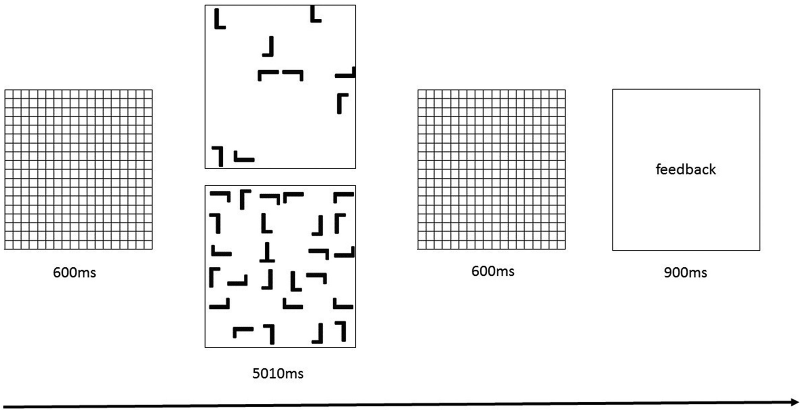

Fig. 1. An example of a trial of detection task. The stimulus on the top was a sample has 9 items without target, the other one was a sample has 25 items with target.

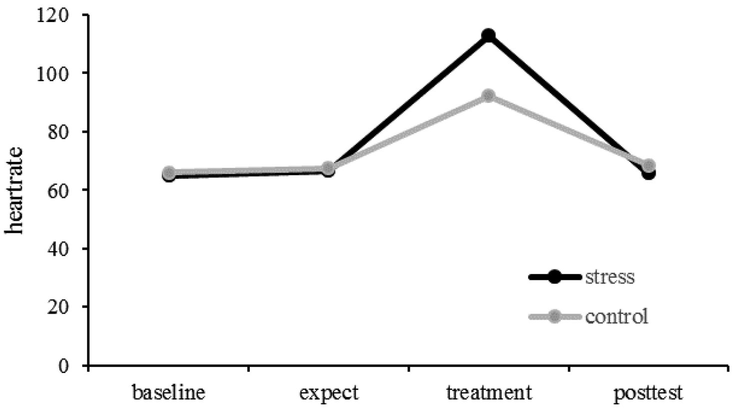

Fig. 2. Mean heart rate at prepare (baseline), expect (be introduced the stress task), during and after the acute stress and control condition.

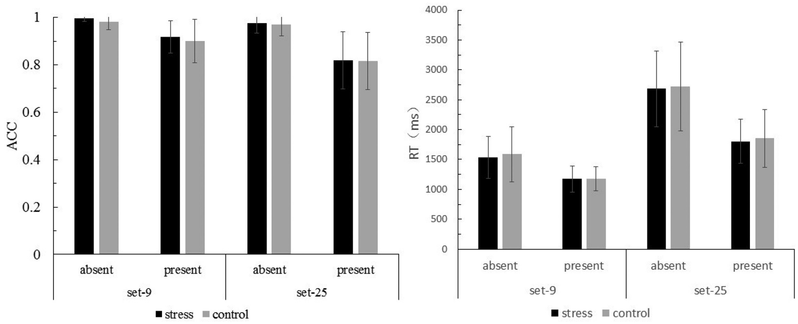

Fig. 3. The left figure showed accuracy (ACC) of experiment 1. And the right figure was mean reaction time (RT) of experiment 1. All the error bars were standard error.

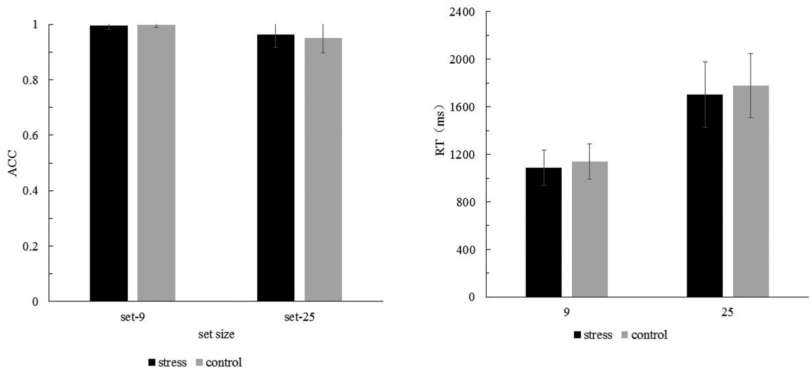

Fig. 4. The left figure showed accuracy(ACC) of experiment 2, and the right figure was mean reaction time(RT) of experiment 2. All the error bars were standard error.

of stimuli was 9 items or 25 items. Participants were asked to detect whether the target ‘T’ was present or not among distractors ‘L’. If the target was present, pressed left arrow, and if the target was absent, pressed right arrow.

In experiment 2, the procedure of single trial and stimuli were similar to experiment 1, but target T was present on all trails. Participants were asked to detect the target and determined the orientation of targets by pressing four corresponding arrow keys.

3 Results

3.1 Stress Effect

The repeated measures ANOVA, 2 (stress/control) × 4 (baseline/expect/treatment/posttest), revealed significant main effects in groups, $F(3, 240) = 646.05$, $p < 0.05$, $\eta^2 = 0.89$. And a main effect between groups was also significant, $F(1, 80) = 5.79$,

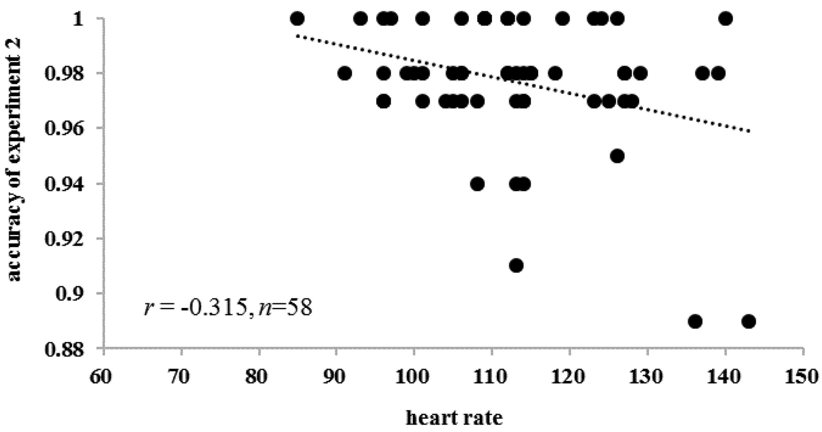

Fig. 5. The scatter plots of simple correlation analysis show the negative correlation between the heart rate and the accuracy of experiment 2 for participants of stress condition.

Table 1. Correlation between heart rate of treatment and accuracy and reaction time of participants in stress condition in both experiment 1 and 2.

	ACC		RT	
	r	*p*	*r*	*p*
Experiment 1	0.017	0.9	0.014	0.913
Experiment 2	−0.315*	<0.05	0.03	0.819

*p < 0.05; ns = not significant.

$p < 0.05$, $\eta^2 = 0.068$. The further simple effect analysis revealed that (1) the heart rate in treatment stage was higher than the other stages for both stress condition and control condition, (2) in treatment stage, heart rate of the participants under stress condition was higher than that of control condition ($p < 0.05$), (3) in the other stages included baseline, expect and posttest, no significant differences were found between stress and control condition (Fig. 2).

3.2 Data Analysis

In experiment 1, the repeated measures ANOVA of accuracy of 2 (stress/control) × 2 (set size:9/25) × 2 (absent/present) revealed significant main effects of set size and absent/present of target, $F_{set\ size}(1, 80) = 578.12$, $p < 0.05$, $\eta^2 = 0.88$; $F_{present}(1, 80) = 157.80$, $p < 0.05$, $\eta^2 = 0.66$. No significant difference was found between stress condition and control condition, $F(1, 80) = 1.16$, $p = 0.29$, $\eta^2 = 0.014$. The interaction effect of set size and present was significant, $F_{size \times present}(1, 80) = 17.77$, $p < 0.05$, $\eta^2 = 0.18$. Other interaction effects were not found.

The results of reaction time was similar. Both effects of set size and present were significant. $F_{set\ size}(1, 80) = 578.15$, $p < 0.05$, $\eta^2 = 0.88$; $F_{present}(1, 80) = 329.18$,

$p < 0.05$, $\eta^2 = 0.80$. The interaction effect of set size and present or absent was significant, $F_{size \times present}(1, 80) = 110.78$, $p < 0.05$, $\eta^2 = 0.58$. the difference between stress condition and control condition was not significant $F(1, 80) = 0.15$, $p = 0.70$, $\eta^2 = 0.02$ (Fig. 3).

In experiment 2, the repeated measures ANOVA of 2(stress/control) × 2(set size:9/25) revealed the main effect of set size were significant for both accuracy and reaction time, $F_{ACC}(1, 80) = 50.36$, $p < 0.05$, $\eta^2 = 0.39$, $F_{RT}(1, 80) = 616.98$, $p < 0.05$, $\eta^2 = 0.89$. But no differences between stress condition and control condition were significant for both accuracy and reaction time (Fig. 4).

Regarding the relationship between heart rate and the performance of visual search tasks, the correlation analysis between heart rate of treatment stage and both ACC (accuracy) and RT(reaction time) of two experiments revealed that for the participants of stress condition, a significantly negative correlation between HR and the ACC of experiment 2 ($r = -0.315$, $p < 0.05$) was found (Table 1 and Fig. 5).

The results of present study demonstrated that the physiologically autonomic response induced by acute stress was related with the identification stage of visual search, but not related with the detection stage. And lower heart rate under stress condition implicated response was related with better performance of visual search. Horowitz and Wolfe [4] argued that the visual system does not accumulate information about identity of targets. The identification task required participants to pay more mental resource which is limited under stress.

4 General Discussion

In this study we investigated the relationship between physiological responses to acute stress and the performance of visual search in special professional people such as special police. We asked participants to walk aloft as a stressor to induce an acute stress response. These participants were induced higher heart rate than participants under control condition. And higher heart rate was negatively correlated with accuracy of targets' identification. This result suggests that stronger autonomic stress responses are related to worse performance of identification stage of visual search.

This negative association between physiological response under acute stress and behavioral performance of visual search may suggest that the stronger responses for stress impair the cognitive processing of visual search. The current result was consistent with previous studies. Some studies found that acute stress attenuated cognitive functions such as executive function and working memory [11, 12]. And this result was also consistent with the study about the attenuated effect of anxiety on visual search [14, 15].

The mechanism underlying this result may be that higher heart rate reduces the cognitive resource which was used to detecting and recognizing targets. And stronger responses of acute stress may change the strategy of visual search or trade off. Another explanation of the underlying mechanism may be some common factor effects both heart rate and the performance of task. Previous study found that people trained would have smaller heart rate change under stress, this is to say, people who trained may have a smaller physiological responses under stress [16, 17].

Some limitations of this study have to be acknowledged. First, participants in this study were special police cadets. Further studies should test other special professional group such as security check inspectors or air traffic controllers. Second, the stress intensity of our study was relatively moderate, this may be the reason that only the accuracy of identification task was effected attenuated by stress.

The findings of the present study implicate that stress influenced on certain stage of visual search. This point is very helpful to making more appropriate direction to improve the interface between human and computer or other devices. And the results also provided suggestions about employee selection of high-stress job, such as special police, air traffic controller and so on. Physiological responses to stress can be a predictor of the job candidates' work efficiency in emergency.

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