Abstract

The purpose of this study was to compare the cardiovascular responses to different types of mental stress. Ten healthy males performed a mental arithmetic task (MA) on one day and were exposed to white noise (WN, 80dB) on another day. Both the MA and the WN were composed of four 5-min consecutive periods with a 3-min rest between them. On each day, the systolic and diastolic blood pressure (SBP and DBP), mean arterial pressure (MAP), cardiac output (CO), and total peripheral resistance (TPR) were measured continually during the entire experimental period. The changes from the baseline (\( \Delta \)) in all periods were calculated for both mental stresses.

As for the results, the \( \Delta MAP \), \( \Delta CO \), \( \Delta HR \), and \( \Delta TPR \) in the MA did not significantly change during the task periods. However, in the WN, the \( \Delta MAP \) and \( \Delta TPR \) showed significant increases over the time of the consecutive periods. In addition, we discuss the response patterns for the two mental stresses. We examine three hemodynamic reactivity patterns: a cardiac pattern characterized by increased CO and decreased TPR, a mixed pattern characterized by a moderate increase in both CO and TPR, and a vascular pattern characterized by increased TPR and decreased CO. The results show that throughout all task/exposure periods, the response pattern remained the same for six subjects in each stress. Furthermore, of these six subjects, half showed the same response pattern in both the MA and the WN.

In conclusion, compared to the MA task, consecutive WN exposure showed an accumulation of stress responses. A change in TPR contributed to a gradual increase in MAP in the WN. It is also possible that among the subjects there were different types of response to the MA and WN. J Physiol Anthropol 26(2): 165–171, 2007 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.26.165]

Keywords: cardiovascular responses, response pattern, mental task, white noise

Introduction

There are many kinds of mental stresses which are ubiquitous in our daily life. Some, such as noise, are common to both humans and other animals (Tomei et al., 2000; Jain and Boldwin, 2003), but others are peculiar to human beings. These latter are caused by the inability to adjust to rapid changes in society and the environment—i.e., techno stress, which can be evaluated by an experimental model such as a mental task (Iwanaga et al., 2005). It is known that repeated exposure to mental stresses have been associated with numerous health effects, including essential hypertension. Based upon early studies, in which elevated blood pressure was found after acute exposure to noise or mental tasks, it has been postulated that persons exposed to noise or mental tasks for prolonged periods might develop increased blood pressure and thus an increased risk for cardiovascular disease (Tomei et al., 2000; Lusk et al., 2002; Ring et al., 2002).

There are two approaches that have been discussed as ways of understanding the relationship between stress reactivity and disease risk. One of them is that through an evaluation of the magnitude of physiological responses, it is possible to hypothesize that exaggerated responses to mental stress may be implicated in the etiology of cardiovascular disease, including coronary disease and essential hypertension (Fredrikson and Matthews, 1990; Pickering and Gerin, 1990). The other approach involves knowledge about response patterns: that individuals exhibiting similar blood pressure reactions to mental stress may be implicated in the etiology of cardiovascular disease, including coronary disease and essential hypertension (Fredrikson and Matthews, 1990; Pickering and Gerin, 1990). The other approach involves knowledge about response patterns: that individuals exhibiting similar blood pressure reactions to mental stress may be implicated in the etiology of cardiovascular disease, including coronary disease and essential hypertension (Fredrikson and Matthews, 1990; Pickering and Gerin, 1990).
with the risk of suffering cardiovascular disease.

Recently, a noninvasive continuous blood pressure monitor that can measure beat-to-beat pressures by a cuff worn on the fingers (Portapress Model-2, TNO-TPD BMI) was used to evaluate effectively the response of the circulatory system. The measurement principle of this monitor involves computing the stroke volume from the arterial pressure by simulating a nonlinear, time-varying, three-element (aortic characteristic impedance, arterial compliance, and systemic vascular resistance) model. The cardiac output (CO) was calculated by the stroke volume x heart rate, and the peripheral resistance was predicted from the mean pressure and model mean flow (Wesseling et al., 1993). In prior studies, the reliability of the measurement of the CO (by the model flow method) was verified (Wesseling et al., 1993; Sugawara and Tanabe, 2001). Furthermore, we compared the model flow method and the CO2 re-respiration method in our previous study and obtained a significant correlation between the two methods (unpublished data).

The purposes of this study were to compare the cardiovascular responses to different mental stresses and to clarify the character of the responses. In addition, we wanted to verify whether the response patterns remained the same during the task/exposure periods or whether the response patterns changed with the change of tasks.

Methods

Subjects

The subjects in this research included ten males. The mean age was 23 (SD1.5) years old. Subjects were requested to refrain from exercising and drinking alcohol during the night before the experiment and were prohibited from drinking caffeine beverages or smoking cigarettes during the two-hour period immediately preceding the experiment. All subjects gave fully informed consent to participate in the study.

Mental stresses

The mental stresses consisted of a mental arithmetic (MA) task and white noise (WN) exposure. The MA task consisted of serial subtractions of the number 17 beginning with different four-digit numbers. Subjects were instructed to say the answer out loud as quickly as possible; if they made any mistakes, they were quickly warned, and continued the task as the experimenter indicated. The WN task was produced by commercially available software (Sound-editor) and provided through a headphone. The sound pressure level was 80 dBA. Subjects were told to be quiet and to relax physically during the white noise exposure periods.

Procedure

Subjects performed the MA task on one day and were exposed to the WN on another day. Both the MA and WN were conducted at the same time of day and under the same conditions. Subjects were asked to be quiet for at least 15 min after they reached the laboratory, before the recording sessions began. As indexes of the circulation, the systolic and diastolic blood pressure (SBP and DBP), mean arterial pressure (MAP), heart rate (HR), cardiac output (CO), and total peripheral resistance (TPR) were measured continuously by a noninvasive continuous blood pressure monitor (Portapress Model-2) during a 5-min rest period (baseline), four 5-min task (exposure) periods (Period 1, Period 2, Period 3, and Period 4) with a 3-min rest period between them, and a 10-min rest period (recovery).

Statistical analyses

We calculated the mean of every minute for all indexes. Cardiovascular measures from each 5-min task (exposure) period and each 5-min baseline period were averaged to obtain mean cardiovascular measures for that period. Change scores (Δ) were calculated by subtracting respective baseline values from values averaged during each task period. A series of one-way ANOVA and correlation analyses were calculated. The level of significance was set at p<0.05.

Results

Comparison between stresses

We calculated the mean of every minute to express the tendency of change. The changes of ΔMAP, ΔCO, and ΔTPR for two mental stresses are shown in Figure 1. The scatter diagrams for ΔMAP and ΔCO and for ΔMAP and ΔTPR for the MA task and the WN exposure are shown in Figure 3 (n=40). For the MA task, the results of one-way ANOVA showed that ΔMAP, ΔCO, ΔTPR, and ΔHR did not significantly change during the task periods. The correlation analyses showed that the positive correlations between ΔMAP and ΔCO and between ΔCO and ΔHR were significant and also that the negative correlation between ΔCO and ΔTPR was significant (Table 1). These results showed that the arithmetic task tended to cause an increase in CO that elevated the blood pressure and that CO was elevated by an increase in HR, while the magnitude of the MAP remained stable throughout the task periods. For the WN exposure, the results of one-way ANOVA showed that ΔCO and ΔHR did not significantly change during the task periods. However, ΔMAP in Period 1 was significantly lower than in Period 3, and ΔMAP in Period 1 was significantly lower than in the other periods (Figure 2). The correlation analyses showed that the positive correlations between ΔMAP and ΔTPR and between ΔCO and ΔHR were significant and also that the negative correlation between ΔCO and ΔTPR was significant (Table 1). These results showed that the WN exposure tended to cause an increase in TPR that elevated the blood pressure but that the CO and HR were not clearly changed during the task periods, while the increase of MAP could be explained by the accumulation effect of TPR.

The response patterns

Table 2 shows the response patterns on the MA task and
Fig. 1  Change in $\Delta$MAP, $\Delta$CO, and $\Delta$TPR for the MA task and the WN exposure ($n=10$) during the baseline, four 5-min task periods with a 3-min rest period between them and a 10-min recovery. Values are means and SE; the black lines on the quadrature axis display the task/exposure periods.
Fig. 2 Mean (SD) ΔMAP in Period 3 was significantly higher than in Period 1, and Mean (SD) ΔTPR in Period 1 was significantly lower than in the other periods on the WN exposure \((n=10)\).

Fig. 3 The scatter diagrams of ΔMAP and ΔCO and of ΔMAP and ΔTPR for the MA task and WN exposure \((n=40)\). A positive correlation between ΔMAP and ΔCO on the MA task, and a positive correlation between ΔMAP and ΔTPR on the WN exposure are significant \((p<0.001)\).
WN exposure for all subjects. There were three response patterns: (1) the cardiac pattern (C), characterized by increased CO and decreased TPR ($\Delta$CO and $\Delta$TPR, $\Delta$CO and $\Delta$TPR, and $\Delta$CO and $\Delta$HR for the MA task and WN exposure. ($n=40$, 10 subjects×4 task periods)

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<tr>
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<th>MA task</th>
<th>WN exposure</th>
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<tr>
<td></td>
<td>$\Delta$MAP</td>
<td>$\Delta$CO</td>
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<td></td>
<td>$\Delta$TPR</td>
<td>$\Delta$TPR</td>
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<tr>
<td>DMAP and DCO</td>
<td>0.662**</td>
<td>-0.111</td>
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<tr>
<td>$\Delta$MAP and DTPR</td>
<td>0.300</td>
<td>0.426**</td>
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* $p<0.05$
** $p<0.01$

Table 2 The change of response patterns for the MA task and the WN exposure

<table>
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<tr>
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<th>MA task</th>
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<tr>
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<td>Period 1</td>
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<tr>
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<td>V</td>
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<td>subject 2</td>
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<td>subject 5</td>
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<td>subject 6 #</td>
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<td>subject 7</td>
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<td>subject 8</td>
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<td>subject 9 #</td>
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<tr>
<td>subject 10</td>
<td>C</td>
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C: the cardiac pattern characterized by increased CO and decreased TPR; V: the vascular pattern characterized by increased TPR and decreased CO; M: the mixed pattern characterized by increases in both CO and TPR; #: the subjects who showed the same response pattern throughout both the MA task and the WN exposure.

Discussion

The present study compared the cardiovascular responses to the mental arithmetic task and the white noise exposure. The MA task caused cardiac and vascular responses characterized by increases in CO and TPR, but the WN exposure caused a clearly vascular response characterized by an increase in TPR (Figure 1). On the MA task, the CO showed a tendency to decline over time, the TPR showed a tendency to increase, and the magnitude of the MAP remained stable throughout the task periods. This result agrees with a prior study concerning the underlying hemodynamics of the pressure response to a prolonged stress where during the course of exposure there was a greater cardiac reaction earlier rather than later during a task, the vascular reaction was greater later than it had been earlier, and the MAP remained similar throughout the task (Ring et al., 2002).

It is known that the nature of mental stress influences the circulation response. Some tasks such as the mental arithmetic task caused a beta-adrenergic activation of the sympathetic nervous system characterized by an increase in CO and should be considered as myocardial tasks (Sherwood et al., 1990; Kasprzowicz et al., 1990; Iwanaga et al., 2005). In the present study, on the MA task both CO and TPR responses were found, and the response pattern showed not only the cardiac pattern but also the mixed pattern and the vascular pattern (Table 2). However, a significant correlation was found only between $\Delta$MAP and $\Delta$CO (Table 1). This suggests that the magnitude
of MAP was related to CO on the MA task and that the character of the stress was not always represented by the response pattern. On the other hand, the WN exposure caused an increase in the MAP over the time of consecutive periods, and a significant correlation was found between MAP and TPR (Table 1). This showed that the increase of the MAP can be explained by an increase in the TPR and suggests that the WN exposure caused an alpha-adrenergic activation characterized by an increase in TPR but having little effect on CO, thus being similar to vascular tasks, such as the cold pressure test by Bongard et al. (2002) and the anger recall interview task by Lawler et al. (2001).

From the viewpoint of the response pattern, the present study showed three response patterns on the MA task and the WN exposure: the cardiac pattern (C), the vascular pattern (V), and the mixed pattern (M) (Table 2). In the present study as well as in a previous study (Bongard et al., 1998), we used a classification which judged the response patterns by a positive or negative value of ΔCO and ΔTPR on each task/exposure period, although the mean and mean ± SD of CO and TPR can also be used to define the response pattern (Lawler et al., 2001). In terms of results, we found that six subjects showed the same response pattern during each stress and that half of these showed the same pattern throughout both the MA task and WN exposure. We also found that most subjects showed the vascular and mixed patterns on WN exposure, even those who had shown a stable cardiac pattern on the MA task. This further proves that the WN exposure easily caused the vascular response.

In our previous study (Liu et al., 2006), we examined the test-retest reproducibility of circulatory responses to the same mental task on different days. The results of a two-way ANOVA showed that the main effect on the subjects indicated by the MAP, CO, and TPR was significant, but that the effect of the experiment day was not significant. In addition, significant correlations were obtained between experiment days for ΔMAP and ΔCO, showing that the reproducibility of blood pressure and cardiac output was good and suggesting that the cardiac pattern remained stable throughout the experiment days for the same mental task. In the present study, we found that some subjects showed the same pattern even for different stresses but that others did not. We suggest that several response types may exist and that the subjects who show the same pattern may maintain a stable response pattern; we anticipate that they may have a higher or lower risk of suffering hypertension. These results support the viewpoint of polytypism, which asserts that human beings can be divided into several response types (even though the origin of the polytypism is uncertain). Since the number of subjects in this study is not very large, we think that it is necessary to examine further subjects, including the classification method in the future.

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References


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