Effects of a Single Cognitive Task on Power Spectra of R-R Interval and Arterial Blood Pressure

Abstract: The present study was designed to examine the effects of a single cognitively demanding task on the R-R interval and systolic blood pressure (BP) power spectra. Ten healthy volunteers were asked to perform an English transcription task for 90 minutes using a word processor, and to read books as a non-task control. The influences of both posture and respiration were controlled in assessing the task effects. Performance of the single cognitive task significantly increased the normalized low-frequency component (% LF) of the BP spectrum following the task, as compared to the non-task control in the sitting position. However, the supine position did not produce the post-task increase in % LF of the BP spectrum. The spectral components of the R-R interval spectrum remained unchanged after the task. These results suggest that the post-task increase in sympathetic activity may be reflected by the BP spectrum under sympathetic predominance in the sitting position.

Key words: Autonomic nervous system — Blood pressure variability — Heart rate variability — Power spectrum analysis — Cognitive tasks

In today’s workplaces, many workers have engaged in various types of cognitively demanding tasks that require sustained attention. Such cognitive tasks entail prolonged monitoring of a visual display terminal (VDT) and quick responses to the VDT stimuli. Such tasks are reported to affect the autonomic nervous system 1-3). In order to ensure the health of the workers performing such cognitive tasks, it is essential to establish reliable methods for evaluating the autonomic nervous system functions.

Power spectrum analysis of R-R interval and arterial blood pressure (BP) variabilities has been proposed as a promising technique to non-invasively assess sympathetic and parasympathetic activities 4-7). We have already reported that an English transcription task significantly increased the normalized low-frequency component (% LF) of the R-R interval spectrum during the task, and that the increase in % LF of the R-R interval spectrum was recovered immediately after cessation of the cognitive task 8). However, the cognitive task effects on the arterial BP spectrum were not explored in our previous paper.

The purpose of the present study was to further examine effects of a single...
cognitive task on the autonomic nervous system. To this end, we performed a simultaneous power spectrum analysis of R-R interval and arterial BP variabilities before and after the task. We controlled both influences of posture (supine vs. sitting positions) and respiration (spontaneous vs. metronome breathing).

METHODS

Ten healthy volunteers (5 men and 5 women aged 20 to 23 years) participated in the present study. All subjects gave their informed consent before the study. None had a history of cardiovascular diseases. Consumption of caffeine or other drugs was prohibited during the experiment. Before and after a single cognitive task or casual reading as the non-task control was imposed, electrocardiogram (ECG; CM5 lead), non-invasive blood pressure (JENTOW-7700, Nihon Colin, Japan), and respiratory activity (TR-711T, Nihon Kohden, Japan) were continuously measured under each of the following four conditions: supine position with the subject breathing spontaneously; supine position with controlled breathing frequency at a rate of 15 breaths/min synchronized with a metronome; sitting position with spontaneous breathing frequency; and sitting position with metronome-regulated breathing. Each session lasted for 5 minutes. A five-minute rest was given after each postural change. Tidal volume was not controlled.

All electrophysiological signals were monitored with an electroencephalograph (EEG-4217, Nihon Kohden, Japan) and were recorded with an FM tape recorder (XR-7000L, TEAC, Japan). The cognitive task in the present study consisted of transcription typing of an English-language scientific manuscript using a word processor for 90 minutes. The subjects were asked to perform the task at their own pace without rest. No reward or penalty was given for task performance. Each subject participated in both the task and non-task control on the same day. The order of performance of the task and the non-task control was counterbalanced across subjects and time of day (morning [9:30–12:00] and afternoon [13:30–16:00]).

The stored ECG and BP signals were digitized off-line at a sampling frequency of 500 Hz on a personal computer (Macintosh Centris 650) equipped with a data acquisition system (MP100WS, BIOPAC Systems, U.S.A.). The beat-to-beat R-R intervals and systolic BP were measured and stored in a computer disk. Two hundred fifty-six-second time series of R-R intervals and systolic BP were interpolated linearly at 2 Hz. Those interpolated data were subjected to power spectrum analysis using a fast Fourier transform on a personal computer (NEC PC-9801 BA). In both the R-R interval and systolic BP spectra, low-frequency (LF) and high-frequency (HF) spectral components were calculated as the powers integrated over a frequency range from 0.05 to 0.15 Hz and over a range from 0.15 to 0.50 Hz, respectively. Percentage values (% LF and % HF) were calculated by dividing the LF or HF powers by the total power integrated over a range
of 0.02–0.50 Hz and multiplying by 100. Means of R-R intervals (meanRR) and systolic BP (meanSBP) were also computed. The principal respiratory frequency was estimated from the peak value of the power spectrum of respiratory signals on a microcomputer (Signal processor 7T18, NEC San-ei, Japan).

The % LF and % HF of R-R interval and systolic BP spectra, meanRR, meanSBP, and respiratory frequency were submitted to four-factor analysis of variance (ANOVA) with repeated measures. The factors included posture (supine, sitting), respiration (spontaneous, controlled), task (task, non-task), and measurement period (pre, post). Post hoc analyses were made on significant ANOVA results using the Newman-Keuls test.

RESULTS

R-R interval spectrum

The effect of task or the interactions with task were not statistically significant for any variables. The effect of posture was significant for % LF (p < 0.05), % HF (p < 0.05), and meanRR (p < 0.01). The effect of respiration was also significant for % LF (p < 0.05) and % HF (p < 0.01). These results are summarized in Table 1. The sitting position produced an 18% increase in % LF, a 13% decrease in % HF, and an 8% decrease in meanRR compared to the supine position. Metronome breathing resulted in a 13% decrease in % LF and a 19% increase in % HF without a significant change in meanRR.

Systolic BP spectrum

The effect of posture and the posture x task x measurement period interaction were significant for % LF (p < 0.05, in both cases). This interaction is illustrated in Fig. 1. The % LF was significantly higher following the cognitive task than following the non-task control in the sitting position, but it was not significantly higher in the supine position. The effect of posture was significant for % HF, indicating that the % HF in the sitting position was greater than that in the supine

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<thead>
<tr>
<th>Posture</th>
<th>Respiration</th>
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<tbody>
<tr>
<td></td>
<td>Spontaneous</td>
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<tr>
<td>% LF</td>
<td>29.2 ± 1.5</td>
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<tr>
<td>% HF</td>
<td>49.4 ± 2.0</td>
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<tr>
<td>meanRR (ms)</td>
<td>1047.1 ± 16.9</td>
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Values are means ± SE of 10 subjects.
a, b: Significantly different from supine position at p < 0.05 and p < 0.01, respectively.
c, d: Significantly different from spontaneous breathing at p < 0.05 and p < 0.01, respectively.
position (40.1 ± 3.3% vs. 31.2 ± 3.5%, p < 0.01). No other significant main effects or interactions were obtained.

Respiratory frequency

No significant effects were observed, except for the significant effect of respiration (spontaneous vs. controlled, 0.27 ± 0.005 Hz vs. 0.25 ± 0.001 Hz, p < 0.05).

**DISCUSSION**

In the present study, the % LF of the systolic BP spectrum increased significantly following the performance of a single cognitive task, as compared to a non-task control in the sitting position. By contrast, the % LF of the systolic BP spectrum did not change significantly for the supine position. The spectral components of the R-R interval spectrum were unaffected after the performance of the single cognitive task.

It should be noted that the task effects on the % LF of the systolic BP spectrum were modified by posture. In agreement with previously reported findings\(^6,6,10\), our postural change results show that the sitting position is characterized by increased sympathetic activity. The LF component of the systolic BP spectrum has been regarded as a marker of vasomotor sympathetic activity\(^6,11\). The present results, therefore, indicate a task-induced increase in sympathetic activity superimposed upon sympathetic predominance in the sitting position. However, results indicating that task effects were not found in the supine position suggest...
that increased sympathetic activity with the task may be counteracted by parasympathetic predominance associated with the supine position.

It has been demonstrated that slower breathing (< 0.15 Hz) increases the LF components of arterial BP as well as R-R interval spectra\textsuperscript{12}. In the present study, such a shift in respiratory frequency was not found after the task. Accordingly, the possibility that the observed increase in % LF of arterial BP spectrum in the sitting position resulted from the slower breathing can be ruled out.

The immediate recovery of % LF of the R-R interval spectrum after the cognitive task found here agrees with our previous observation\textsuperscript{8}, as well as the results of Pagani et al.\textsuperscript{13} The LF component of the R-R interval spectrum is thought to reflect the LF component of the arterial BP spectrum mediated through the arterial baroreceptor reflex\textsuperscript{6, 14}. The sensitivity of arterial baroreflex has been reported to be reduced by psychological challenges such as mental arithmetic\textsuperscript{15, 16}. Thus, the absence of a post-task increase in % LF of the R-R interval spectrum may be explained by the lowered sensitivity of the arterial baroreflex.

It is of prime importance for worker health to minimize excessive elevation of sympathetic activity caused by cognitive tasks\textsuperscript{17}. We need to look for ways to correct the imbalance of sympatheto-parasympathetic activity. In the present study, the supine position canceled the post-task increase in sympathetic activity. Based on this finding, it can be inferred that resting at the worksite in the supine position leads to recovery from work-related fatigue more efficaciously than resting in the sitting position.

\textbf{REFERENCES}


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