# Effect of mental activity on heart rate, heart rate variability and respiratory rate in healthy volunteers


## Abstract

**Introduction:** The link between mental stress and cardiac autonomic regulation plays a significant role in the patho physiological process of cardio neural feedback loop. This study assessed the effect of mental arithmetic and silent reading on heart rate variability, heart rate and respiratory rate in young healthy volunteers. **Materials methods:** R-R intervals were recorded for five minutes in ten healthy volunteers aged 22-24 years of either sex while resting, doing mental arithmetic, and silent reading in a sitting position. Time and frequency domain approaches were used to measure heart rate variability (HRV). In them, heart rate and respiratory rate were also calculated. Using the paired 't' test, mean differences in values were evaluated between resting and mental arithmetic; resting and quiet reading conditions. **Result:** Heart rate and respiratory rate were significantly higher during mental arithmetic ($p = 0.012$, $p<0.0001$ respectively) and silent reading compared to resting state ($p=0.005$, $p=0.0002$ respectively). There was no significant change in HRV during mental arithmetic and silent reading compared to resting state. **Conclusion:** Mental arithmetic and silent reading primarily evoke a rise in respiratory rate and heart rate.



***Key words:*** *Mental activity, heart rate, heart rate variability, respiratory rate*




## Introduction

The autonomic nervous system controls a number of physiological activities that take place involuntarily in our body systems. Normal functioning of ANS is crucial in preserving homeostasis, effective working of the various visceral organs and their physiological functions like spontaneous heart rhythm, breathing and gastro-intestinal movements [1]. Indicators of heart rate variability (HRV) are commonly used to assess cardiac sympathetic and parasympathetic activity [2]. Population studies have demonstrated that in healthy adults, decreased HRV predicts mortality [3, 4]. Additionally, reduced HRV is considered to be one of the predictors of mortality in post myocardial infarcted patients [5].The evaluation of diabetic cardiac autonomic neuropathy is another major clinical application of HRV [6,7]. Clinical utility of measurement of HRV is also explored in neurology, psychiatry and cancer [8]. Ongoing research on association between stress and autonomic control has reported increased sympathetic activity during acute respiratory stress and mental stress [9, 10]. However, findings are inconclusive. This study assessed the influence of mental arithmetic and silent reading on heart rate, HRV and respiratory rate.

## Materials and Methods

### Subjects:

The study comprised ten healthy young adults aged 22-24 years of either sex (5 males and 5 females) who volunteered to participate and informed consent was received from the study participants. The study parameters included were, heart rate, HRV and respiratory rate.

### Methods:

The study was carried out between 10 and 11 a.m. Subjects were briefed on the study protocol before beginning the test procedures. ECG was then taken in sitting position for five minutes during the following conditions:

1. Normal (spontaneous) breathing

2. Mental arithmetic

3. Silent reading

For mental arithmetic, the subjects were asked to continuously carry out certain mental calculations as communicated through verbal signals. For silent reading the text was held in front of the subject that was unfamiliar to him/her.

**Data Acquisition:**

The ECG was continuously taken at a rate of 25mm/second through limb lead II of ECG leads. ECG signals were simultaneously acquired and transmitted to a computer using a digital acquisition device. HRV parameters were then calculated using time and frequency domain HRV analysis methods.

**Time domain:**

The time domain HRV measures quantified by computer enabled method were ratio of maximum R-R interval to minimum R-R interval (Max/Min RR), the root mean square of the difference of successive R-R intervals (r-MSSD) and standard deviation of the R-R intervals (SDNN). Values were given in milliseconds.

**Frequency domain:**

The tachogram was analyzed using power spectral density. The power spectral density was done by using the fast Fourier transform method. High Frequency (HF), Low Frequency (LF), and Total Power (TP) were the power spectrum obtained. Absolute power was used to express values ($ms^2$). Normalized units were also used to denote HF and LF (HF norm and LF norm respectively). Fraction low frequency (LF percent) and fraction high frequency (HF percent) were used to express power spectral components. Further Low Frequency–to–High Frequency Ratio (LF/HF Ratio) was also obtained.

**Heart rate:**

The averaged RR interval from 5 minutes during resting, mental arithmetic and reading was considered as heart rate for each activity and expressed as heart rate/minute.

**Respiratory rate:**

Respiratory rate was calculated separately during resting, mental arithmetic and silent reading and expressed as respiratory rate/minute



**Statistical Analysis:**

As data on HRV parameters were highly skewed it was log transformed. Paired t test was used for comparison of mean differences of all the study parameters between resting and mental arithmetic / silent reading. Statistical significance was taken to be at $P<0.05$.

**Results**

The data on each state is given as mean with standard deviation and the comparison between two conditions is given as mean difference with standard deviation. Comparison of study parameters between resting state and mental arithmetic is presented in table 1 and comparison of study parameters between resting state and silent reading is presented in table 2. Comparison of heart rate and respiratory rate between silent reading and mental arithmetic is presented subsequently in the appropriate section of the result presentation.

**Comparison of study parameters between resting state and mental arithmetic**

**Comparison of HRV parameters:**

There was no significant difference in Max/Min RR r-MSSD, SDNN between resting state and mental arithmetic (table 1). There was no significant change in total power, HF (absolute), LF (absolute), HF (nu), LF (nu), LF%, HF% and LF/HF during mental arithmetic compared to resting state (table 1).

**Comparison of heart rate and respiratory rate between before and during mental arithmetic:**

Heart rate was significantly higher in mental arithmetic condition compared to resting state (p= 0.012, table 1). The respiratory rate was significantly higher in mental arithmetic condition compared to resting state (p<0.0001, table 1)

**Comparison of study parameters between resting state and silent reading**

Comparison of HRV parameters: There was no significant difference in Max/Min RR, r-MSSD, SDNN between resting state and silent reading (table 2). There was no significant difference in Total Power, HF (absolute), LF (absolute), HF (nu), LF (nu), LF%, HF% and LF/HF during silent reading compared to resting state (table 2).

**Comparison of heart rate and respiratory rate between resting and silent reading:**

Heart rate was significantly higher in silent reading condition compared to resting state (p= 0.004, table 2). The respiratory rate was significantly higher in silent reading condition compared to resting state (p=0.0002, table 2).

**Comparison of heart rate and respiratory rate between silent reading and mental arithmetic**

There was no significant change in heart rate between mental arithmetic and silent reading conditions (Mean difference = -2.22±3.304, t=-0.67, p=NS). There was no significant difference in respiratory rate between mental arithmetic and silent reading conditions (mean difference = 0.3 ±0.63, t= 0.20, p= NS)

**Discussion:**

In the present study, we investigated autonomic modulation in response to five minutes mental activities such as mental arithmetic and silent reading. HRV parameters, heart rate and respiratory rate were considered. Among these study parameters, only heart rate and respiratory rate were higher in response to mental activity compared to resting state.

In the present study, HRV parameters obtained both from time and frequency method did not change significantly during mental arithmetic and silent reading compared to resting state (table 1 and table 2 respectively). In the study of Luciano Bernardi et al and Aupma Deepak et al mental load in the form of mental arithmetic showed significant increase in HRV parameters suggestive of sympathetic activity [10, 11]. In contrast, in another study pNN50 an index of parasympathetic activity decreased significantly [12]. In the present study no significant change in HRV parameters suggestive of parasympathetic as well sympathetic function was observed. Mental activity is speculated to be high when the optimal resources for an acceptable task completion exceed operator capacity [13]. Thus, it appears that in our study subjects, offered mental tasks/mental load was not exceeding the operator capacity and therefore no significant changes were observed in HRV. Additionally, the difference in study findings between the present study and Luciano Bernardi et al, could be due to the difference in study design between the two studies. In their study electrocardiogram was done for three minutes in supine position unlike five minutes in sitting position in the present study [10]. In their study, for mental arithmetic tasks subjects were asked not only to perform mentally but also made to write the answer against time pressure [10]. In contrast, in the present study subjects performed only mental calculation as communicated through verbal signals. In the study of Anupama Deepak et al, SDNN was significantly higher during mental arithmetic compared to resting state [11]. In their study SDNN was obtained from five minutes ECG during mental arithmetic similar to our study design. But ECG tracing was in supine position. Thus, it appears that position of the subject could also be another confounding factor in assessment of influence of mental activity on HRV parameters.

In the present study heart rate increased significantly during mental arithmetic and silent reading (table 1 and table 2 respectively). This finding is in accordance with the findings of some previous studies [10, 11, 14,]. In the mental arithmetic state heart rate ranged from 85 beats/minute to 94 beats/minute. Whereas during silent reading, heart rate range was from 76 beats/minute to 86 beats/minute. Even though lower and upper limits of heart rate observed in mental arithmetic state were relatively higher compared to silent reading, the mean difference between these two conditions did not differ significantly. Thus, it could be stated that mental activity irrespective of the type of mental task undertaken evokes autonomic modulation at the SA node.

Respiration is the body's most powerful oscillator, regulating functions in response to environmental demands and preserving homeostasis [15]. When people concentrate or perform a difficult activity, their breathing patterns differ according to the intensity and time of activity. Accordingly, in the present study respiratory rate was significantly higher during mental arithmetic and silent reading [table1 and table 2]. This finding is in agreement with the findings of Bernardi et al, who had also observed higher respiratory rate during mental arithmetic and silent reading [10]. Thus, respiratory rate could be an important physiological parameter in assessing autonomic modulation in relation to mental health.

In the experimental set up, mental stress is assessed mainly by a mental arithmetic test. It has been proven that mental activity in the form of mental calculation increases sympathetic activity as assessed by HRV [10, 11]. However, in the present study, there was no significant change in HRV under mental arithmetic and silent reading conditions. On the other hand, there was a significant rise in heart rate and respiratory rate under mental arithmetic and silent reading compared to resting state.

Conclusion

Thus, it could be concluded that mental arithmetic and silent reading primarily evokes a rise in respiratory rate and heart rate.

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**Table 1: Study parameters between resting state and mental arithmetic**

| Variables | Resting (mean± SD) | Mental calculation (mean± SD) | Mean difference (mean± SD) | *t* value | *P* value |
|---|---|---|---|---|---|
| Max/Min RR | 0.33±0.20 | 0.29± 0.12 | 0.04±0.22 | 0.57 | 0.579 |
| r-MSSD (ms) | 1.67±0.33 | 1.58± 0.20 | 0.08±0.41 | 0.61 | 0.55 |
| SDNN (ms) | 1.79 ±0.21 | 1.72±0.11 | 0.06 ± 0.23 | 0.82 | 9.43 |
| HF Power (ms2) | 2.96 ±0.56 | 2.95± 0.51 | -0.0004± 0.77 | 0.0001 | 0.999 |
| LF Power(ms2) | 3.28 ± 0.35 | 3.32± 0.36 | -0.03± 0.62 | 0.15 | 0.88 |
| Total Power (ms2) | 3.72 ±0.32 | 3.75± 0.33 | -0.03± 0.54 | 0.17 | 0.86 |
| HF Power (n.u) | 1.46±0.22 | 1.44± 0.20 | 0.01±0.25 | 0.12 | 0.90 |
| LF Power (n.u) | 1.80± 0.09 | 1.81 ±0.09 | -0.01 ±0.14 | 0.22 | 0.82 |
| LF/HF Ratio | 0.33 ±0.30 | 0.37±0.29 | -0.03±0.40 | 0.22 | 0.82 |
| LF% Power | 1.56±0.14 | 1.57±0.06 | -0.003±0.17 | 0.05 | 0.96 |
| HF % Power | 1.23±0.26 | 1.20±0.29 | -0.03 ±0.35 | 0.05 | 0.95 |
| Heart rate (per min) | 79.82±3.54 | 83.96±3.712 | -4.14±4.23 | 3.09 | 0.012 |
| Respiratory rate (per min) | 15.4±0.72 | 17.8±0.43 | -2.24 ±0.69 | 10.26 | <0.0001 |

Change in autonomic and cardio- respiratory parameters during mental arithmetic compared to resting state in young healthy subjects

**Table 2: Study parameters between resting state and silent reading**

| Variables | Resting (mean ±SD) | Silent reading (mean ±SD) | Mean difference (mean ±SD) | *t* value | *P* value |
|---|---|---|---|---|---|
| Max/Min RR | 0.33±0.20 | 0.26±0.13 | 0.06 ± 0.19 | 0.99 | 0.34 |
| r-MSSD (ms) | 1.67±0.33 | 1.55 ±0.22 | 0.11±0.30 | 1.15 | 0.27 |
| SDNN (ms) | 1.79 ±0.21 | 1.71 ±0.13 | 0.08 ± 0.18 | 1.40 | 0.19 |
| HF (ms2) | 2.96 ±0.56 | 2.81 ±0.43 | 0.13± 0.30 | 1.37 | 0.20 |
| LF (ms2) | 3.28 ± 0.35 | 3.14 ± 0.38 | 0.14 ± 0.30 | 1.47 | 0.17 |
| Total Power (ms2) | 3.72 ±0.32 | 3.58± 0.33 | 0.13± 0.21 | 1.95 | 0.08 |
| HF Power (n.u) | 1.46±0.22 | 1.48±0.16 | -0.01± 0.24 | 0.13 | 0.89 |
| LF Power (n.u) | 1.80± 0.09 | 1.80 ±0.092 | -0.006 ± 0.10 | 0.18 | 0.85 |
| LF/HF Ratio | 0.33 ±0.30 | 0.32±0.25 | 0.008 ±0.34 | 0.07 | 0.94 |
| LF % Power | 1.56±0.14 | 1.46±0.17 | 0.009 ±0.20 | 0.14 | 0.89 |
| HF % Power | 1.23±0.26 | 1.23±0.20 | 0.0006 ± 0.19 | 0.09 | 0.92 |
| Heart rate (per min) | 79.82±3.54 | 83.18± 3.42 | -3.36 ± 2.83 | 3.75 | 0.004 |
| Respiratory rate (per min) | 15.4±0.72 | 17.5±0.45 | -2.1 ±1.19 | 5.87 | 0.0002 |

Change in autonomic and cardio- respiratory parameters during silent reading compared to resting state in young healthy subjects