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ORIGINAL PAPER

Heart rate variability analysis under varied task difficulties in mental arithmetic performance

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Abstract
Mental calculation demanding tasks cause changes in the autonomic modulation of the cardiac function. Heart rate variability (HRV) is a parameter to understand the autonomic changes. To examine HRV in young individuals in the performance of two levels of arithmetic mental calculation tasks. We assessed 22 participants (18–25 years; both male and female) who performed two levels of mental arithmetic calculations, i.e., 15 easy and 15 calculative. Each task was for 10 s, for both easy and calculative and presented in random manner, through Superlab 4.5 (Cedrus Inc.) and electrocardiogram data were acquired by MP35 (Biopac Inc., Goleta, California, USA). Acqknowledge 4.1 and KUBIOS 2.1 software were used for HRV analysis. Decreased heart rate in calculative task as compared to easy task ($p < 0.01$) was analyzed. SD1 and SD2 values were higher during calculative task. However, short-term fluctuation ($\alpha 1$) was higher and the long-term fluctuation ($\alpha 2$) was found to be lower for the easy task. Task comparative changes in the HRV parameters (Low frequency and High frequency) including Heart Rate, showed that transition from easy to calculative task and vice-versa showed an increase in all these parameters and a decrease in same parameters, respectively. As the task difficulty increases, heart rate decreases along with significant variations in different linear and non-linear HRV parameters; which are influenced by the autonomic nervous system under mental-arithmetic resulting in mental stress.

Keywords Autonomic nervous system · Heart rate variability · Mental-arithmetic · Mental stress

1 Introduction

A greater cognitive demand is being imposed by the increasing use of the modern technology when compared to the physical demands in a number of work environments, which makes the understanding of mental workload and mental stress caused by it essential. Working efficiency is decreased due to stress and there are also some chronic clinical conditions including hypertension and cardiovascular diseases. Earlier detection of stress can prove to be beneficial in reducing the impact of such diseases in our lives; which represents stress-study as a subject of increasing interest. Many researchers have studied respiration, heart rate (HR), heart-rate variability (HRV), electroencephalogram (EEG), electrodermal response and even eye gaze as parameters to analyze the mental effort based mental stress [1–7].

Since decades, researchers have advocated mental arithmetic (MA) to be a causative factor for increased mental workload and mental stress [5, 6, 8–11]. Correlation between MA tasks and autonomic nervous system (ANS) responses has also been shown at times. Mental arithmetic tasks have been previously used in autonomic function testing and reported to provoke changes in cardiac function after there is an increase in the sympathetic arousal [12, 13]. However, the effects of increase in levels of task difficulty during MA remain open to be addressed. Most of the physiological measures use a single level task model and compare it with the resting condition of the performing subject. But, it also needs to be seen that when the task demand increases, the ANS may start behaving differently [1–3]. RR intervals with HR monitoring has been widely used as a parameter for studying ANS

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and analyzing HRV gives the measure of sympathetic and parasympathetic branches of the ANS (sympathovagal balance) under a stressed condition [3–5]. Heart rate and HRV analysis has been shown to be following a similar pattern in the ultra-short HRV measures (10-s) as obtained in the traditional 300-s paradigms [14–17].

Heart rate and HRV as a physiological measure have been used to analyze the autonomic activity during the MA tasks [5–7, 10, 11]. Further, several research groups have reported the effect of task difficulty in MA calculations and mental work load but changes in the autonomic parameters of an individual when subjected to different levels of MA calculation tasks was found to be missing. Therefore, in a multi-level task condition, study of the behavior of ANS and the changes within the system must become evident.

Based on the review and conclusions of the earlier studies, subsequent focus was thought to be implied on taking the multi-level task difficulty in MA. A set of MA tasks was designed having two levels of mental calculations. In this paper, an approach has been described to study the effects of two different levels of MA tasks on the autonomic responses giving a measure of the mental workload and its assessment.

2 Materials and methods

2.1 Subjects

For signal acquisition, 22 subjects participated strictly on voluntarily basis; all lying within the age group of 18–25 years (consisting of 14 male and 8 female volunteers). All the subjects were explained and demonstrated a sample paradigm and care was taken that every query of the volunteers regarding the experimental procedure was answered to their satisfaction. They were required to fill up and sign a consent form including a small health questionnaire before the experiment. All the subjects were having a normal vision or corrected-to-normal vision and hearing.

2.2 Task design

The task assigned in this study was MA calculation. An instruction paradigm for the task was designed using Superlab 4.5 (Fig. 1). It is a cue-based paradigm (Fig. 2), worked in real time with the signal acquisition system MP35 (Biopac Systems Inc., Goleta, California, USA). There were two sets of mental calculation instructions designed for the experiment i.e. easy and calculative; each set consisting of 15 questions each. The easy mental calculation tasks consisted of easy level questions like "2 + 2.9", "3.7 + 4.1" etc. and the higher-level questions consisted of calculative level questions like (4.65 × 7.82)/41.9 etc. Two sets of desktop were utilized for the work connected together in real time for the paradigm part. One of the monitors displayed the MA instructions and on the other, the signal which was being recorded with the cue applied was displayed.

2.3 Recording procedure

The easy and the calculative tasks appeared in a random manner on the computer screen. The subjects were provided with a response sheet where they were required to write down the answers for the MA calculations which were performed by them. The pen-and paper method for taking the output from the subjects was done to provide a real-feel of the MA calculation performance. Although, no pen-paper calculation was

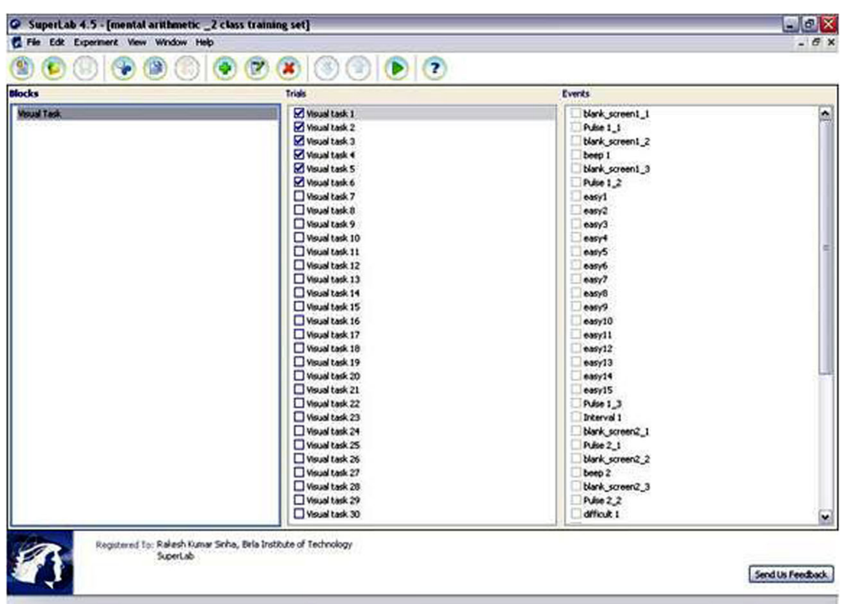


Fig. 1 Screenshot of the interface for Superlab 4.5, used for development of the cue-based paradigm to record ECG data during the mental arithmetic task

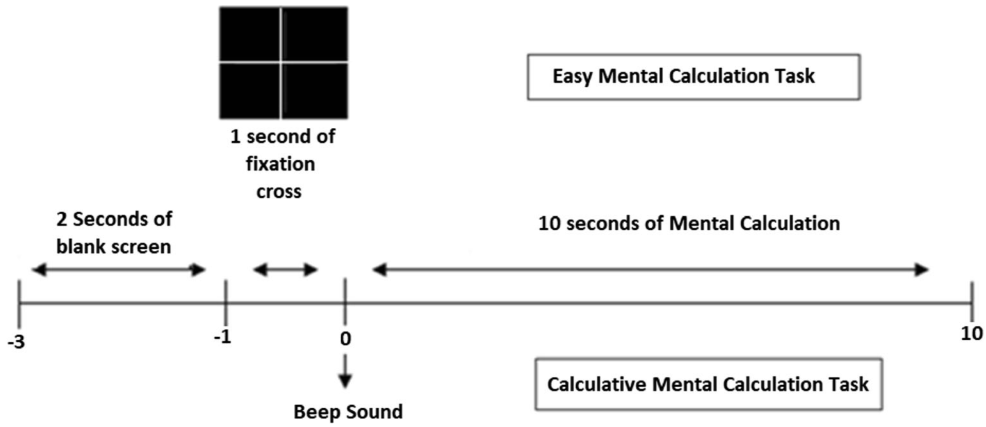


Fig. 2 Representation of the 13 s cue-based paradigm designed for the Easy and Calculative Mental Arithmetic tasks

performed, the subjects were asked to calculate the given tasks for 10 s only with their mental engagement. The paradigm started with a blank screen (black in color) and remains for 2 s; followed by a fixation cross for 1 s. This fixation cross served as an indicative signal for the subject that the task (easy or calculative) was about to begin. The time allotted for each MA calculation for each individual task was 10 s after that a response time of 3 s was allotted during which the subjects were supposed to write their responses; doesn't matter whether the answers were correct or incorrect. This paradigm is explained in Fig. 2. Before the start of the recording session the subjects were instructed well and were made to perform a similar task of short duration for making them well acquainted with the task to be performed.

In order to perform the physiological measurements electrocardiogram (ECG) signal was recorded in accordance with the cue from the paradigm. For recording, armed chair was used where the subject was seated with foot on an insulated surface. Electrocardiogram was recorded from single channel with Lead-II positions of the electrodes with sampling frequency of 200 samples per second. The recording setup and the screenshot of the recording are demonstrated in Figs. 3 & 4, respectively. Single session continuous recording of the subjects was done throughout all the 15 easy and 15 calculative tasks appearing randomly on the screen. It was a single subject single session recording.

2.4 Heart rate variability

Heart rate variability gives the variations that occur between consecutive heartbeats within a given time interval. The time difference between successive R waves gives a time series of RR intervals and a variation in such time series of consecutive heartbeats is called a tachogram also referred to as index of the autonomic neural control of cardiopulmonary system. Heart rate variability occurs as a result of continuous changes in the sympathetic and parasympathetic innervations [18]. It has several components that have been widely studied such as the

Fig. 3 Snapshot of the experimental paradigm with subject

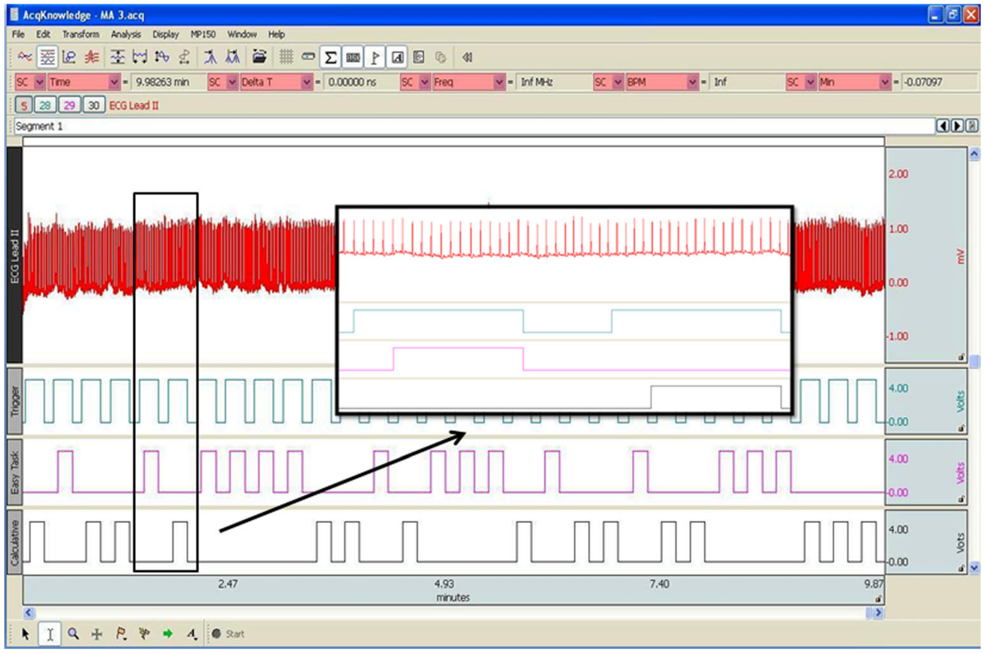


Fig. 4 Screenshot of the signal recording procedure, with cue and ECG signal

respiratory sinus arrhythmia (RSA), low frequency (LF) and high frequency (HF). The RSA is said to range from 0.15 Hz to 0.40 Hz and the origin of this HF component has been believed to be from parasympathetic part of the nervous system. LF component usually ranging from 0.04 Hz to 0.15 Hz has also been widely studied. The LF band is thought to be of both sympathetic and parasympathetic origin. However, some researchers believe it to be mainly of sympathetic origin [9, 19]. These components of HRV studies have been found to correlate with mental, physical and attentional stress [9].

For the selection of R-wave peaks a threshold level of 0.5 V was set and the calculation of interpolated HRV (IHRV) was done from the recorded ECG signals at 8 Hz spline resampling frequency by linear interpolation method.

2.4.1 Frequency-domain analysis

The power spectrum density (PSD) estimate is calculated for the RR interval series in the frequency-domain analysis method. The fast Fourier Transform (FFT) based methods are usually used for PSD estimation in HRV analysis. Here, the HRV spectrum is calculated using the Welch's periodogram method where it is divided into overlapping segments. The averaging of the spectra of these segments is then done to obtain the required spectrum which helps in reducing the variance of the FFT spectrum.

Welch Periodogram is a method by which a large time-sampled waveform can be frequency-transformed by partitioning the data into shorter segments. Here each segment is transformed and all of these are then arranged to create a composite frequency space waveform. In Welch's periodogram the data segments are subjected to a window *w(n)* before the computation of the individual periodograms, where the data segments can be assumed to be sectioned into

$$K \leq \frac{N}{M} \tag{1}$$

Where, N is the number of points in a data sequence, M denotes the number of samples and K represents the number of over-lapping segments.

The Welch Periodogram estimator is given by;

$$P(fn) = \frac{1}{K}\sum_{k-1}^{k} I_k(fn) = \frac{L}{UK}\sum_{k-1}^{k} |A_k(n)|^2 \tag{2}$$

where, L is the length of the segments, and K is the number of segments into which the data is broken. Also,

$$U = \frac{1}{L}\sum_{j=0}^{L-1} W^2(j) \tag{3}$$

where, U is the energy involved.

2.4.2 Poincare analysis

For the evaluation and representation of HRV from the point of view of a nonlinear dynamic system is a Poincare plot, a graphical approach to plot the value of given heart period on abscissa against the value of the subsequent heart period, where the overall shape of distribution of data points describes the dynamics of the system [20]. Poincare plot is one among the most commonly used nonlinear method of analysis of HRV and is simple to interpret. It represents graphically the correlation between successive RR intervals. The standard deviation of the points perpendicular to the line of identity ($RR_j = RR_{j+1}$) are denoted by SD1 and SD2 which, is described by short-term variability (caused by RSA) and long-term variability (related to time-domain measures SDSD & SDNN), respectively. The points obtained above and below this line of identity show increase (decrease in HR) and decrease (increase in HR) in RR interval respectively and the points on the line of identity have an equal RR interval. The ellipse serves as a primary visual aid, and the important data are present in the numerical values of *SD1* and *SD2*.

$$SD1^2 = \frac{1}{2} SDSD^2 \tag{4}$$

$$SD2^2 = 2SDNN^2 - \frac{1}{2} SDSD^2 \tag{5}$$

2.4.3 Detrended fluctuation analysis (DFA)

The DFA is the root-mean square fluctuation of an integrated and detrended time series, which measures the correlation between the signals. In the very first step of the DFA analysis the RR interval time-series is integrated.

$$y(k) = \sum_{j=1}^{k} \left(RR_j - \overline{RR} \right), \quad k = 1, \ldots, N \tag{6}$$

where, RR is the average RR interval, and RR_j is the j^{th} RR interval.

The integrated series is then divided into segments, which are of equal length n. A least square line is fitted into the data within each segment. Let $yn(k)$ denote these regression lines. The integrated series $y(k)$ is then detrended by subtracting the local trend within each segment. The root-mean square fluctuation of this integrated and detrended time series is calculated by

$$F(n) = \sqrt{\frac{1}{N} \sum_{k=1}^{N} (y(k) - yn(k))^2} \tag{7}$$

An F (n) increase with segment length as this computation is repeated over different segment lengths to yield the index *F(n)* as a function of segment length n. A linear relationship on a double log graph indicates the presence of fractal scaling where the fluctuations can be characterized by scaling exponent α (the slope of the regression line) relating *log F(n)* to *log n*.

In DFA, the correlations are divided into short-term and long-term fluctuations. Hence, the short-term fluctuations have been characterized by α_1, which is obtained from the (*log n, log F(n)*) graph within range $4 \le n \le 16$ (default values). Similarly, the slope α_2 is obtained by default from the range $16 \le n \le 64$ and characterizes long-term fluctuations.

2.5 Statistical analysis

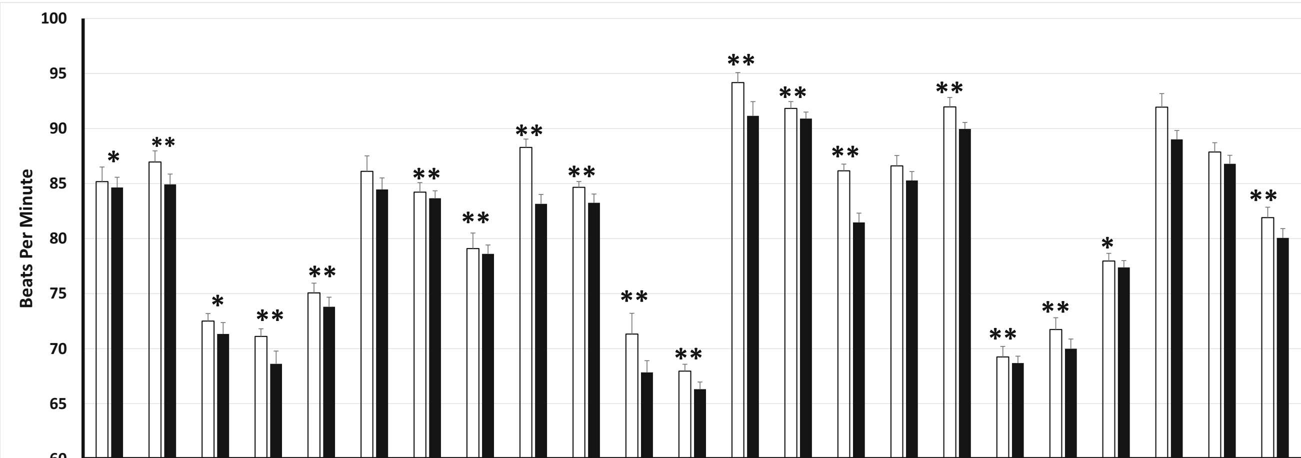
The statistical analyses were performed on MS Excel (MS Office 2007, Microsoft Inc) and also verified manually. Significance of the changes in HR during the easy MA task and the calculative MA task were calculated using the paired Student's *t*-distribution. For analysis the mean HR of the individual subjects for both the easy and the calculative tasks were analyzed.

3 Results

The very first step was to derive the HRV data from the raw data. Further, analysis was done based on the HRV/IHRV obtained from the raw data. The raw ECG signal was used for obtaining IHRV using the AcqKnowlwdge 4.0 software. The IHRV obtained from the AcqKnowledge 4.0 (Biopac Inc., Goleta, California, USA) software served as input for the HRV analysis tool KUBIOS HRV version 2.1 [21]. The summary of the output obtained from this showed a variety of analyses been performed both in the time-domain and the frequency domain. The mean HR values for each individual subject obtained from the Kubios output were averaged for both the levels of tasks i.e. easy MA and calculative MA tasks, respectively. Based, on the average data obtained from each individual subject standard error calculation was done. There was a decrease in the beats per minute of each subject with an increase in the level of the MA calculation task. There are observable variations in the extent of the difference in the values for task difference obtained for each individual subject. Among all the 22 subjects, who had volunteered for the study under this experiment; 9 subjects (MA2, MA4, MA9, MA11, MA12, MA13, MA15, MA17 and MA21) have shown a significant decrease in the values for beats per minute when compared to the other subjects as shown in the Fig. 5.

Moreover, upon the application of the *t*-test all the 22 subjects showed significant difference among the two tasks in accordance with Fig. 5. It was found that for $P < 0.01$; 16 of 22 subjects (MA2, MA3, MA4, MA5, MA7, MA8, MA9, MA10, MA11, MA12, MA13, MA14, MA15, MA17, MA18 and MA19) gave significant output. For $P < 0.05$; 3 of 22 Subjects (MA1, MA3 and MA20) showed significance. Thus, a total 19 of 22 subjects showed significance in the *t*-test. The overall average obtained for all the subjects was also significant for $P < 0.01$.

The tachogram plot for the subjects depicts a clear separation between the two levels of MA tasks assigned to the subjects (Fig. 6). The plot between the instantaneous HR (IHR) and time shows that IHR for the calculative MA task to be less or lower than that of the easy MA task. Initially, at the onset of the task, both easy and calculative MA tasks both originate from the same position but separate out as the tasks proceed.



	MA1	MA2	MA3	MA4	MA5	MA6	MA7	MA8	MA9	MA10	MA11
□ Easy	85.1829	86.9653	72.4990	71.1113	75.0705	86.1143	84.2225	79.0990	88.2868	84.6583	71.3180
■ Calculative	84.6464	84.9271	71.3348	68.6209	73.8044	84.4646	83.6663	78.6126	83.1601	83.2480	67.8443

	MA12	MA13	MA14	MA15	MA16	MA17	MA18	MA19	MA20	MA21	MA22	Average
□ Easy	67.9574	94.1755	91.8295	86.1586	86.6085	91.9663	69.2442	71.7416	77.9586	91.9407	87.8736	81.9083
■ Calculative	66.3091	91.1585	90.9011	81.4693	85.2835	89.9567	68.6929	69.9859	77.3810	89.0134	86.7962	80.0581

Fig. 5 Subject-wise mean ± standard error variations (22 subjects) of heart rate during the task performance of easy and calculative mental arithmetic calculations showing higher BPM in easy task as compared to calculative task along with the respective *P* value for their t-test

As the tasks have been randomly presented to the volunteers, differences depending on the preceding and the succeeding tasks are noticeable. In the HF FFT result, where an easy task is succeeded by a calculative task 15 out of 22 subjects show a decrease in the HF value, whereas in the case of easy task succeeding a calculative task 12 of 22 showed an increase in their respective HF values (Fig. 7a). In the LF FFT result, where an easy task is succeeded by a calculative task 12 out of 22 subjects show a decrease in the LF value, whereas in the case of easy task succeeding a calculative task 12 of 22 showed an increase in their respective LF values (Fig. 7b). A mixed response can be seen in the transition of tasks from easy to easy and that from calculative to calculative. In the Mean HR result, where an easy task is succeeded by a calculative task 16 out of 22 subjects show a decrease in the mean HR whereas in the case of easy task succeeding a difficult task 14 of 22 showed an increase in their respective mean HR (Fig. 7c). A mixed response can be seen in the transition of tasks from easy to easy and that from calculative to calculative. Table 1 further shows the differences in task transitions averaged for all the subjects for various HRV parameters.

In Poincare Analysis, the subjects showed lower values of SD1 and SD2 during the easy task than that shown during the

Fig. 6 Normalized Heart rate variability for easy mental arithmetic and calculative mental arithmetic showing a separation beginning after the 5th second from the onset of the task over a time period of 13 s paradigm

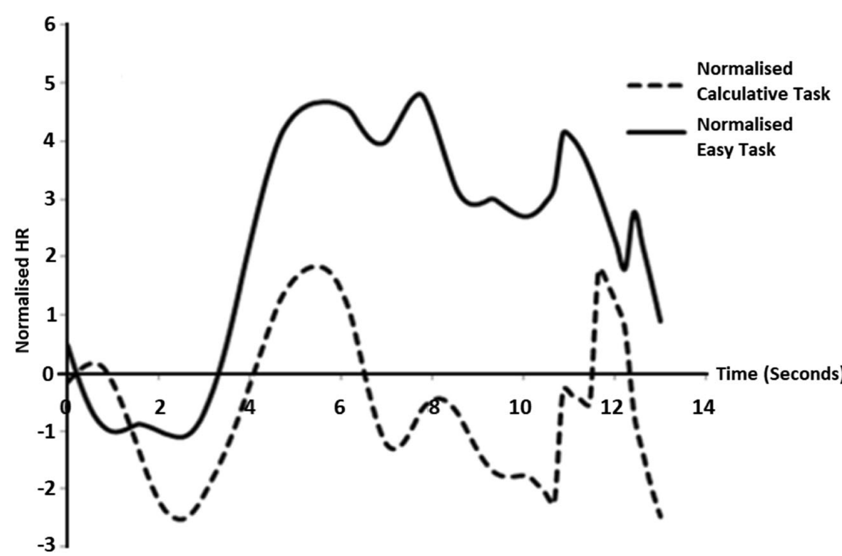
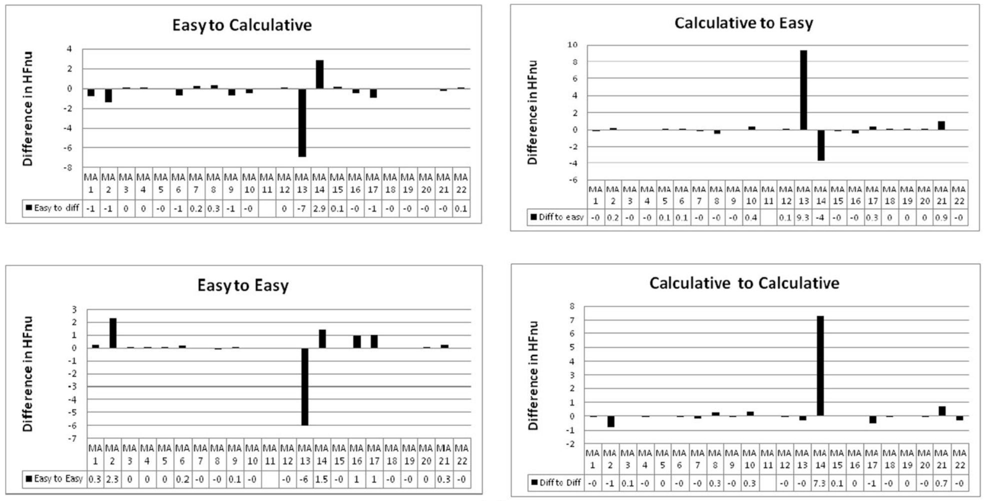
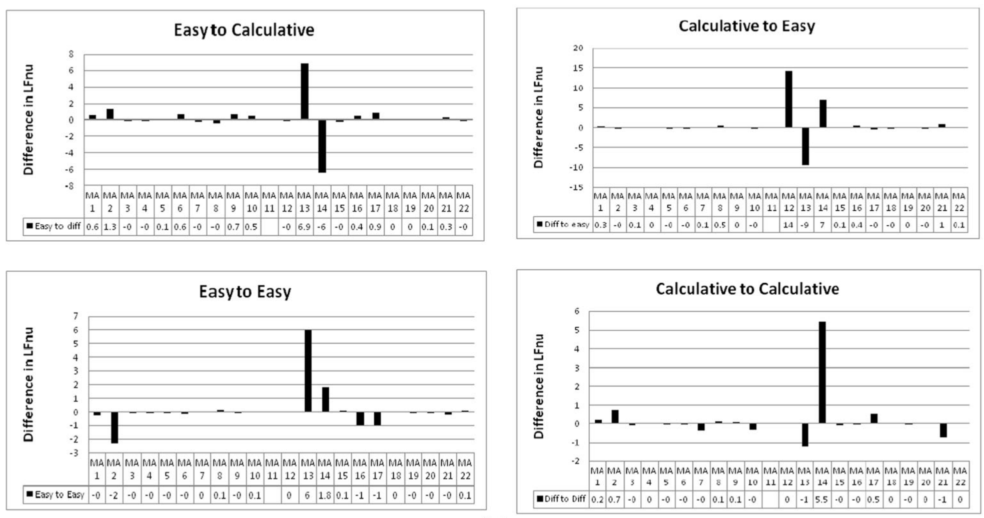


Fig. 7 Subject-wise changes obtained due to task transition during performance of easy and calculative mental arithmetic calculation tasks in **a** High Frequency, **b** Low Frequency of the power spectrum and in **c** mean HR changes



(a)



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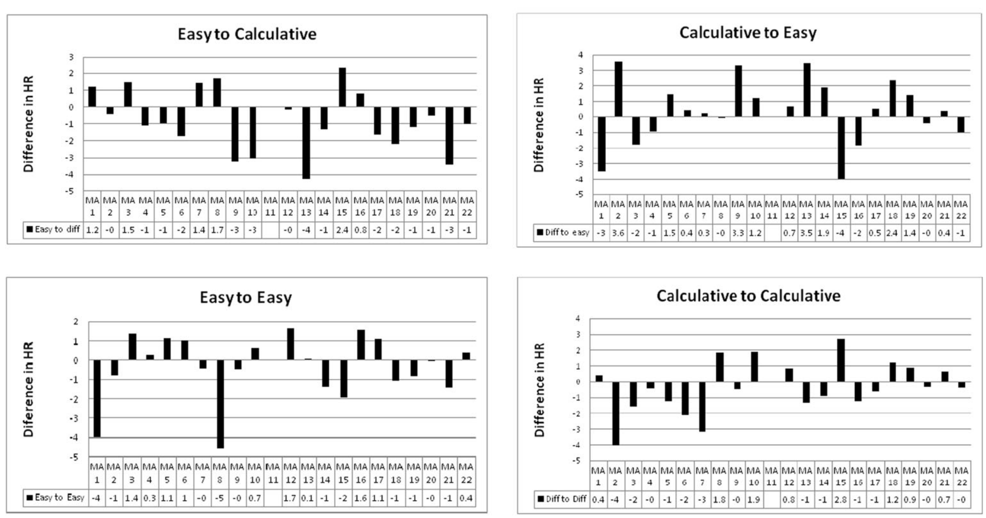


(c)

Table 1 Variations in the parameters for transition in tasks during MA performance averaged for all 22 subjects

Task Transition Parameters	Easy to Calculative Task	Calculative to Easy Task	Easy to Easy Task	Calculative to Calculative Task
SD1 (ms)	0.024228	0.234454	−0.0626	−0.1563
SD2 (ms)	1.44235	−0.08925	−0.33079	−2.56041
α_1	0.015502	−0.02035	0.016487	0.007678
α_2	−0.07887	0.053156	0.027452	−0.05379
HF (power %)	0.042959	−0.12344	−0.19243	0.279057
LF (power %)	0.759614	−4.17899	−0.88629	3.362057
Mean HR(1/min)	−0.492672	−0.0324353	−0.262827	−0.354194

calculative task. Visual inspection of the graph (Fig. 8) show an elliptical shape which lies at the center of the quadrant, and the graphs are symmetrical for both the calculative and the easy MA tasks. In the DFA analysis, $\alpha 1$ and $\alpha 2$ both showed lower values for easy task whereas showed higher values for the calculative task (Fig. 9). Spectral analyses by FFT methods show a clear distinction between the easy and the calculative MA tasks (Fig. 10a and b). There is a lower LF and HF waveform in calculative task when compared to that during easy task.

4 Discussion

In the present work, MA task has been evaluated for two categories viz. easy and calculative MA calculation Task. The observed results have shown a decrease in the HR of the performing subjects in the calculative MA task when compared to that of the easy MA task. This can be observed clearly in Figs. 5 & 6. Considering the HR, the statistical analyses also suggest a significant difference between the HR at the time of easy and calculative MA task. In 16 out of the 22 subjects, it was found to be significant at $P < 0.01$ and 3 out of 22 showed significance at $P < 0.05$ making the total number of subjects showing significance to be 19 out of 22. Moreover, the spectral analyses of ECG signal have also shown significant changes which are observable in LF and HF bands.

The vagal response to any baroreceptor stimulation has been reported to take around 240 milliseconds in humans [22], which is fast enough to register a delay in the next cardiac cycle. It has been reported at times that upon being exposed to a stressor, the autonomic system gets triggered [1, 2, 8, 18, 23–25], where the parasympathetic nervous system (PNS) is suppressed and the sympathetic nervous system (SNS) is activated. Further, when the stressor is removed or is no longer present, a negative feedback system stops cortisol production in the body, and a sympathovagal balance is said to be established through homeostasis between the PNS and the SNS [26]. It is also an established practice that, HRV are measured from RR-interval time series known as the tachogram. The variations in time between the consecutive R-peaks reflect the status of the ANS because the HRV is said to be regulated by the balance of the sympathovgal system [26]. Observing the results obtained for HR, it can be suggested that the PNS is getting suppressed with the onset of the task and the SNS is being triggered. But, as the HR obtained in the easy task is greater when compared to that during the calculative task, it can be related that is surely the act of mental stress which in turn is affecting the sympathovagal balance.

Low frequency has been shown experimentally to be influenced by both the sympathetic and parasympathetic activity [18, 27, 28]. Although, some researchers believe that the LF

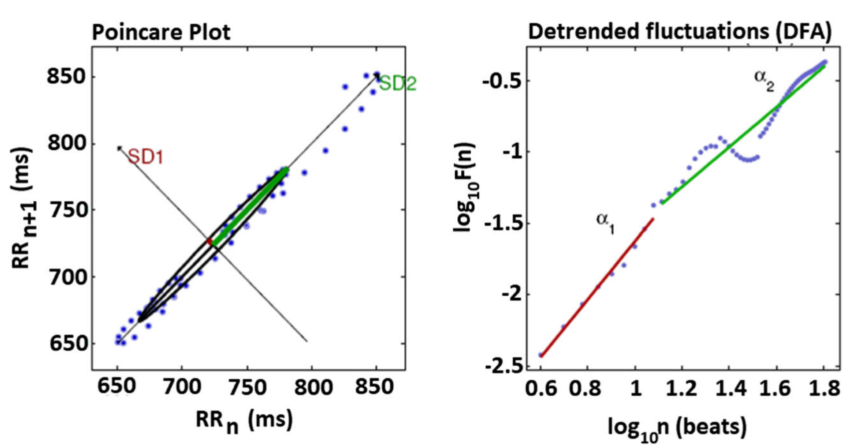


Fig. 8 Plot for Poincare and DFA analysis during Calculative Mental Arithmetic Task

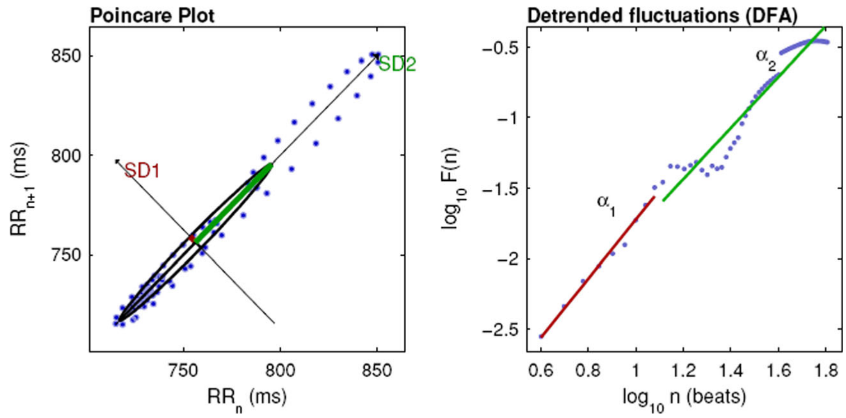
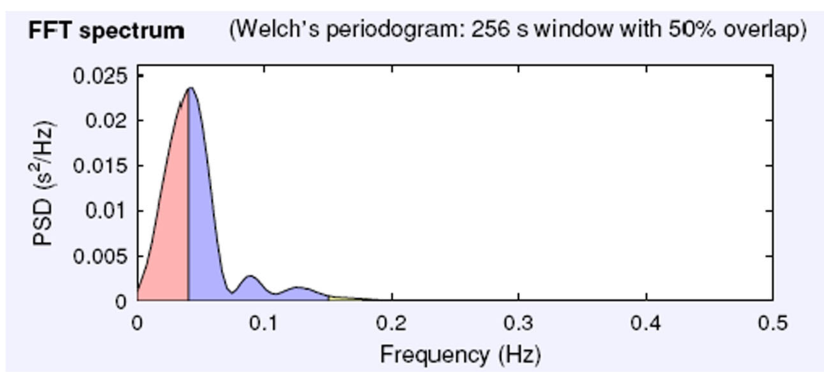
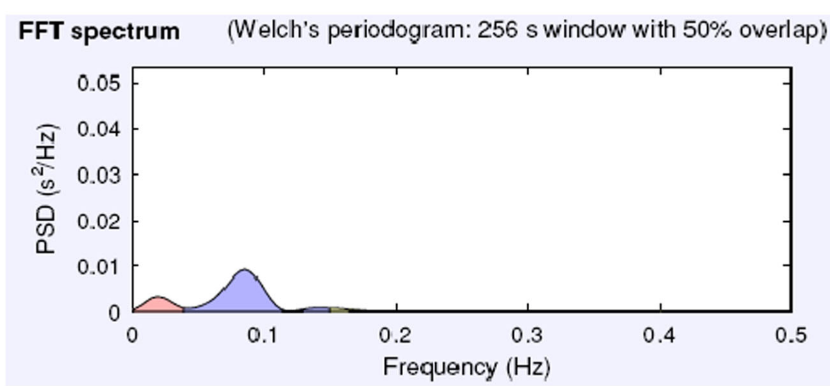


Fig. 9 Plot for Poincare and DFA analysis during Easy Mental Arithmetic Task

range is mainly associated with the sympathetic activity and the HF range is mainly associated with the parasympathetic activity [18, 28]. Mental arithmetic task enhances linear casual coupling from the vascular to the cardiac system, and conversely has been said to decrease with fatigue [25, 29]. Reduction in LF power is thought to be result of a defensive cardiovascular system associated with attention demanding information processing [30], which also very well observable in the results is obtained for the MA tasks. The principle subcomponent of the HF component is the respiratory sinus arrhythmia (RSA), the power of which depends on the respiratory rhythm, i.e. if the respiratory rhythm is stable RSA power is high, whereas if the respiratory rhythm is unstable the RSA power is low. Therefore, it is advantageous to control respiratory rhythm to a periodic pre-determined frequency to eliminate the respiration effect from the assessment of the parasympathetic nerve activity; however, it is not practical to do so as it would impart an additional stress on the subject [28]. In the results obtained here, the value of HF component is decreased in task transition from difficult to easy suggesting a decrease in the respiratory rhythm which shows that the RSA is unstable, and the parasympathetic activity is high. Now, for the transition from easy to difficult the reverse holds true here. Thus, the sudden shifting in the level of tasks during the



(a)



(b)

Fig. 10 Representative plot for FFT Spectrum analysis during **a** Easy Mental Arithmetic Task and **b** Calculative Mental Arithmetic Task experiment is triggering the PNS activity and inhibiting the SNS activity until a sympathovagal balance is achieved.

The control of the normal rhythm of heart is done by the membrane processes of the cardiac sinoatrial (SA) node, which in turn is modulated by both the sympathetic and parasympathetic divisions of the ANS. There is release of the acetylcholine by the post ganglionic parasympathetic terminals at the SA node, which in turn slows the rate of SA node depolarization and discharge by binding to muscarinic cholinergic receptors and activating the transmembrane potassium channel. In contrast nor-epinephrine is released by sympathetic terminals in the SA node and increases the speed of SA node rhythm via a β1 receptor-mediated second messenger cascade of inter cellular signals. In addition to these classic neurotransmitter actions, the chronotropic state of the heart can be modulated by a variety of neuropeptides, such as neuropeptide Y, which appears to be co-localized with the conventional neurotransmitters in autonomic terminals [31–34]. Even if the chronotropic control of the heart is attributable largely to direct autonomic innervation of the SA node, other factors can influence the HR. Apart from these direct neural innervations of heart, the HR can also be modulated by the sympathetic system by releasing adreno-medullary catecholamines. Variations in the activity of rennin-angiotensin system can also be among the humoral factors affecting the HRV [23, 35]. Humoral influences on the HRV have been said to be apparent denervation of the cardiac system which is evident from the observation that the LF HR variations effected by humoral changes and the HF fluctuations are mostly due to the respiratory effect of the SA node [28]. Posture has also been discussed to play a role in the regulation of HRV as it has been said that sympathetic tone is minimum when the position of an individual supine and is higher when the same individual is standing.

The results obtained during this experiment and their analysis show that mental load such as MA tasks have a definite influence upon the autonomic responses. The spectral analyses of HRV provide a strong evidence for changes in autonomic responses during different levels of the MA tasks. Changes in such parameters can be clearly seen in our experimental results; their further analysis provide important results which clearly show the importance of HRV analysis using its spectral components (LF and HF) along with HR changes.

5 Conclusion

The findings of this experiment suggest distinct changes in the autonomic parameter short ECG segments with task performance; easy and calculative mental arithmetic calculations. It was observed that with the increase in the level of the complexity of difficulty of mental task, there is a decrease in the heart rate. The results obtained from the components of the ECG viz. HF and LF also suggest that sympathetic and the parasympathetic activities get altered with the change in the level of task difficulty. Moreover, mental stress can be suggested to be a causative factor for such changes. There are other parameters also for the analysis of autonomic changes, but ECG and HRV analysis can be said to give a reasonably clear and monitored evaluator results. Thus, overall findings here in the present experiment suggest that with the increase in the level of task difficulty (from easy to calculative mental arithmetic) there is an increase in the mental stress which causes changes in the autonomic responses; which is depicted by the changes in the HRV parameters with task change.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article is based on the ECG data acquired from normal human volunteers in the laboratory considering the ethical guidance. No drug or invasive technique is used. The volunteers donated their data with written consents.

Informed consent Informed consent was obtained from all individual participants included in the study. The communicating author certifies that all the authors of the manuscript have contributed in this research work and gone through its content before submitting to the journal.

Certificate of originality *This is to certify that the article submitted for publication in '**Health and Technology**' has not been published, nor is being considered for publication elsewhere.*

(Rakesh Kumar Sinha)

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