Cardiac autonomic flexibility is associated with higher emotional intelligence

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Abstract: Emotional intelligence influences affect related outcomes, and accounts for the individual differences in efficient emotion regulation. Autonomic Nervous system activity is a major component of emotional response in which the excitatory sympathetic and inhibitory parasympathetic nervous systems interact antagonistically to produce varying degrees of physiological arousal and regulation. This study aimed to explore how cardiac autonomic reactivity to emotion elicitation is related to and can predict trait emotional intelligence of an individual. Fifty-three college students participated in a five-part cardiac recording session, followed by questionnaires on Trait Emotional Intelligence, and a feedback form to indicate emotional arousal. High trait EI individuals had a higher vagal response at rest and lower emotional reactivity in response to film clips measured as change in cardiac autonomic responses from baseline to emotional state. Cardiac autonomic response at baseline and reactivity in emotional state predicted emotional intelligence. Lower emotional reactivity and higher autonomic flexibility are associated with higher emotional intelligence.

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PUBLIC INTEREST STATEMENT
Every person wants to efficiently manage interpersonal and interpersonal emotions. Emotional intelligence (EI) plays an important role in determining who makes the most of his or her emotions; it is a set skills and abilities associated with recognizing, managing, regulating and utilizing their own emotions and those of others. Various studies have explored the psychological, health-related and performance-related aspects to EI but the biological correlates remain largely unexplored. This study aims to find the relation between one of the biological variables—cardiac autonomic response—and trait emotional intelligence of an individual and gain knowledge about how this biological variable can be used to predict EI.
Subjects: Psychology; Emotion Physiology

Keywords: Trait Emotional Intelligence; cardiac autonomic response; heart rate variability; emotional reactivity

1. Introduction

1.1. Emotional intelligence

Emotions are crucial for our everyday functioning but can become maladaptive when expressed at the wrong time or at the wrong intensity level. We markedly differ in the way we identify, express, understand, regulate, and use our own and other’s emotions and this is determined by our emotional intelligence (EI). (Sarrionandia & Mikolajczak, 2020) EI focuses on understanding who makes the most of his/her emotions and has two complementary conceptions—Ability EI (AEI) and Trait EI (TEI). (Peña-Sarrionandia et al., 2015) AEI is best assessed via performance tests and captures what an individual is capable of doing in an emotional situation, whereas TEI focuses on emotion-related dispositions and affect-related aspects of personality and captures how much of this knowledge/competence translates into practice. (Mikolajczak et al., 2008) Thus the present paper focuses on TEI perspective.

Trait Emotional Intelligence is a constellation of emotion-related traits that capture an individual’s typical way of processing emotion-related information and reacting in emotional situations. The “perceiving emotions” branch of EI helps in efficient selection of emotion regulation (ER) strategy. (Barrett et al., 2001) The “emotion regulation” and the “managing emotions” branches are associated with being open to both pleasant and unpleasant emotions, being able to recognize the value of feeling certain emotions in specific situations, and understanding which short and long term ER strategies work best. Emotion Regulation forms the core of EI as it benefits from developed skill on the other three branches. (Brackett et al., 2013) EI has been established as a significant predictor of psychological, somatic, and social adjustment and is also causally associated with these, as increasing TEI by training has shown to improve facets associated with all the 3 of them like higher emotional wellbeing, less stress, fewer psychological disorders, better interpersonal relationships and also improvement in job performance and work attitudes. (Sarrionandia & Mikolajczak, 2020)

1.2. Cardio autonomic response to emotions

Each emotional experience is associated with physiological changes and a key source of these changes is the Autonomic nervous system (ANS). Emotional experience is associated with varying degrees of physiological arousal by the autonomic nervous system. The excitatory sympathetic nervous system (SNS) and the inhibitory parasympathetic nervous system (PNS) are branches of ANS which interact to produce different degrees of physiological arousal. The ease with which an individual can transition between various arousal states is dependent on the ability of the ANS to rapidly vary heart rate (HR) which is reflected as heart rate variability (HRV) and acts as an indicator for autonomic flexibility and emotion regulation (ER) capacity. (Steinmetz et al., 2016) HRV is the beat to beat variability and can be calculated using both time domain and frequency domain measures. Most commonly used time domain measures for short-term recordings are RMSSD (Root Mean Square of Successive Differences) and SDNN (Standard Deviation of NN interval) which indicate high-frequency variations/vagal modulation and overall variability, respectively. In the study of emotions and autonomic responses special attention has been given to heart rate variability due to tonic parasympathetic influence emanating from the Vagal nerve as it is responsive to environmental demands and underlies the ability to regulate emotions and respond adaptively to emotional provocation. (Rash & Prkrachin, 2013)

At rest, heart rate is slowed due to increased PNS activity (via vagal nerve), thus an increase in heart rate during an emotional episode indicates reduced PNS influence or increased SNS influence. (Levenson, 2014) Cardiac vagal activity or parasympathetic activity can be measured as the High
frequency component of heart waveform or RMSSD of RR interval in heart waveform, while sympathetic activity can be indicated by heart rate. (Kreibig, 2010) (Appelhans & Luecken, 2006)

HRV is believed to be a key index of emotional well-being. (Campos, 2017) (Ortega, 2016) If a person has persistent stressors like poor sleep, anxiety, unhealthy diet, dysfunctional relationships, social isolation, lack of exercise etc., the ANS (Autonomic Nervous System) balance gets disrupted and one’s sympathetic system (fight or flight) goes into overdrive, which can be identified by a lower resting HRV. Lower HRV shows lower resilience and flexibility. (Campos, 2017) Changes in emotional response from baseline to emotion induction, indicates emotional reactivity. (Rash & Prkachin, 2013) Previous studies have shown mixed results on the relation between EI and emotional reactivity but these studies depend largely on self-report of emotional arousal rather than physiological measurement. (Fernández-Berrocal & Extremera, 2006)

1.3. Emotional intelligence and autonomic nervous system

Previous research has shown that TEI has both structural and functional neurobiological correlates. Patients with lesions in ventromedial prefrontal cortex (vmPFC) and amygdala, (areas responsible for emotional processing) have lower EI (Bar-On et al., 2003), also healthy individuals with higher EI have greater grey matter volume and density in vmPFC (Tan et al., 2014) indicating it to be one of EI’s structural correlates. With respect to functional correlates, trait EI has been found to be associated with neurological activity in both resting and active/emotionally laden conditions, with higher trait EI individuals showing greater resting left frontal activation. (Sarrionandia & Mikolajczak, 2020)

But there is a paucity of research on the autonomic effects of trait EI during resting and active conditions. (Petrides et al., 2016) Few available studies showed how trait EI buffers the effect of stress by reducing HPA axis reactivity or by lowering the increase in heart rate variability in response to stress. (Mikolajczak et al., 2007) (Laborde et al., 2011) A study showed that low EI males have lower parasympathetic and higher sympathetic activity at rest and are thus more prone to developing hypertension. (Garg & Agarwal, 2019) Another study showed that 2 trait EI factors—“perception of emotions” and “managing own emotions” show significant correlation with cardiovascular measures of emotional arousal during sadness and cheerfulness in females. (Papousek et al., 2008). Moreover, the few studies done show inconsistent results, a recent work by Zysberg and Raz (2019) found no association between trait EI and the cardiac vagal regulation during self-induced sadness unlike what was observed in the meta analysis recently done by Sarrionandia and Mikolajczak (2020). (Zysberg & Raz, 2019) (Sarrionandia & Mikolajczak, 2020) Thus it should be highlighted that there is a lack of research on the effects of TEI on biological variables, other than the few mentioned above, not much is known about the physiological correlates of trait EI. (Sarrionandia & Mikolajczak, 2020)

We sought to understand how cardiac autonomic responses to positive and negative emotion elicitations vary with individual differences in TEI as this knowledge may inform future research on biological correlates of TEI. Individual differences in cardiac autonomic reactivity to emotions can be seen by RMSSD for heart rate variability (HRV) as it is a measure of parasympathetic/cardiac vagal responding. HRV is an index for the capacity of the central autonomic network to adjust to environmental demands, and is an objective measure of regulated emotional responding as brain circuits critical for self-regulation are linked to the heart. (Appelhans & Luecken, 2006) The effect of EI on affective outcomes is mediated by ER, (Hughes & Evans, 2018) (Mestre et al., 2016) (Hughes & Evans, 2016) and a lower HRV can indicate difficulties with ER. (Visted et al., 2017) ER and regulation of ANS share neural networks within the brain and thus high HRV is associated with better ER and serves as an indicator of functioning of the brain regulatory systems. (Williams et al., 2015) Lower HRV leads to lower vagal withdrawal, which is responsible for calming down when the stressor has passed.

Another factor that varies is the emotional arousal and sympathetic activity which can be indicated via heart rate (HR). One of the most common physiological indicators of transitory, short-
term arousal level is HR (pulse). (Appelhans & Luecken, 2006) (Kreibig, 2010). Although HR does not differentiate between specific emotional experiences, but is a widely used tool to measure arousal, which is highly associated with magnitude of emotional experience. (Zysberg & Raz, 2019)

1.4. The present study
The cardiac autonomic network (CAN) receives input about the physiological conditions inside the body and sensory information about the external environment which allows it to dynamically modulate emotional expression, arousal and regulation. The output from CAN influences the heart through SNS and PNS and is reflected as heart rate and heart rate variability. (Appelhans & Luecken, 2006). This article will measure HR and RMSSD at baseline rest, and in emotional state.

We were interested in examining the influence of TEI on cardiac autonomic responses to Ekman’s 6 basic emotions, using film clips. (Ekman, 1999) Since emotions affect autonomic responses, individual differences in TEI are likely to have an influence on how an individual physiologically responds to different emotions. Earlier studies have shown that High EI people are more efficient at retrieving positive memories both during positive mood (mood maintenance) and negative mood (mood repair) and are thus more efficient at regulating negative emotions than their low EI counterparts. (Ciarrachi et al., 2000)

Three general hypothesis were tested. First, we hypothesised that high EI individuals will portray greater autonomic flexibility/emotion regulation capacity at rest. Second, we hypothesised that high EI will be associated with lower cardiac autonomic reactivity to emotion elicitation, especially for negative emotions. Third, we tested the hypothesis that the cardiac autonomic response at rest and reactivity to the basic emotions will together predict the EI of an individual.

2. Methods

2.1. Participants
A sample of 55 participants was recruited from the student population of IIT Kharagpur, out of which 2 were removed due to incomplete data. In sum, data from 53 participants was analysed (M_age = 25.15, SD_age = 2.97, 30 males and 23 females). Exclusion criteria included any ongoing physical or mental health problems and or use of medications. All the participants signed an informed consent form before taking part in the study, and were also informed that they had the right to quit the experiment at any time. They were debriefed about the purpose of the study at the end of the experiment. The experimental procedure and the video content shown to the participants were approved by the Institutional Ethics Committee (IEC) of IIT Kharagpur.

2.2. Apparatus and materials

2.2.1. Physiological measures
The physiological data was recorded using the FMCW radar sensor, namely the mmWave TI sensor which operates at 80 GHz. It is a real-time millimetre-wave radar-based, non-contact vital sign monitoring system that is capable of detecting the heart and breath waveform and has a sampling rate of 20 frames per second. It provides high accuracy in the range of 0.6 to 1 m. (Al-Masri & Momin, 2018) It has a built in DSP and ARM processor for post-processing and give accurate heartbeat waveforms and breathing waveforms. The heart beat waveform is later analysed and physiological variables of heart rate and RMSSD were extracted by the standardised methods (Shaffer & Ginsberg, 2017) using MATLAB.

2.2.2. Psychological measures
Trait EI was measured using the Schutte Self Report Emotional Intelligence Test (SSEIT). It is a self-report TEI scale which consists of 4 factors—perception of emotion, managing own emotions, managing other’s emotions, and utilization of emotion. It is a 33-item self-report inventory in which the respondents rate themselves using a 5-point scale. The total scale and its sub-factors
showed high test retest reliability—0.78. The internal consistency of the scale as measured by Cronbach’s alpha is 0.90. (Schutte et al., 2009) This scale was chosen as it is distinct from standard personality factors. (Ciarrochi et al., 2000)

*Emotional Experience Feedback form* was given at the end of each emotion eliciting video, in which the respondent had to rate how emotional he/she felt while watching the video. The rating ranged from 1 to 5, with 1 indicating not at all and 5 indicating extremely.

### 2.3. Procedure

Before entering the experiment room, participants completed the Demographic information form, consent form and SSEIT. (Smith, 2013) They were then taken to the experiment room for psychophysiological assessment. The participants were shown a neutral clip and 6 emotion eliciting film clips for the basic emotions—Joy, Disgust, Surprise, Sadness, Anger, and Fear. Each emotion elicitation was done on a separate day, which we will call a trial, to ensure that the induction of one emotion does not interfere with the induction of another. A 1 minute neutral video was shown at the beginning of each trial to bring the participants to a baseline state. The physiological recordings during the neutral video served as baseline for the experiment.

Participants were seated in a straight chair in front of a computer screen. The non-contact-based FM CW sensor, and a webcam was already placed right beside the screen. The participants were instructed to sit quietly, wear headphones and click the start button on the screen to play the video clips. The start button simultaneously initiated the emotional video, webcam and FM CW sensor in the background while the participant watched the video. Each trial lasted for 4–5 minutes which allowed sufficient sampling of heart period for time domain analysis to obtain HR and RMSSD. (Shaffer & Ginsberg, 2017). The participants filled a feedback form about their emotional experience at the end of each emotion eliciting video. Surprise emotion was eliminated from the study as inducing them through video clips was resulting in mixed emotional responses. While filling the feedback form, many participants reported feeling scared or excited, instead of surprised.

The clips were identified on the basis of a pilot study on 10 participants and some earlier studies (such as The Emotional Movie Database (Carvalho et al., 2012), Emotion Elicitation Using Films (Ray & Gross, 2007), and The Indian Spontaneous Expression Database for Emotion Recognition (Happy et al., 2015) etc.). Some videos were found to elicit multiple emotions, which were rejected as they may lead to a mixed emotional expression. The final clips used are mentioned in Figure 1:

The video recordings of participant’s face while watching the emotion eliciting clips were validated by psychologists to ensure that the clips elicited the intended emotions.

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*Figure 1. Emotion eliciting video clips; Fear: The eye movie elevator scene; Anger: Women abusing child servant; Sadness: Weak and malnourished children suffering; Disgust: Eating live cockroaches; Joy: Sofia Vergara and Penelope Cruz sell Pantene shampoo.*

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*Emotion eliciting video clips*

| Emotion | Time (mins) |
|---------|-------------|
| 00:00   |             |
| 01:12   |             |
| 02:24   |             |
| 03:36   |             |
| 04:48   |             |
| 06:00   |             |

Legend:
- Fear
- Anger
- Sadness
- Disgust
- Joy
2.4. Data analysis
The heart beat waveform obtained was filtered using the Savitzky-Golay filter for noise and random body movement’s artefacts reduction and the SNR enhancement without distorting the heartbeat signal. R peaks were detected to obtain the RR intervals and heart rate. The following measures were obtained for each trial:

Baseline HR—The most common physiological indicators of transitory, short-term arousal level is HR (pulse). (Appelhans & Luecken, 2006)

Δ Emotion HR—The difference between HR at baseline and during each trial to obtain emotional reactivity due to increase sympathetic nervous system’s activity.

Baseline HRV—Heart rate variability refers to the beat to beat variability of RR interval and can be used to provide physiological insight regarding cardiovascular control. RMSSD—Root mean square of successive differences is a measure of high-frequency variations or vagal modulation. (Smith & Fernhall, 2011)

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RMSSD = \sqrt{\frac{1}{N-1} \sum_{n=1}^{N} (RR_n - RR_{n-1})^2}
\]

Δ Emotion HRV—The difference between RMSSD at baseline and during each trial to obtain emotional reactivity due to increase parasympathetic nervous system’s activity.

2.5. Statistical analysis
All psychometric data were screened for potential outliers and missing values. There was no missing data or outliers. Inspection of skew, kurtosis, and histograms for the variables indicated the presence of reasonably normal distributions among variables. Paired t-test was conducted on HR, RMSSD at baseline and in emotional state to see if there is any significant difference between these 2 states. In order to test our first hypothesis that higher trait EI will be associated with greater autonomic flexibility characterised by greater RMSSD at baseline bivariate correlations were performed among SSEIT scores of EI and cardiac autonomic responses (HR and RMSSD) at baseline. For the second hypothesis, bivariate correlations were performed between SSEIT scores and cardiac autonomic reactivity to the 5 emotions which was measured as the difference between HR, RMSSD at baseline and during emotion elicitation. In order to test the third hypothesis, multiple linear regression was performed to assess whether the cardiac autonomic responses at baseline and reactivity during emotion elicitations were a predictor of trait emotional intelligence of an individual. Backward regression was also performed to identify the most significant set of predictors of EI. All the statistical analysis was performed in SPSS software.

3. Results

3.1. Manipulation check and descriptive statistics
Subjects were asked to rate the extent to which they felt the intended emotion on a 5 point scale (1: not at all, 5: extremely) immediately after the video got over. Feedback form ratings indicated that the intended emotion was successfully induced with varying intensity. Table 1 below presents descriptive statistics and associated standard deviations for the demographic, psychological and physiological variables. The mean EI score across many samples has been found to be 133.36, with a standard deviation of 12.83, which is similar to the mean score obtained during this study (Mean: 131.74, Std, Deviation: 13.61). Heart rate of a participant while watching emotional clips is shown in Figure 2.

Paired T- test was conducted between HR and HRV at baseline and during emotional state which revealed that HR was significantly elevated during emotion elicitation relative to baseline. Mean differences and SEM are given in Table 2. Except for Joy, RMSSD did not differ significantly between baseline and emotional state.
3.2. Association between trait EI and cardiac autonomic response and reactivity

Bivariate correlations were used to assess the relationship between, Emotional intelligence, and cardiac response at baseline and cardiac reactivity during emotional state, and gender which are shown in Table 3. There was no relationship between cardiac reactivity and gender. The total EI score was positively associated with Baseline HRV (RMSSD) and Δ Disgust HR; and negatively associated with Δ SAD HRV and Δ ANGER HRV. Of interest, EI score was not associated with cardiac autonomic response during joy. Sub-factors of EI—Perception of emotion, managing own emotions, managing other’s emotions, and utilization of emotions – also showed various significant correlations. All the sub factors were associated with Baseline HRV among others. Perception of emotion was positively associated with Δ Disgust HR, and negatively with Anger HRV. Managing other’s emotions showed positive association with Δ Disgust HR, and negative with Δ SAD HRV.

### Table 1. Descriptive data

| Variable           | Mean   | Std. Deviation |
|--------------------|--------|----------------|
| Gender             | 0.44   | 0.50           |
| Perceived emotion  | 38.14  | 5.7            |
| Manage own emotion | 36.86  | 4.75           |
| Manage other’s emotion | 32.18  | 3.68           |
| Utilize emotion    | 24.56  | 3.47           |
| Total EI           | 131.74 | 13.61          |
| Feedback Joy       | 3.55   | 1.07           |
| Feedback Disgust   | 3.62   | 1.38           |
| Feedback Sad       | 3.48   | 1.19           |
| Feedback Anger     | 3.86   | 1.16           |
| Feedback Fear      | 3.39   | 1.14           |
| Baseline HR        | 76.45  | 12.71          |
| Baseline RMSSD     | 57.81  | 12.46          |
| Joy HR             | 81.82  | 7.16           |
| Joy RMSSD          | 54.39  | 6.48           |
| Disgust HR         | 82.45  | 3.06           |
| Disgust RMSSD      | 59.69  | 6.77           |
| Sad HR             | 81.25  | 3.26           |
| Sad RMSSD          | 55.17  | 5.79           |
| Anger HR           | 81.92  | 4.07           |
| Anger RMSSD        | 53.82  | 8.05           |
| Fear HR            | 82.53  | 4.50           |
| Fear RMSSD         | 55.78  | 7.17           |
| Δ Joy HR           | 4.84   | 22.29          |
| Δ Joy RMSSD        | −3.104 | 16.42          |
| Δ Disgust HR       | 0.51   | 24.12          |
| Δ Disgust RMSSD    | −1.48  | 16.92          |
| Δ Sad HR           | −0.58  | 24.632         |
| Δ Sad RMSSD        | −5.65  | 16.84          |
| Δ Anger HR         | 1.82   | 22.52          |
| Δ Anger RMSSD      | −5.34  | 18.46          |
| Δ Fear HR          | 6.74   | 17.6           |
| Δ Fear RMSSD       | −1.12  | 15.5           |

Note. N = 53; HR = Heart rate; RMSSD = Root mean square of successive differences, EI = Emotional Intelligence
Utilization of emotion was negatively associated with Δ Joy HRV, and Δ Anger HRV. Surprisingly “Managing own emotions” branch did not show any correlation with cardiac autonomic reactivity, nor did cardiac autonomic reactivity during fear show any correlation with EI scores.

3.3. *Predictors of trait EI*

3.3.1. *Regression analysis using RMSSD (indicator of parasympathetic activity change)*

In the analysis of total EI, the final regression model was significant, \( R = 0.56 \) F (6, 40) = 2.57, \( P < 0.05 \). The \( R^2 \) value of 0.312 indicated that nearly 31% of the variability in total EI was predicted by Baseline HRV, Δ Joy HRV, Δ Disgust HRV, Δ Sad HRV, Δ Anger HRV, and Δ Fear HRV. Beta weights and t-values for each predictor can be found in Table 4:

**Table 2. Paired T test between HR and HRV at baseline and during emotional state**

| Variable               | Mean diff | SEM  | Sig (2 tailed) |
|------------------------|-----------|------|----------------|
| Baseline HR—Joy HR     | −5.31*    | 2.23 | 0.022          |
| Baseline HR—Disgust HR | −6.36*    | 2.02 | 0.003          |
| Baseline HR—Sad HR     | −4.80*    | 1.93 | 0.017          |
| Baseline HR—Anger HR   | −5.95*    | 2.16 | 0.009          |
| Baseline HR—Fear HR    | −5.70*    | 1.99 | 0.007          |
| Baseline RMSSD—Joy RMSSD | 4.23*    | 1.79 | 0.023          |
| Baseline RMSSD—Disgust RMSSD | −0.83 | 2.06 | 0.687          |
| Baseline RMSSD—Sad RMSSD | 2.64    | 1.73 | 0.135          |
| Baseline RMSSD—Anger RMSSD | 3.5     | 3.35 | 0.143          |
| Baseline RMSSD—Fear RMSSD | 2.28    | 2.08 | 0.28           |

Note. \( N = 53; \) HR = Heart rate; RMSSD = Root mean square of successive differences, EI = Emotional Intelligence *\( P < 0.05 \)

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Table 3. Bivariate correlations between psychological and physiological variables

| Variable                  | Gender | B HR | B HRV | Δ J HR | Δ J HRV | Δ D HR | Δ D HRV | Δ S HR | Δ S HRV | Δ A HR | Δ A HRV | Δ F HR | Δ F HRV |
|---------------------------|--------|------|-------|--------|---------|--------|---------|--------|---------|--------|---------|--------|---------|
| 1 Perception of emotion   | -.155  | -.180| 414** (0.004)| .245  | -.183  | .313* (0.027)| -.008  | .024  | -.226  | .071  | -.296* (0.039)| .170  | -.099  |
| 2 Managing own emotions   | .026  | -.065| 328* (0.026)| .136  | -.120  | .097  | -.173  | -.017  | -.197  | .137  | -.128  | .078  | -.081  |
| 3 Managing other's emotions | .011  | -.239| 370* (0.011)| .171  | -.143  | .373** (0.008)| .107  | -.044  | -.370** (0.008)| .133  | -.201  | .158  | -.197  |
| 4 Utilization of emotion  | .137  | .081| 300* (0.043)| -.081 | -.301* (0.034)| .187  | -.001  | -.019  | -.182  | -.058  | -.362* (0.011)| -.063  | -.221  |
| 5 Total EI                | -.019  | -.144| 469** (0.064)| .177  | -.235  | .316* | -.035  | -.012  | -.312* | .098  | -.312* | .125  | -.179  |

Note. N = 53; HR = Heart rate; RMSSD = Root mean square of successive differences, EI = Emotional Intelligence; B HR: Baseline HR; B HRV: Baseline HRV; Δ J HR: Joy HR reactivity; Δ J HRV: Joy HRV reactivity; Δ D HR: Disgust HR reactivity; Δ D HRV: Disgust HRV reactivity; Δ S HR: Sad HR reactivity; Δ S HRV: Sad HRV reactivity; Δ A HR: Anger HR reactivity; Δ A HRV: Anger HRV reactivity; Δ F HR: Fear HR reactivity; Δ F HRV: Fear HRV reactivity

*P < 0.05
**P < 0.01

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Table 4. Regression analysis of EI and cardiac vagal reactivity (HRV)

| Variable          | Model |  |  |  |  |
|-------------------|-------|---|---|---|---|
|                   | B     | SE | Beta | t  |
| Δ Joy HRV         | -0.58 | 0.339 | -0.489 | -1.71 |
| Δ Anger HRV       | -0.291 | 0.28 | -0.325 | -1.04 |
| Δ Fear HRV        | 0.414 | 0.295 | 0.396 | 1.405 |
| Δ Sad HRV         | 0.286 | 0.398 | 0.235 | 0.717 |
| Δ Disgust HRV     | 0.128 | 0.143 | 0.154 | 0.897 |
| Neutral HRV       | 0.412 | 0.536 | 0.345 | 0.768 |

Note. N = 53; HR = Heart rate; HRV: Heart rate variability (RMSSD = Root mean square of successive differences), EI = Emotional Intelligence
*P < 0.05

3.4. Regression analysis using HR and RMSSD (Indicator of both sympathetic and parasympathetic activity change)

Likewise for predicting EI from both sympathetic and parasympathetic reactivity, backward regression was used. The final model was significant, R = 0.619, F (8, 40) = 2.484, P < 0.036, with R² = 0.383, indicating that 38% of the variability in Total EI was predicted by Neutral HR, Δ Joy HR, Δ Joy HRV, Δ Disgust HR, Δ Sad HR, Δ Anger HRV, Δ Fear HRV, and Gender. Δ Joy HRV was a significant predictor within the model. Beta weights and t-values for each predictor can be found in Table 5.

4. Discussion

Basic emotions—joy, disgust, sadness, anger and fear were induced in the laboratory by showing emotion-inducing film clips, chosen from standardised databases and a pilot study, to investigate the association between cardiac autonomic reactivity to different emotions and EI. Feedback form responses indicated that the intended emotion was induced in the participants. In support of our first hypothesis, high EI showed significant association with both Heart rate and Heart rate variability at baseline indicating high emotion regulation capacity and autonomic flexibility. (Appelhans & Luecken, 2006) This result is in line with previous research as EI is associated with efficient handling of emotions personally and socially as low HRV at baseline is associated with difficulties in emotion regulation. (Williams et al., 2015) Reduced HRV is also associated with psychiatric disorders, especially the ones with poor social cognition and emotion regulation. (Quintana & Heathers, 2014) High vagally mediated heart rate variability is linked with quality of

Table 5. Regression analysis of EI and cardiac autonomic reactivity (HR and HRV)

| Variable          | Model |  |  |  |  |
|-------------------|-------|---|---|---|---|
|                   | B     | SE | Beta | t  |
| Neutral HR        | -0.826 | 0.737 | -0.693 | -1.121 |
| Δ Joy HR          | -0.45 | 0.273 | -0.46 | -1.651 |
| Δ Joy HRV         | -0.718 | 0.273 | -0.606 | -2.633* |
| Δ Disgust HR      | 0.142 | 0.113 | 0.221 | 1.256 |
| Δ Sad HR          | -0.685 | 0.68 | -0.419 | -0.713 |
| Δ Anger HRV       | -0.255 | 0.246 | -0.285 | -1.039 |
| Δ Fear HRV        | 0.365 | 0.285 | 0.349 | 1.28 |
| Gender            | -3.696 | 4.521 | -0.141 | -0.878 |

Note. N = 53; HR = Heart rate; HRV: Heart rate variability (RMSSD = Root mean square of successive differences), EI = Emotional Intelligence
*P < 0.05
life, compassion and emotion regulation while low HRV is linked to depression, anxiety, paranoia, self-criticism, rumination, worry, high neuroticism, and low parasympathetic activation which aids the occurrence of dysfunctional emotion regulation strategies. (Steinmetz et al., 2016) (Di Simplicio et al., 2012) (Kirby et al., 2017)

Our second hypothesis was supported. There was a significant association between cardiac autonomic reactivity and Emotional Intelligence of an individual. Higher the trait EI score, lower was the change in HRV and HR from baseline to emotional state. Different emotions are associated with varying degrees of sympathetic and parasympathetic activity. Anger is characterised by sympathetic activation and parasympathetic inhibition resulting in increased HR and decreased HRV; contamination-related disgust is associated with sympathetic—parasympathetic co-activation resulting in an increased HR and HRV; fear response is accompanied by decreased cardiac vagal influence (RMSSD) and increased HR; crying sadness is associated with sympathetic activation while non-crying sadness is characterised by sympathetic parasympathetic withdrawal; and finally happiness is characterised by increased cardiac activity due to vagal withdrawal resulting in increased HR and decreased HRV. (Kreibig, 2010) Emotion elicitation results in a modification in ANS activity due to emotional arousal and reactivity thus a decreased modification in ANS activity indicates higher control over emotional reaction and tendency to stay calmer. (Fernández-Berrocal & Extremera, 2006). These results support the claim that people scoring high on EI tests regulate their emotions better than people scoring low on EI tests, they can modify the track of one or more components of their emotional response more efficiently. (Peña-Sarrionandia et al., 2015). Also, high EI individuals are more efficient at retrieving positive memories both during positive mood (mood maintenance) and negative mood (mood repair). (Ciarrochi et al., 2000). The lack of association between “managing own emotions” and emotional reactivity may be because high EI individual’s ER processes cannot be fully automatic as they are adaptive, open to emotions, and regulate them only when they seem problematic. Individuals scoring high on “managing own emotions” branch are open to both pleasant and unpleasant emotions, they recognize the value of feeling certain emotions in specific situations, and understand which short and long-term ER strategies work best, thus have a more flexible approach towards emotional reactivity and regulation. (Peña-Sarrionandia et al., 2015)

Our third hypothesis was supported, a higher emotional intelligence could be predicted by cardiac autonomic response at baseline and reactivity to emotion elicitations. Gender along with a greater change in parasympathetic activity during fear and sympathetic activity during disgust, and lesser change on parasympathetic activity during anger and joy and sympathetic activity during sadness and joy, along with lower sympathetic activity at baseline significantly predicted emotional intelligence. Since EI is the ability and willingness to attend to and modify emotions in self and others, often through empathy and controlled emotional expression, a great way to assess EI would be to have people face real or simulated situations that are emotionally charged and see how they react. (Systems, n.d.). Thus we tried to predict EI from ANS responses to different emotion elicitations. This is the first study to predict EI using cardiac autonomic reactivity. A positive effect of Δ Fear HRV on TEI indicates greater parasympathetic activity, thus a greater tendency to regulate fearful emotions as compared to other negative emotions. Of interest was positive effect of Δ Disgust HR on TEI, indicating greater sympathetic activity/emotional reactivity to disgust. “Managing other’s w emotions” branch of EI specifically showed positive correlation with Δ Disgust HR. This may be due to the tendency of high trait EI individuals to confront adversity rather than escape them, they use problem-focused coping rather than avoidant coping strategies. (Goldenberg et al., 2006) (Zeidner & Kloda, 2013)

4.1. Limitations
Several limitations can be taken into account, one of them being the sample, which is from a specific population (students in IIT Kharagpur). Cultural and age-related restriction may limit the generalizability of our findings. To develop a predictive model of EI more work needs to be conducted with additional measures for explicit ER, ERQ (Emotion regulation questionnaire) score, social intelligence, in depth analysis of emotion intensity changes to find out the starting point of
ER processes, whether it is right in the beginning of an emotional situation, or does it occur after a certain threshold of emotional intensity or arousal has been attained. Cardiac vagal reactivity is one of the many autonomic responses arising from a variety of sympathetic and parasympathetic interactions, and the association between this variable and EI does not necessarily imply causation or inform about underlying mediating processes.

4.2. Conclusion

In summary, the present study examined the relationship between individual differences in cardiac autonomic response and reactivity to different emotion elicitations. All the emotions resulted in a significant increase in HR, and either an increase or decrease in HRV suggesting varying interactions between sympathetic and parasympathetic activity in emotional state. Higher trait emotional intelligence was associated with lower emotional reactivity, and higher vagally mediated heart rate variability at rest, indicating greater autonomic flexibility and emotion regulation capacity. Lower emotional reactivity and higher ER capacity indicated by HRV predicted higher trait emotional intelligence. Future work can be conducted on a larger sample and by using other channels of information like thermal imaging, GSR etc. These findings will help develop a model in future which can be used to predict an individual’s EI ability on the basis of their ER and arousal and social intelligence. Brain, 126(8), 1790–1800. https://doi.org/10.1093/brain/awg177

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