ABSTRACT:
Drawing on psycho-physiological research emphasizing the importance of facilitating the emotion-cognition or heart-brain interaction through self-regulation techniques, the present study aimed at investigating the efficacy of heart rate variability (HRV) on heart-brain coherence through self-regulation techniques suggested by Institute of HeartMath. Sixty-three Iranian university students and high school students participated in this study. The TestEdge program was used to enable students to self-generate an optimal psycho-physiological state in order to increase HRV measures and heart-brain coherence. Running paired samples t-tests and Wilcoxon Signed Ranks tests, the results confirmed that the application of IHM self-regulation techniques significantly reduced the subjects’ low coherence ratio but increased the mid and high coherence ratio on the posttest than the pretest among subjects. Moreover, the subjects had a lower heart rate on the posttest than the pretest. These results indicated that utilizing IHM self-regulation techniques increased heart-brain coherence ratio.

Key words: Biofeedback; Heart-Brain Coherence; Heart-Rate Variability; Self-Regulation Techniques; TestEdge Program

1. INTRODUCTION
Historically, heart was referred to as the center of wisdom and emotion by divine religions and some philosophers such as Aristotle and Avicenna. Furthermore, earlier studies (Cannon, 1927; Lacey & Lacey, 1978) in addition to more recent MRI neuro-imaging findings provide evidence that the heart transmits complex patterns of neurological, hormonal, and electromagnetic information to the brain (Ardell, 1994; Armour, 2007; Armour & Ardell, 2004; Armour & Kember, 2004; McCraty, 2003a & b, 2004, 2005, 2011; McCraty & Rees, 2009; Thayer & Lane, 2009). The heart’s electromagnetic field influences the heart rate variability (HRV) and the brain of others “at a distance of 5 feet” (McCraty, 2004, p. 11) which signifies the effect of teachers in the class. McCraty (2003b) defines HRV as “naturally-occurring beat-to-beat changes in heart rate, which is reflective of heart-brain interactions and autonomic nervous system dynamics” (p. 2) due to
changes in our emotional states (McCraty, Atkinson, Tiller, Rein,& Watkins,1995). Therefore, the analysis of HRV is one of the most valuable tools in examining the interactions between heart and brain or heart-brain coherence.

### 2. Review of the related literature

#### 2.1. Emotional factors in learning

Coleman (2008) defines Emotional Intelligence as the ability to monitor and use emotional information. Suggested by Gould, Cameron, Daniels, Woolley, and McEwen (1992), negative emotions cause reduction in cell proliferation in subgranular zone (SGZ) of the dentate gyrus in the hippocampus while antidepressant treatments increase it. In 2001 Shors and her colleagues found some potential roles for the SGZ in cognitive development. Research in the new discipline of neurocardiology has confirmed that the heart acts as a sophisticated information encoding and processing center (Armour & Ardell, 2004) which is particularly sensitive to changes in emotional states (Tiller, McCraty, & Atkinson, 1996). Stressful situations increase HRV and decrease the function of corpus callosum and cerebral cortex (Wolpow, Johnson, Hertel, & Kincaid, 2011) which leads to heart-brain incoherence and deficiency in learning.

#### 2.2. Theoretical basis of heart-brain interaction

From the social cognitive learning theory (Bandura, 1986), much of human learning occurs in a social environment; learners have an ability to influence their own self-beliefs which can affect their learning (Bandura, 2001). Learners are active participants in learning (Dornyei, 2005) and move from other regulation to self-regulation to control their learning (Lantolf, 2006). This is in accordance with research in psychophysiology and neurobiology which show that learning emotional regulation techniques significantly enhances attention, memory, comprehension, and reasoning (Bradley, et al., 2009; Schore, 1994).

Many researchers (e.g. Erbe, 2007; Joseph, 2010; Stober, 2004; Laskey & Hetzel, 2010) suggest different self-regulation strategies like positive thinking, relaxation, self-assessment, think aloud, and reciprocal teaching. Wolpow, et al. (2011) presents a six-category self-care plan (pp. 58-59) to prevent the negative consequences of bad feelings. Furthermore, it has been shown that heart plays a critical role in regulating the autonomic nervous system and affecting our emotional experience (Armour, 2007; Bradley, McCraty, Atkinson, Arguelles, & Rees, 2007; Bradley, et al. 2009; Bradley, et al., 2010; Childre, & Rozman, 2005; Kim, 2011). By biofeedback training, one learns to control heart rate or other physical or mental processes (McCraty, 2001). Based on research on psychophysiology of emotions and heart–brain coherence (Arguelles, McCraty, & Rees, 2003; McCraty, 2005; McCraty, Atkinson, Tomasino, & Bradley, 2009; Tiller, et al., 1996), the Institute of HeartMath (IHM) has developed some tools and techniques focusing on heart intuition (perceive information outside our consciousness, Pearsall, 1999) and heart intelligence (respond to emotionally relevant information, McCraty & Rees, 2009) that teach students skills to self-regulate stress and other emotional learning impediments (Arguelles et al., 2003; Bradley et al., 2007; McCraty, 2005).

Presenting electrophysiological evidence of heart intuition, McCraty et al. (2004) found we can intentionally experience certain positive feelings to advantageously affect our heart rhythm which is an important indicator of one’s capacity to adapt effectively to environmental demands. Dalton (2013) mentions a variety of HRV applications such as regulating autonomic nervous system, synchronizing brain alpha rhythms with the heart, and cognitive development. Assessing HRV is a useful measurement of psychophysiological coherence in which the autonomic nervous system, cardiovascular, hormonal, and immune systems are working efficiently and harmoniously. HRV patterns are more ordered during positive emotional states while negative feelings cause irregular HRV pattern indicating that the signals produced by the two branches of the autonomic...
nervous system are out of sync with each other (Childre & Rozman, 2005; McCraty, 2001, 2005, 2011; Reich, 2009).

2.3. Neurological basis of heart-brain interaction
Neurologists discovered that the “rhythmic beating patterns of the heart are transformed into neural impulses that directly affect the electrical activity of the higher brain centers” (Childre & Martin, 1999, p. 11). They discovered a neural pathway whereby input from the heart to the brain could either inhibit or facilitate the brain’s electrical activity.

This interrelationship is explained based on field theory and holographic principles by Laszlo (1995, p. 100) and also by Kafatos and Nadeau (1990, p. 185) applying systems theory. Based on holographic principles, intuitive perception accesses a field of energy into which information about future events is spectrally enfolded. One method of measuring the neurological heart-brain interaction is analyzing HRV from electrocardiograms. The normal HRV is due to the synergistic action of the two autonomic nervous system branches. Comprised of the TestEdge program and emWave technology, the IHM goal is training to monitor heart rhythms in order to achieve low levels of stress and better performance. Focusing on positive emotions is the first intervention to increase heart-brain coherence by self-regulation techniques such as Cut-Thru (Childre & Rozman, 2002), Freeze-Frame, Heart Lock-In (McCraty & Childre, 2003), and Neutral Tool (Childre & Rozman, 2005). A software program, emWave Desktop, collects and translates HRV data into graphics to show if physical, cognitive, and emotional systems are in sync or not.

3. The study
The primary goal of the present study was to investigate the relationship between IHM self-regulation techniques and heart-brain coherence. The following question was addressed:

1. Is there any significant relationship between students’ HRV and their use of IHM self-regulation techniques?

4. METHODOLOGY
4.1. Participants
The participants were chosen from seven intact classes among 43 Iranian university students (male and female) and 20 female high school students.

4.2. Instruments
The following instruments were used: 1) The Student Activity Guide (Novosel, 2012) to present the understanding of treatment, 2) an adapted form of the Self-Care Checklist (Wolpow, et al., 2011) to deal with anxiety, 3) IHM self-regulation techniques to facilitate managing emotions and pay attention to the area of the heart with an intentional positive emotion in order to change afferent cardiac input pattern sent to the brain, and 4) an emWave Desktop device to record the participants’ HRV.

4.3. Procedure
Delivering instruction was according to the following stages: pretest, describe, model, advanced practice and feedback, posttest, and generalization (Ellis, Deshler, Lenz, Schumaker, & Clark, 1991). The main behavioral objective was to enable students how to recognize their emotions and try to be released from negative emotions to achieve more heart-brain coherence. A 180-minute adapted lesson plan was used (Novosel, 2012). At first, using the Student Activity Guide, the key words and concepts were defined. Then, for dealing with anxiety, the strategies of Self-Care Checklist were introduced. Next, the steps of IHM self-regulation techniques were provided. These techniques are involved in 1) breathing slowly and calmly, 2) recognizing stressful feeling, 3) shifting the focus away from mind and focus for at least 10 seconds on the area around the heart while breathing normally, 4) recalling a positive feeling or thing to neutralize any stress, and 5) using intuition to listen to the heart (Childre, 1998; Reich, 2009) to recognize and reprogram their subconscious emotional memory pathways and bring the solar plexus and heart into alignment. This synchronizes the brain and heart and increase internal coherence (Childre &
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Rozman, 2002). All was carried out via interactive modeling of the techniques.

To measure HRV, a pulse sensor plugged into USB of a computer was clipped to the earlobe of each student to collect and translate HRV patterns into graphics. The more coherence was achieved, the smoother and more wavelike heart rhythm patterns became. Furthermore, a tri-colored bar graph indicated the degree of attained coherence: low, medium, and high coherence.

To determine participants’ heart-brain coherence, coherence level ratio and average heart rate of participants were measured before and after treatment.

4.4. Materials

Reading materials were selected from passages of Mosaic1 (Wehmann & Knezevic, 2008). In order to have same grade reading difficulty of pre- and posttest passages, Fry Graph Readability Formula (1968) was used to provide the measure of the readability.

4.5. Data gathering

To depict electrophysiological coherence scores, the participants were seated about four to five feet apart from the researcher in order to minimize the possibility of HRV interference from one heart to another. The data were stored in a data-storage of emWave Desktop.

4.6. Design

The design of the present study was one comparison group pre/posttest design (Best & Kahn, 2006). The between-subject factors were coherence level ratio and average heart rate. Self-regulation techniques were considered as independent variables and HRV was considered as dependent variable.

5. Data analysis and results

The data were analyzed using both parametric (paired-samples t-test) and non-parametric tests (Wilcoxon Signed Ranks Test). The first research question was decomposed into four minor questions because the heart rate variable was measured on a nominal scale while the coherence level ratios were percentages. Moreover, the high, mid and low coherence level ratio could not be compared using a single analysis due to the fact that their total sum was 100. The normality of the data was checked. As displayed in Table 1, the ratios of skewness and kurtosis over their respective standard errors were all within the ranges of +/- 1.96 except for the pretest of high coherence ratio. That is why the third minor null hypothesis was analyzed using non-parametric Wilcoxon test.

| Table 1. Testing Normality Assumption

<table>
<thead>
<tr>
<th>N</th>
<th>Skewness Statistic</th>
<th>Std. Error</th>
<th>Ratio</th>
<th>Kurtosis Statistic</th>
<th>Std. Error</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreLowCoh 63</td>
<td>-.402</td>
<td>.302</td>
<td>-1.33</td>
<td>.352</td>
<td>.595</td>
<td>0.59</td>
</tr>
<tr>
<td>PreMidCoh 63</td>
<td>-.403</td>
<td>.302</td>
<td>-1.33</td>
<td>.080</td>
<td>.595</td>
<td>0.13</td>
</tr>
<tr>
<td>PreHighCoh 63</td>
<td>1.663</td>
<td>.302</td>
<td>5.51</td>
<td>4.043</td>
<td>.595</td>
<td>6.79</td>
</tr>
<tr>
<td>PostLowCoh 63</td>
<td>-.156</td>
<td>.302</td>
<td>-0.52</td>
<td>-.862</td>
<td>.595</td>
<td>-1.45</td>
</tr>
<tr>
<td>PostMidCoh 63</td>
<td>.486</td>
<td>.302</td>
<td>1.61</td>
<td>.874</td>
<td>.595</td>
<td>1.47</td>
</tr>
<tr>
<td>PostHighCoh 63</td>
<td>.460</td>
<td>.302</td>
<td>1.52</td>
<td>-.516</td>
<td>.595</td>
<td>-0.87</td>
</tr>
</tbody>
</table>

Note. Pre = pretest, Post = posttest and Coh = coherence ratio

5.1.1 Minor null-hypothesis 1-1

A paired samples t-test was run to compare the subjects’ low coherence ratio during the pretest and posttest. According to the results displayed in Table 2, the subjects had a lower low coherence ratio (M_{posttest} = 66.40, SD = 12.13) after treatment compared with the pretest (M_{pretest} = 82.71, SD = 7.39).
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Table 2. Paired Samples Statistics; Pretest and Posttest of Low Coherence Ratio

<table>
<thead>
<tr>
<th>Low Coherence</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>82.71</td>
<td>63</td>
<td>7.391</td>
<td>.931</td>
</tr>
<tr>
<td>Posttest</td>
<td>66.40</td>
<td>63</td>
<td>12.130</td>
<td>1.528</td>
</tr>
</tbody>
</table>

Table 3. Paired Samples Statistics; Pretest and Posttest of Low Coherence Ratio

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T</td>
</tr>
</tbody>
</table>

5.1.2 Minor null-hypothesis 1-2

To compare the subjects’ mid coherence ratio during the pretest and posttest, a paired samples t-test was run. Based on the results displayed in Table 4, after receiving IHM self-regulation techniques, they had a higher mid coherence ratio (M<sub>posttest</sub> = 16.48, SD = 5.66) compared with pretest (M<sub>pretest</sub> = 11.90, SD = 4.42).

Table 4. Paired Samples Statistics; Pretest and Posttest of Mid Coherence Ratio

<table>
<thead>
<tr>
<th>Mid Coherence</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>11.90</td>
<td>63</td>
<td>4.420</td>
<td>.557</td>
</tr>
<tr>
<td>Posttest</td>
<td>16.48</td>
<td>63</td>
<td>5.665</td>
<td>.714</td>
</tr>
</tbody>
</table>

The results of paired-samples t-test (t (62) = 8.75, p = .000, r = .532 representing a large effect size) indicated that the subjects had a significantly higher mid coherence ratio on the posttest. Thus, the minor null-hypothesis 1-2 was rejected. The application of IHM self-regulation techniques increased the mid coherence ratio significantly.
Table 5. Paired Samples Statistics; Pretest and Posttest of Mid Coherence Ratio

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>T</th>
<th>Df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.571</td>
<td>7.321</td>
<td>.922</td>
<td>-6.415 - 2.728</td>
<td>-4.956</td>
<td>62</td>
<td>.000</td>
</tr>
</tbody>
</table>

Figure 2: Means on Pretest and Posttest of Mid Coherence Ratio

5.1.3 Minor null-hypothesis 1-3

Based on the results of Wilcoxon Signed Ranks Test run on the subjects’ high coherence ratio (Table 6), the difference between pre and posttest had a higher positive mean rank (MR = 32.34). In other words, the subjects showed a higher high coherence ratio on the posttest than the pretest.

Table 6. Mean and Sum of Ranks; Pretest and Posttest of High Coherence Ratio

<table>
<thead>
<tr>
<th>PostHighCoh – PreHighCoh</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative Ranks</td>
<td>5</td>
<td>16.00</td>
<td>80.00</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>56</td>
<td>32.34</td>
<td>1811.00</td>
</tr>
<tr>
<td>Ties</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on the results of the Wilcoxon test (Z = -6.219, p = .000, r = .858 indicating a large effect size), there was a significant difference between pre and posttest of high coherence ratio and subjects had a higher mean rank on posttest. Thus, the minor null-hypothesis 1-3 was rejected.

Table 7. Wilcoxon Signed Rank Test Statistics

<table>
<thead>
<tr>
<th></th>
<th>Z</th>
<th>Asymp. Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PostHighCoh – PreHighCoh</td>
<td>-6.219b</td>
<td>.000</td>
</tr>
</tbody>
</table>

Figure 3: Mean Ranks; Pretest and Posttest High Coherence Ratio

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5.1.4 Minor null-hypothesis 1-4
A Wilcoxon Signed Ranks Test was run to compare the subjects’ average heart rate during the pretest and posttest. Based on the results displayed in Table 8 and Table 9, the subjects had a higher average heart rate on the pretest, i.e. the difference between pretest and posttest had a higher positive mean rank (MR = 35.79). It means there was a lower average heart rate of the subjects on the posttest than pretest.

Table 8. Mean and Sum of Ranks; Pretest and Posttest of Heart Ratio

<table>
<thead>
<tr>
<th>PreAvHR – PostAvHR</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative Ranks</td>
<td>13</td>
<td>13.31</td>
<td>173.00</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>48</td>
<td>35.79</td>
<td>1718.00</td>
</tr>
<tr>
<td>Ties</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. PreAvHR < PostAvHR
b. PreAvHR > PostAvHR
c. PreAvHR = PostAvHR

The results of the Wilcoxon test (Z = -5.55, p = .000, r = .766 representing a large effect size) and a lower mean rank on posttest indicated that there was a significant difference between the subjects’ heart rate on pretest and posttest. Thus the minor null-hypothesis 1-4 was rejected.

Table 9. Wilcoxon Signed Rank Test Statistics

<table>
<thead>
<tr>
<th></th>
<th>PostHighCoh – PreHighCoh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>-5.551b</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks

Figure 4: Mean Ranks; Pretest and Posttest Average Heart Rate

6. DISCUSSION
Regarding the research question which decomposed into four minor research questions, the results of paired-samples t-tests and Wilcoxon Signed Ranks Test indicated that the application of IHM self-regulation techniques reduced the subjects’ low coherence ratio significantly but it increased the mid and high coherence ratio significantly among subjects on average. Moreover, there was a significant difference between the subject’s heart rate on pretest and posttest. They had a lower mean rank on posttest. As it mentioned before, heart rhythm coherence biofeedback has been used in various educational settings with excellent results. For instance, McCraty et al. (1999) found that at-risk middle school children who were taught emotional self-management skills exhibited significant improvements in areas including stress and management, risky behavior, work management and focus, and relationships with teachers, family and peers. Segerstrom and Nes (2007) argue that
HRV is a kind of parasympathetic control over the heart and “more parasympathetic input results in more variable intervals between heart beats, that is, higher HRV” (p. 275). They conclude that HRV measures could be a likely candidate to index self-regulatory capacity and activity because brain structures involved in self-regulation and those involved in autonomic nervous system regulation overlap considerably, particularly with regard to the prefrontal cortex. The results of their study confirmed the case; subjects making a higher level of self-regulatory effort had higher HRV measures than subjects with lower self-regulatory effort (Segerstrom & Nes, 2007). In a study involving 60 sixth through eighth grade students, Arguelles et al. (2003) found increased stress resiliency in the training group who had practiced IHM regulation techniques in comparison to the control group that did not learn the technique (p. 19). Findings have been shown to correlate directly with improvement in cognitive performance, increased attention and focus, improved emotional competence and classroom behaviors, and reduced perception of stress (McCraty et al., 2009; Tiller, McCraty, & Atkinson, 1996).

Moreover, according to Fabes and Eisenberg (1997, cited in Appelhans & Leucken, 2006), higher levels of resting respiratory sinus arrhythmia have been associated with greater self-reported emotion regulation and the use of constructive coping strategies in university students. They found that those with lower resting respiratory sinus arrhythmia experienced greater negative emotional arousal in response to stress, which interfered with their ability to implement adaptive regulative strategies. Other investigation, in a similar vein, revealed that HeartMath’s programs are effective in improving HRV and emotional stability (Arguelles et al., 2003; Bradley et al., 2007; Bradley et al., 2009; Bradley et al., 2010; Lloyd, Brett, & Wesnes, 2010; McCraty, 2003b, 2005, 2011; McCraty et al., 1999). The result of the present study is totally in line with the results of these studies.

7. CONCLUSION
The new understanding of the physiology of positive emotions and the key role played by the heart in the generation of emotional experience have exciting implications for higher-order thinking skills, learner readiness, decision making, and test-taking, as well as for social and emotional behavior. Accordingly, practical tools have been developed that enable students to self-regulate the physiological processes underlying effective learning and performance. The most obvious conclusion which can be drawn from the above mentioned studies and this study is that all have generally supported the premise that higher HRV measures reflect a greater capacity for regulated emotional responses.

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34. No. ED511589.)


