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The Effects of Heart Rate Variability on Reading Performance among Iranian EFL Learners

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Abstract

Psychophysiological studies and MRI neuro-imaging findings provide evidence that heart rate variability (HRV) which is in control of our emotions affects our brain cognitive centers. It has been shown that coherent heart-brain interaction can change the pattern of the afferent cardiac input that is sent to the brain. For this purpose, the Institute of HeartMath (IHM) has proposed a kind of biofeedback training, the TestEdge program, which self-regulates negative emotional learning impediments by increasing HRV measures. It leads to an optimal self-generated psychophysiological state that has an important role in cognitive development through autonomic nervous system dynamics. In the present study, through using IHM self-regulated techniques and tools, the TestEdge program was performed on 63 Iranian EFL learners. In particular, the main purpose of this study was to investigate the effects of HRV measures on reading comprehension performance. The data was measured and recorded by emWave Desktop device. The results confirmed that the intentional heart-focus techniques led to a beneficial mode of psychophysiological coherence of heart-brain interaction. The results indicated significant differences among EFL students with different levels of high, mid, and low coherence and their reading performance.

Keywords: biofeedback training, heart-brain coherence, heart-rate variability (HRV), reading performance, TestEdge program

Introduction

Our emotions and cognitive factors reciprocally influence each other. Neurophysiologists have found a mechanism and a neural path whereby input sent from the heart to the brain can facilitate or inhibit the brain's electrical activity which in return has an influential effect on our cognitive centers (Ardel, 1994; Armour, 2007; Armour & Ardell, 2004; Armour & Kember, 2004; Goleman, 1995; McCraty, Atkinson, & Tomasino, 2001). HeartMath researchers have discovered that the heart plays a crucial role in the processing and decoding of our emotionally intuitive information (McCraty, Atkinson, & Bradley, 2004) that is not limited by the boundaries of time and space (McCraty & Rees, 2009).

The recent studies based on psychophysiological theory that explains emotional, behavioral, and cognitive processes, in addition to physical systems dealing with learning have documented that changes in heart rate or HRV measures are reflective of the interactions occurred between heart and brain (Bradley et al., 2010; Lloyd, Brett, & Wesnes, 2010; Thayer & Lane, 2000; Thayer & Lane, 2009). As HRV indices are associated with prefrontal cortical activity and have a direct connection to emotions, and since emotions directly affect cognitive function, then intentional and purposeful increase of related HRV measures through the HeartMath program could increase cognitive function and academic performances (McCraty, 2003)

Emotional intelligence has been defined as the ability to discriminate and monitor our own and other people's feelings or emotions by using emotional information to guide thinking and behavior (Colman, 2015). It has been revealed that learning disability frequently co-occurs with emotional problems (Coleman & Vaughn, 2000; Goleman, 1995; Nelson, Benner, & Rogers-Adkinson, 2003). Therefore, a better understanding of heart and emotion can help educators facilitate learning.

The heart electrical signal can be measured on any part of the body using electrodes that monitor the electrocardiogram (ECG) signal. Neurophysiologists have shown that there are interactions among heart, brain and autonomic nervous system dynamics. This means that cognitive function could be increased through high measured of HRV. Therefore, one of the most reliable and valid research tools in examining the degree of heart-brain coherence might be the analysis of HRV. These changes are due to changes in emotional states (McCraty, Atkinson, Tiller, Rein, & Watkins, 1995; McCraty, Atkinson, Tomasino, Goelitz, & Mayrovitz, 1999). As it is illustrated in Figure 1, the circuits in the amygdala organize our familiar emotions, whether they are coherent or incoherent. However, if feedback patterns which are generated by the heart and control systems of blood pressure are incoherent and disordered, disharmony is expected as familiar, which will have effects on learning.

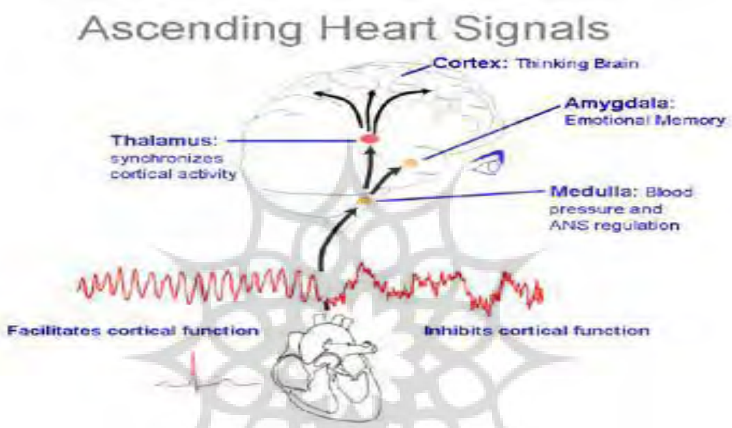

Figure 1. Ascending Heart Signals (Bradley et al., 2007, p. 21)

In order to manage emotion by conscious mental control, making involuntary or subconscious bodily processes as brain waves or heartbeat, called biofeedback training (McCraty et al., 2001), can provide the individual with a quantifiable indicator of their emotional status. One can learn to control the heart rate by using information from its recordings to manipulate it by conscious mental management and control. One emotional learning intervention is the TestEdge program provided by the HeartMath Institute (Bradley et al., 2007). This program consists of some techniques and tools that explain and teach how to focus on our positive emotions and feelings to self-regulate emotional impediments to increase HRV that eventually enhance learning and performance.

Self-regulated learning has been defined by Zimmerman (1989) as “the degree to which students are metacognitively, motivationally, and behaviorally active participants in their own learning” (p. 329) with a reciprocal causation among behavioral, personal, and environmental processes. Bandura (2001) assumes people have a capability or agency to affect their own behavior and also the environment purposefully. Expert learners develop self-regulated learning strategies to evaluate their level of understanding to enhance academic outcomes and monitor their performance (Wolters, 2011; Zimmerman, 1989, 2008).

Recently the integration of emotional self-regulation skills training programs has become an increased priority in education. It has been found that heart plays a crucial role in controlling and adjusting the autonomic nervous system. It is also influential in affecting the emotional experience. In fact, self-regulated strategies are influential in bringing heart and brain into coherence. These strategies could be implemented in education through some programs such as TestEdge (Armour, 2007; Bradley, Atkinson, Tomasino, Rees, & Galvin, 2009; Bradley et al., 2007; Bradley et al., 2010; Brantmeier, 2005; Kim, 2011; Lloyd, Brett, & Wesnes, 2010). There are many tools and techniques such as TestEdge program that individuals can use in their own process of self-development. Confirmed by psychophysiological research on emotions and heart–brain coherence (Arguelles, McCraty, & Rees, 2003; McCraty, 2005; McCraty, Atkinson, Tomasino, & Bradley, 2009), these programs teach students emotional self-regulation techniques which are effective in improving emotional stability and academic performance.

The purpose of this study was to investigate whether IHM self-regulation techniques were influential in monitoring emotions to give rise to students' HRV measures and heart- brain coherence. The study also investigated the effects of HRV measures on reading comprehension performance in particular. The premise of this study was that cognitive factors and emotions reciprocally influence each other negatively and positively (Goleman, 1995). This study drew on psychophysiological research that emphasizes the significance of facilitating the heart-brain or emotion-cognition connection through psychophysiological techniques. It was intended to investigate the relationship between students' psychophysiological coherence gained through biofeedback training with reading comprehension performance through HeartMath techniques and tools. The following questions were addressed to fulfill the purpose of this study.

RQ1: Does biofeedback training have any effect on HRV?
RQ2: Does HRV affect reading comprehension performance of Iranian EFL learners?

Method

Participants

The research participants were both male and female students ranging in age from 16 to 25. They were 63 Iranian EFL students who were selected from six intact classes among Iranian EFL high school and university students.

Instruments

The passages of *Mosaic1*were selected as reading materials (Wegmann & Knezevic, 2008). In order to determine the reading difficulty level of the content of passages of pretest and posttests, Fry Graph Readability Formula (Fry, 1968) was done to indicate the amount of the readability of passages. The same grade reading level difficulty was found on the Fry Readability Graph. Before and after the treatment, the degree of psychophysiological coherence and heart-brain interactions as well as the participants' reading performance were examined through the administration of the following instruments:

1) The Student Activity Guide (Novosel, 2012): It was used to provide the perception and understanding of treatment. The main purpose of treatment was teaching students to be familiar with their positive or negative emotions experienced in their life. By knowing their feelings and through using self-regulated techniques they were able to manage and control their feelings during different activities.

2) An adapted form of the Self-Care Checklist (Wolpow, Johnson, Hertel, & Kincaid, 2009): Self care refers to any intentional activity that we do in order to take care of our physical, mental and emotional health. Good Self care is a human requisite, a professional necessity, and an ethical imperative to deal with our anxiety and lower it to improve our mood. The main purpose of all is to help them.

3) IHM self-regulation techniques: techniques like Freeze-Frame and Heart Lock-In (McCraty & Childre, 2003), Neutral Tool (Childre & Rozman, 2005) and Cut-Thru (Childre & Rozman, 2002) were used to make

changes in the patterns of afferent cardiac input that is sent to the brain through managing emotions and focusing on heart.

4) A software emWave Desktop instrument was employed to record the participants' HRV and their level of coherence.

5) Some pre and post reading comprehension tests including multiple measures of reading comprehension: Test of Silent Word Reading Fluency – TOSWRF (Mather, Hammill, Allen, & Roberts, 2004) and Test of Silent Contextual Reading Fluency – TOSCRF (Hammill, Wiederholt, & Allen, 2006) were administered to measure the participants' reading performance.

After the treatment, each participant's proficiency level was compared with their own level not with others; therefore, homogeneity or reading proficiency level was not considered as a variable in this study.

Procedure

Based on Novosel (2012), an adapted 180-minute lesson plan was used to accomplish the main behavioral objective of this study. It helped the students how to identify and control their emotions to achieve high psychophysiological coherence. At first, the Student Activity Guide (Novosel, 2012) was used to explain different kinds of positive and negative emotions with high or low energy. It was explained that these emotions can get in the way of performing or affect our behavior. This explanation was essential in providing the definitions of key words and new concepts requisite to understanding the treatment. They were asked to think of the range of emotions they experienced during the week and write down at least two emotions with high/low energy negative emotions followed by writing down high/low energy positive emotions.

Then, the Self-Care Checklist strategies were introduced to make the participants become aware of how to deal with their negative feelings. The participants were told that this checklist and its suggestions might require adaptation to their own situation and preferences. They were asked to take what they like, and leave the rest. After that, different IHM self-regulation techniques were used to facilitate effectively the skills required in managing the emotional impediments in learning and performance. These techniques were designed to utilize a shift in the focus of attention to the heart with an intentional self induction of a positive and favorable emotional feeling resulting in an alteration in the pattern of afferent cardiac input that is being sent to the emotional and cognitive areas of the brain. Combining this coherent pattern with an intentionally generated feeling of appreciation reinforces an inherent response between our body's physiology and a positive emotion. Therefore, the IHM self-regulation techniques were practiced step by step. They are entangled with 1) Neutral Tool (Childre & Rozman, 2005), which is a kind of stress-relief technique applied to help students how to reduce their tension, anxiety, and worry to make better decisions, 2) Freeze-Frame defined by Reich (2009) as a "self-management technique where individuals focus on their heart and re-experience a feeling of compassion that allows individuals to disengage from disruptive mental or emotional states" (p. 55), 3) shifting away the focus from mind to the area around the heart for at least 10 seconds while they are breathing normally, 4) bringing the memory of a positive thing or feeling into their mind to neutralize any anxiety, and 5) listening to their heart based on heart intuition to identify and reprogram the subconscious emotional memory pathways to increase coherence (Childre & Rozman, 2002). All were performed by guided practice, group practice, and interactive modeling of these techniques.

Collecting HRV patterns and the data of each participant individually and then translating them into graphics were the next steps done by the emWave desktop software. This system has powerful tools such as the Power Spectrum for measuring sympathetic and parasympathetic activities of the autonomic nervous system in addition to the power of the waves. The Desktop system enables us to save and recall past sessions for different users. HRV waveforms are acquired with the use of a sensor placed on either the left or right earlobe. Using this sensor, the researchers collected each participant's heart rate variability data and translated them into graphics. This device was also plugged into the USB port connected to the computer to show graphics on the screen. The more coherence was achieved, the smoother and more regular heart rhythm patterns became. Three colored (green, blue, and red) bar graphs (Figure 2) showed the degree of attained coherence: high, medium, and low coherence.

Figure 2. Heart Rate Variability Monitor

Figure 3. The USB Port

Figure 4. Earlobe Pulse Sensor

To measure the probable effects of HRV on reading performance, a validated reading comprehension test based on TOSWRF and TOSCRF was administered before and after the treatment. The TOSWRF measures a learner's reading skill level by scoring the number of printed words that he or she can identify in three minutes. Generally, students are presented with rows of words with no spaces appear between words. They were ordered by reading difficulty as determined by a leveled word frequency list. TOSCRF was exactly the same with the only difference in recognizing printed sentences instead of words during five minutes. Validity studies on these two tests, according to Novosel (2012), provide evidence that they are reliable and valid instruments for screening students to determine their general reading ability or find reading difficulties.

Design

The design of this study was quasi-experimental, since random selection was not possible for the researcher. It was the One-Group Pretest-Posttest Design in which, in the same setting, a defined group of individuals served as their own control group. Measurements were made on them before and after the implementation of a treatment. There was no comparison between this group and a control group. The effects of the treatment were judged by the difference between the pretest and posttest measurements. Wilcoxon Signed Ranks nonparametric test and path model analysis were conducted to examine the pre- and posttest differences between the participants. The between-subject factors included performance on the these measures: (a) electrophysiological assessment of HRV and coherence level ratio, (b) reading comprehension test including TOSWRF, TOSCRF, and reading comprehension passage.

The variables of this study were as follows: Self-regulation techniques and heart-brain coherence were the independent variables and HRV measures and reading performance were the dependent variables.

Results

Testing the first null hypothesis

Running Wilcoxon Signed Ranks Test on the subjects' high coherence ratio (Table 1), the results indicated that the participants' high coherence ratio on the posttest was higher in comparison with the pretest (MR = 32.35).

Table 1
Mean and Sum of Ranks: High Coherence Ratio of Pretest and Posttest

		N	Mean Rank	Sum of Ranks
PostHC – PreHC	Negative Ranks	5[a]	16.01	80.00
	Positive Ranks	56[b]	32.35	1812.00
	Ties	2[c]		
	Total	63		

a. PosttestHighCoh < PretestHighCoh
b. PosttestHighCoh > PretestHighCoh
c. PosttestHighCoh = PretestHighCoh

Furthermore, a significant difference was found between the pretest and posttest of high coherence ratio and the students' mean rank on the posttest was higher (p=.000, Z= -6.21, r= .858), showing a large effect size (Table 2).

Table 2
Wilcoxon Signed Rank Test Statistics[a]

	PostHC – PreHC
Z	-6.219[b]
Asymp. Sig. (2-tailed)	.000

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

Based on the results in Table 2, the first null-hypothesis was rejected. Figure 5 shows the significane of the difference more vividly.

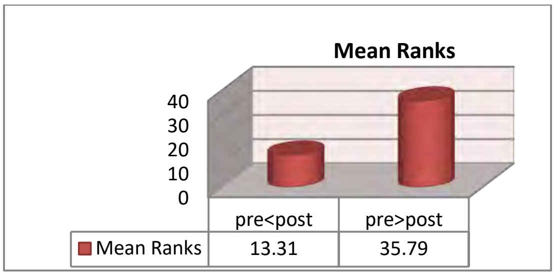

Figure 5. Pretest and Posttest High Coherence Ratio

Testing the second null hypothesis

Three separate path models were tested in order to find the effect of HCR on the participants' reading performance. The logic behind running path models was that the higher HCR, the higher the reading performance.

Path Model of Low Heart Coherence Ratio

Path Model 1 (Figure 6) displays the relationships between the pretest and posttest of low HCR and posttest of reading performance. The results indicated that:

A: If the posttest of low HCR increased by one full standard deviation (SD), the posttest of reading performance would decrease by .47 (p = .000) SD. That is to say the higher the low HCR, the lower reading performance.

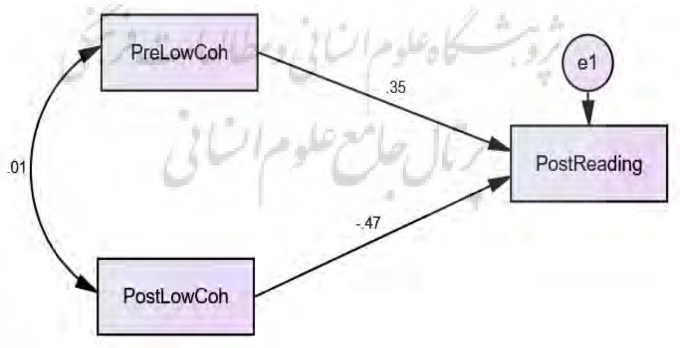

Figure 6. Path Model 1: The Effect of Low HCR on Reading Performance

B: The results shown in Table 3 also indicated that the pretest of low HCR had a significant effect on the posttest of reading performance (beta = .346, p = .000); if the pretest of low HCR increased by one full SD, the posttest of reading performance would increase by .346 SD.

Table 3
Unstandardized and Standardized Regression Weights; Low HCR on Posttest of Reading Performance

			Unstandardized Estimate	S.E.	C.R.	P	Standardized Estimate
PostReading	<---	PreLowCoh	.069	.021	3.345	.000	.346
PostReading	<---	PostLowCoh	-.057	.013	-4.535	.000	-.469

Path Model of Mid Heart Coherence Ratio

Additionally, it was hypothesized that the pretest of mid HCR correlated with the posttest of mid HCR, both of which in turn, affected the reading performance. Path Model 2 (Figure 7) indicated that:

A: If posttest of mid HCR increased by one full standard deviation (SD), the posttest of reading performance would increase by .30 (p = .010) SD (Table 4). That is to say the higher the posttest of mid HCR, the higher the reading performance.

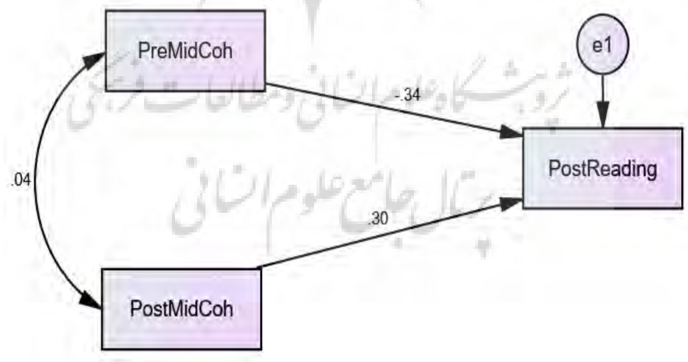

Figure 7. The Effect of Mid HCR on Reading Performance

B: The results also indicated that if pretest of mid HCR increased by one full SD, the posttest of reading performance would decrease by .337 SD. It means that the pretest of mid HCR had a significant effect on the posttest of reading performance (beta = -.337, p = .003).

Table 4
Unstandardized and Standardized Regression Weights; Mid HCR on Posttest of Reading Performance

			Unstandardized Estimate	S.E.	C.R.	P	Standardized Estimate
PostReading	<---	PreMidCoh	-.113	.038	-2.947	.003	-.337
PostReading	<---	PostMidCoh	.078	.030	2.588	.010	.296

Path Model of High Heart Coherence Ratio

Path Model 3 (Figure 8) displays the relationships between the pretest and posttest of high HCR and the posttest of reading performance. It was hypothesized that the high HCR on the pretest correlated with high HCR on the posttest, both of which in turn, affected reading performance. The results indicated that:

A: If the posttest of high HCR increased by one full standard deviation (SD), the posttest of reading performance would increase by .45 (p = .000) SD (Table 5). That is to say the higher the posttest of high HCR, the higher the reading achievement.

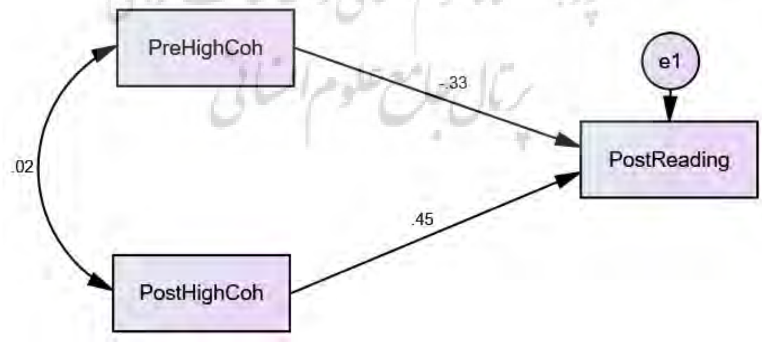

Figure 8. The Effect of High HCR on Reading Performance

Table 5
Unstandardized and Standardized Regression Weights; High HCR on Posttest of Reading Performance

			Unstandardized Estimate	S.E.	C.R.	P	Standardized Estimate
PostReading	<---	PreHighCoh	-.117	.037	-3.147	.002	-.333
PostReading	<---	PostHighCoh	.069	.016	4.249	.000	.450

B: The results in Table 5 also indicated that the pretest of high HCR had a significant effect on posttest of reading performance (beta = -.33, p = .002). That is if pretest of high HCR increased by one full SD, the posttest of reading performance would decrease by .33 SD (Table 5).

Discussion

This study was done as an attempt to explore the relationship between emotion and cognition and tried to determine the effects of heart rate variability on the reading comprehension performance of Iranian learners of English by anxiety reduction through the implementation of IHM self-regulation tools and techniques to increase the coherence between the heart and brain.

Regarding the first research question, the results illustrated that using of IHM self-regulation techniques made a significant increase on average in high coherence ratio among the participants. Moreover, based on the results summerized in Table 6, the low HCR had the lowest contribution to reading performance (beta = -.469, p = .000); the mid HCR had a positive effect on reading performance (beta = .296, p = .010); and finally, the high HCR had the highest effect on posttest of reading performance (beta = .450, p = .000). The results indicated that as the heart coherence ratio increased, the reading performance also increased significantly.

Table 6
Unstandardized and Standardized Regression Weights; Low, Mid and High HCR on Posttest of Reading Performance

			Unstandardized Estimate (b)	S.E.	C.R.	P	Standardized Estimate (beta)
PostReading	<---	PostLowCoh	-.057	.013	-4.535	.000	-.469
PostReading	<---	PostMidCoh	.078	.030	2.588	.010	.296
PostReading	<---	PostHighCoh	.069	.016	4.249	.000	.450

As it was mentioned before, the findings of the related research have shown that using HeartMath's programs has efficiency in improving HRV measures (Arguelles et al., 2003; Bradley et al., 2007; Bradley et al., 2009; Bradley et al., 2010; McCraty, 2003b, 2005, 2011; McCraty et al., 1999). The result of the present study is also in line with the results of these studies. A significant relationship between the students' HRV measures and the application of self-regulation techniques was found. In other words, there was a higher coherence ratio among the subjects after the treatment. This means that the regulated emotional responses are reflected by the higher HRV measures.

The second research question of this study aimed to examine the effects of HRV on the reading performance of English learners. The findings indicated that the path model for the low heart coherence ratio had the least or even negative contribution to the participants' reading comprehension performance while the high heart coherence ratio (HCR) had the highest positive effect on their reading comprehension.

In a similar vein, to find the relationship between emotion and cognition, McCraty (2002) investigated 30 healthy individuals. He studied the relationship between their cognitive performance and the synchronized function of their heart and brain or physiological coherence. The participants performed a discrimination task of oddball auditory before and after the treatment which was training the participants to practice an emotion refocusing technique to instill a favorable and positive emotional state in order to increase the level of psyco-physiological coherence. The heart rhythm coherence derived from the electrocardiograph (ECG), pulse transit time, respiration, and heartbeat evoked potentials of the participants were measured. The level of the heart rhythm coherence increased significantly among the participants during practicing emotion refocusing technique in comparison with baseline and a control group who performed merely a kind of relaxation practice. The findings indicated that ECG-alpha activity was synchronized to the cardiac cycle and that ECG-alpha synchronization significantly increased when heart rhythm coherence achieved to higher level. In turn, the participants' high heart rhythm coherence was associated with significant improvements in decreasing the reaction times (cognitive performance) while lack of ECG-alpha activity due to relaxation practice was not associated with better performance of doing the task.

The Institute of HeartMath has presented new insights into the connection between the cognitive processes and heart's activity. It has been found that psychophysiological coherence and the associated patterns of rhythmic activity of the heart have a significant effect on cognitive processes and intentional behavior (McCraty et al., 2009). McCarty et al. (2009) explain that neurological and cardiac afferent input pattern can either facilitate or inhibit cognitive processing beyond the well-evidential micro-rhythm of cortical facilitation or inhibition which is related with some changes in the heart rate. The results of their study show a significant relationship (r^2 = 0.21; p = 0.02) between the level of the heart rhythm coherence and task performance among all participants and different states. It is confirmed that, due to positive emotions, maintaining psychophysiological coherence prior to doing a task can cause improvements in some aspects of cognition like focused attention and discrimination. This kind of psychophysiological coherence eventually leads to the improvement and progress in cognitive performance. They state that the organization of the heart's rhythmic activity, and therefore, the input pattern of cardiac afferent nerved to the brain, can significantly facilitate or inhibit brain's cortical function. In accordance with the effect of negative emotional feelings on learning, Fabes and Eisenberg (1997, as cited in Appelhans and Luecken, 2006) explain that negative emotions in contrast with positive feelings interfere with the learning ability to implement adaptive coping strategies.

In line with this study, Arguelles et al. (2003) have found that teaching emotional self-regulation skills through utilizing HeartMath tools and techniques would increase HRV measures and boost learning and academic performance as well as emotional well-being improvement and classroom behaviors from the elementary school to the college level. In another study (McCraty et al., 1999), the findings showed that those at-risk school students who were trained to use emotional self-management techniques presented significant enhancements in areas like controlling the stress, managing the work and acting risky behavior. They were able to establish good relationships with family, teachers, and peers as well. Therefore, based on these results, it can be concluded that paying attention to emotional competence skills and learning about them may be helpful in establishing better psychological and physiological response patterns, which is beneficial in learning, behavior, and long-term health as well.

Moreover, in a study conducted by a group of IHM Institute researchers (McCraty, Tomasino, Atkinson, Aasen, & Thurik, 2000), the participant high school students who used HeartMath tools and self-regulated techniques which were designed to increase HRV, demonstrated 35% increase in their math scores and 14% average gain in the reading tests after only three weeks of the treatment. Additionally, the students' hostility, depression and other psychological anxiety decreased significantly. Again in another study, Brantmier (2005) found that anxious and stressful students who gained high scores on anxiety inventories remembered the content of the passage less than those participants who experienced least possible anxiety. Based on the results, highly anxious learners recalled fewer units. Thus, it was concluded reading anxiety could affect the number of important recalled units (Brantmeier, 2005). Similarly, In Bradley et al.'s (2010) study, done on 980 tenth grade students, using electrophysiological measures with controlled pre- and post-interventions, the analysis of the data provided evidence that reduced test anxiety and increased psychophysiological coherence were directly associated with improved test performance. They found that although there was no significant difference between the students' reading comprehension performance and different levels of language anxiety or reading anxiety, a general trend of low level of anxiety going with higher performance was identified. Lloyld, et al. (2010) also conducted a study on children with Attention-Deficit Hyperactivity Disorder (ADHD) and evaluated for cognitive functioning as the primary outcome measure, following a coherence training program in self-regulation skills using HeartMath tools. The participants' improvements were significant in different aspects of cognitive functions such as immediate word recognition, word recall, delayed word recall, and episodic secondary memory.

In respect to the efficacy of HRV coherence ratio in anxiety reduction, Dalton (2013) found a conclusive relationship between the HRV and ITBS achievement test scores in reading, but there was not a great practical direct relationship between HRV measures and academic achievement test scores among the elementary school students (Dalton, 2013). In another study at the college level, the students who used HeartMath tools and techniques demonstrated significant results in reducing anxiety and increasing academic performance in diverse subjects such as math and music (Thurber, Bodenhamer-Davis, Johnson, Chesky, & Chandler, 2010). Likewise, studying 125 college EFL students, Hsu (2004, cited in Wu, 2011) found that anxious students could recall less amount of the content of the text than those students who were less anxious. Furthermore, Sellers (2000) also investigated the possible relationship between language anxiety and reading comprehension among 89 EFL Spanish university students and found that students with high reading anxiety were able to recall less content of the text. Sellers showed that anxiety affects reading comprehension among the students with lower levels of instruction.

Therefore, according to these studies, it can be concluded that there is a negative relationship between specific language skill anxiety and L2 performance, and that students' anxiety decreases with their learning self – regulation techniques in reading classes. These results suggest that low level of students' anxiety in addition to creating a low-anxiety classroom atmosphere can help improve students' reading comprehension performance. In brief, considering the two research questions of this study, it can be concluded that programs teaching emotional self-regulation skills such as HeartMath techniques and tools increase HRV measures and coherence ratio which enhance emotional well-being and boost learning and academic performance from the elementary school to the college level.

Various methodologies have sought to eliminate affective barriers to language learning and make it a more pleasant and less stressful experience. Reading is also a skill subject to variability within the affective factors. The findings of the present study are greatly compatible with the results of studies done in this field. Different studies have indicated that the application of heart rhythm coherence, achieved through biofeedback training, has outstanding results in different educational settings. For example, according to McCraty et al. (1999), middle school students treated with emotional self-regulation techniques showed a significant improvement in areas like stress reduction, work management, risky behavior, attention, and the relationships with their teachers, classmates, and family members. In a study conducted on 60 students by Arguelles et al. (2003), stress resiliency was found more among students who practiced IHM self-regulation techniques in the training group. It was found less in the control group who were not taught the technique. Based on the findings of a number of studies, there is a high correlation directly between HRV measures and improvement in emotional competence, cognitive performance, attention, stress reduction, and classroom behaviors (e.g., McCraty et al., 2009; Tiller, McCraty, & Atkinson, 1996). Moreover, Fabes and Eisenberg (1997, cited in Appellhans & Leucken, 2006) found higher levels of resting respiratory sinus arrhythmia with the application of self- regulation techniques and helpful coping strategies among university students. Their findings indicated that those who had lower resting respiratory sinus arrhythmia responded to stress in a more negative emotional condition, which caused interference with the implementation of adaptive self-regulation strategies. Reading is also subject to variability within the affective factors such as anxiety, motivation, tolerance of ambiguity, and self-efficacy. According to Bradley et al. (2007), the results of studies conducted by Test Edge National Demonstration Study showed a significant reduction in test anxiety with 75% reduced levels, large increases in the state-mandated test scores (from 60% to 70% in mathematics and 26% to 48% in English-language), and positive changes in their students' behavior.

As it was mentioned before, conducting some fascinating research on the heart and its connections with the brain is a relatively new field of study. However, according to studies done in this field in addition to the results of the present study, we can conclude that HRV training may be applicable and effective in intensifying and raising positive emotions and better academic achievement. Learning could be improved when HRV increases by the implementation of programs teaching emotional self-regulation skills such as HeartMath techniques. With respect to the efficacy of high level of psycho-physiological coherence in learners, students will be prepared to achieve a better performance through managing their feelings and reducing their reading difficulties.

However, it should be mentioned that there is not a large body of literature on heart-brain science, and specifically HRV measures, with education and learning. Without doubt, more research is needed in this direction; therefore, it is necessary to make more inquiries in this field to elucidate and verify the results.

Obviously, the limitations of this study should be taken into account as well. For example, some variables like allotted time or the genre and length of passages might change the results. The findings of this study suggested a number of future researches as well. For example, with regard to the significant and influential role of emotion, other instructional strategies can be designed to increase heart-brain coherence. Additionally, more various and wider ranges of scope and contexts to be addressed can be considered in future investigations as well. As anxiety is an influential factor in learning, a comparison between language learning difficulties in second language and foreign language situations can also be made. It would be useful to investigate the relationship between different aspects of language learning and the role of heart-brain coherence in language learning and teaching. Even more, a large amount of religious beliefs and practices are probably to focus on alike psychological processes such as implicit self-regulation to activate cognitive and emotional states. Consequently, it could be interesting to investigate if there is a distinction in HRV measures between students with religious affiliation and other students.

Declaration of interest: none

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