Biofeedback Technique for Improving Human Operator's Cognitive Performance

AUDITYA P. SUTARTO, MUH. NUBLI B. ABDUL WAHAB
Industrial Engineering Department, Centre of Human Sciences and Modern Languages
University of Ahmad Dahlan, University of Malaysia Pahang
Jl Prof Dr Soepomo, Jogjakarta, Locked Bag 12 Gambang Kuantan Pahang
INDONESIA, MALAYSIA
auditya_ps@yahoo.com, mnubli@hotmail.com

Abstract - *An increase in computer-based control and the automation of functions direct to predominantly cognitive tasks assigned to the shop floor. To date, very few psychophysiology–based approaches used to teach the operators how to be relaxed and calm while maintaining cognitive focus on their work performance. The aim of this paper is to evaluate a novel psychophysiology (hear rate variability (HRV) Biofeedback) intervention protocol for the enhancement of cognitive performance. The HRV biofeedback protocol used in this study includes slow breathing technique at which the greatest amplitude of HRV achieved (5-6 breaths/minute at 0.1 Hz), and pursed-lips diaphragmatic breathing. Nine subjects underwent the 6 sessions of HRV biofeedback training. The analysis of Wilcoxon test revealed significant increase ($p < 0.05$) on stroop color-word, memory and arithmetic performance after biofeedback training across eight of nine subjects. This has been supported by significant change ($p < 0.05$) toward lower frequency (LF) oscillation which range from 0.05–0.15 Hz or approximately 5-6 breaths/minute over all sessions. In summary, HRV biofeedback led not only to the generation of highest amplitude of respiratory sinus arrhythmia or HRV at 0.1 Hz, but also resulted in improvement of the operators' cognitive performance. This preliminary study shows promising application of HRV biofeedback in the area of workplace.*

Keywords: Cognitive Performance, Psychophysiology, Heart Rate Variability (HRV), Biofeedback

1 Introduction

The complexity of industrial processes has enormously been increased during the last decades. This tendency originates from a number of reasons, such as the scale enlargement of modern plants, the required specifications dealing with the product quality, and the progress in process control and informatics creating totally new possibilities [1]. To cope with this situation, a great number of environments are moving toward automated system that has led to the less importance of human manual control. Consequently, performance of the human in such systems becomes more critical due to predominantly cognitive tasks assigned to the shop floor [2].

Nevertheless, many human operators perform their cognitive skills, (i.e. memory, attention, and decision-making) below their peak cognitive capacity level. There are a number of cognitive factors that can severely affect performance, including fatigue, boredom, positivity bias and short-term memory effects [3]. A boredom, distracted, tired, or drowsy operator performs low productivity, or worse, poses a threat of accidents with irreparable consequences [4]. Extensive attempts have been carried out to improve operator's cognitive performance include equipment and work station design, proper operator selection, job redesign, and prediction of operator activity and preparatory training. Currently, operators receive ample training in the theoretical knowledge and technical skill required to perform their jobs but very few psychophysiology –based approaches used to improve their cognitive function, mainly in maintaining their attention during work.

The success of operator's executive function in work systems depends not only on their health status, general and professional training, but also on their specific ability to work in a versatile environment for a lengthy period of time with minimal error [4]. In order to ensure such conditions, the development of a safe method to maintain the required cognitive functional level without adverse effects is needed. One of the aims of this paper is to develop a psychophysiology-based training protocol that can quickly teach the operators to be relaxed and calm while maintaining cognitive focus on their work performance.

In the mental workload literature, psychophysiological measurement such as derived from cardiovascular response is frequently used in the last 30 years to index the level of cognitive demand associated with a task [5].

These measures include the electrocardiogram (ECG), blood pressure measures, and measures of blood volume. Based upon the criteria of sensitivity, diagnosticity, ease of data collection, and nonintrusiveness, a measure of electrocardiographic activity, i.e. heart rate variability (HRV) is shown the most promise [6, 7]. The spectral analysis of HRV reveals an inhibitation of the 0.1 Hz mid-frequency component under conditions of increased cognitive demand, e.g., problem solving, increased working memory load [8, 9]. In contrast, it has been proven that higher HRV is linked to creativity, psychological flexibility, and a more developed capacity to adjust cognitive, affective, and physiological responses to stress as well [10].

However, little attention has been paid to use this HRV information as operators' feedback for improving their cognitive performance. Such technique is well known as HRV biofeedback, a potential and fast developed area in the applied psychophysiology domain [11]. HRV-biofeedback training works by teaching people to recognize their involuntary heart rate variability and to control patterns of this physiological response. According to Vaschillo et. al. [12], each individual has a "resonant frequency" at which heart rate variability is the greatest. This resonant frequency is most frequently produced by persons while they are in a relaxed mental stated with a positive emotion, and engaging in smooth full diaphragmatic breathing [11, 13]. Moreover, R McCraty, and D. Tomasino, [14] has presented on heart rhythm coherence feedback to facilitate people in developing a greater awareness of the connection between their emotions, physiology, and behaviour. The effect of this coherency is often experienced as heightened mental clarity, improved decision making and increased creativity [15].

In healthy subjects, extensive studies on application of HRV-biofeedback have been conducted to enhance general performance in education, music, and sport settings. This strategy has been effective to reduce musical performance anxiety [16] and increase test scores in reading and math in high school students [17] and decrease reaction times on auditory discrimination task [18]. In the area of sport, such technique has significant impacts in professional golfing community [14] and batting performance [19]. Furthermore, the benefits of adaptive biological regulation with oscillatory biofeedback have been revealed in the psychophysiological training of emergency assistance doctors prior to and during 24-hour duty shifts [4]. The results from those previous studies are encouraging and indicate the possible effectiveness of using HRV-biofeedback in work place settings. Therefore, in this study, the efficacy of HRV biofeedback training on improving human operator's cognitive performance was assessed.

2 Literature Review

2.1 Cognitive Performance

Cognitive functions refer to an individual's ability to organize information which includes both the acquisition of information (perception), selecting (attention), representing (understanding), and retaining (memory) information, and using it to guide behaviour (reasoning and coordination of motor outputs) [20]. Interventions to improve cognitive functions may be directed at any one of these core abilities.

The widespread implementation of automatic systems, whose control is monotonous and requires predominantly operators' cognitive functions leads to problems of decreased attention, fatigue, and drowsiness. Thus, the ability to maintain sustained attention or vigilance on a given stimulation source or task is a crucial determinant of cognitive performance [21]. The vigilance decrement has been described as a slowing in reaction times or an increase in error rates. Radar operators can have a 70% drop in efficiency within 30 min of commencing a trial, through boredom [22]. Moreover, the result of Clock Test from Mackworth's study showed a 12% decline in the frequency of signal detections after only 30 minutes of performing the task and an 18% drop by the end of the 2-hour session [23].

In addition to attention, short-term memories can be very volatile. Most people have difficulty remembering even three items after 18 s and Marsh et al. [24] suggest that short-term memory can decay within 2 s. The nature of working memory also appears biased to favour gain in certain risk-averse decision-making situations [3]. This bias might affect routine sampling in time-pressured situations and encourage certain memories to be more persistent than others, i.e. fulfilling expectations of species abundances

An example of human skills requiring cognitive functions activation in visual inspection task is summarized in table 1. Such skills are commonly found in other tasks for instance monitoring instrument panel, controlling aircraft traffic, learning and retaining job-related information and recalling that information immediately (e.g. telecommunication operator). Many factors affect visual inspection accuracy including fatigue resulting from overloading the operator and under-loading the operator through boredom or monotony [25]. When an operator is overloaded, actions can be confused and judgments may be unclear. By contrast, if the operator is underloaded attention may drift, signals maybe missed, and performance may be poor.

Researches have studied many strategies to deal with the assessment and maintenance of vigilance and attention in conditions of monotonous activity through either external or internal interventions. Design of control and display, design of work station, and work shift arrangement, are some examples of such external interventions.While operators commonly undergo training in the theoretical knowledge and technical skill as internal interventions, to date,very few psychophysiology approaches have been used to improve operators' cognitive performance. Through applied psychophysiology strategy, visual, auditory, or tactile stimulation are used and, with the operators' active involvement, self-regulation and self control skills can be acquired and used to correct of their state.

Table 1. Human skills required for the visual inspection task [26]

Subtask	Task Description	Major type or Skill	Mental Attributes Required
1	Search the item	Perceptual	Attention, perception, memory
2	Detect a flaw	Perceptual	Detection, recognition, memory
3	Recognize/classify	Perceptual	Recognition, classification, memory
4	Decide status	Perceptual	Judgment, classification, memory
5	Record of information	Manual and perceptual	Memory

2.2 Heart Rate Variability Biofeedback

The human heart is a four-chambered bio-electrical pump beating at an ever changing rate: it is not like a clock that beats at a steady, unchanging rate. This variability in heart rate is an adaptive quality in a healthy body. Heart rate variability (HRV) is defined as a measure of the oscillation of the interval between consecutive heartbeats. HRV is influenced by both of the excitatory sympathetic and the inhibitory parasympathetic branches of the autonomic nervous system (ANS). These two branches which often opposed interact are responsible for modulating individuals' physiological arousal and their capacity to meet the demands of both mental and physical stress.

Since the early 1980s, Heart rate variability (HRV), or sinus arrhythmia, has gained widespread acceptance as a measure of mental effort. The use of HRV in both laboratory and field settings is valued not only because of its nonintrusiveness, but also because of its utility where continuous recording is required [7]. In a 1987 study, Aasman, Mulder, and Mulder [27] found HRV to be associated with the changing levels of user effort. It has been supported by work of Tattersall and Hockey [8] which showed that an increase in mental effort was typically related to a reduction in the power associated with the mid-frequency band in the HRV power spectrum. In spite of extensive studies on the application of HRV as mental (cognitive) task measurement, there is no published research to date on the use of such knowledge as an intervention to enhance operator's cognitive performance.

Recent research suggests a positive role for HRV intervention, known as HRV biofeedback, in improving heart health as well as overall well being. HRV-biofeedback training works by teaching people to recognize their involuntary heart rate variability and to adjust their breathing rate to a resonant frequency (RF), a breathing rate (usually slower than normal breathing) at which respiratory sinus arrhythmia (RSA) is maximized. Over other biofeedback techniques, HRV-biofeedback is more reflective of changes in psychological state, more straightforward to learn and use and more cost effective [14].

In this study, a HRV-biofeedback or resonant frequency training (RFT) biofeedback (note: HRV/RFT can be used synonymously) was employed to enhance operator's cognitive functions while performing their daily work. The protocol was developed based on work of Lehrer, Vaschillo, and Vaschillo [13]. Resonant frequency training (RFT) is a specific biofeedback training strategy that is used most commonly in treating a variety of diseases in which autonomic factors play a role. Cardiac oscillation reflects homeostatic activity and a healthy cardiovascular system (CVS). Lehrer, et al. [13] suggest that HRV training can mediate a homeostatic state in the body. The CVS displays continuous rhythmic variation when in a healthy or homeostatic state. Recent advances in technology and physiological measurement have lead to a growing interest in the relationship between HRV and health outcomes. Current research has shown that when HRV is diminished there is an increased risk of cardiac mortality and morbidity and a number of other poor health outcomes.

It is a common observation among biofeedback clinicians that heart rate variability biofeedback (HRV BFB) produces large increases in heart rate variability in almost everyone, usually within a few minutes of the beginning of training [12]. A large amount of researches has shown that maximal increases in amplitude of heart rate oscillation are produced when the CVS is rhythmically stimulated by paced breathing at a frequency of about 0.1 Hz (6 breaths per minute. This effect is linked to resonance properties of the CVS resulting from activity of the heart rate (HR). This resonance property is determined particularly by the baroreflex and other physical characteristics of the circulatory system (easily quantifiable as blood volume), but not by respiration [28].

Heart rate oscillations in the frequency range of 0.15–0.4 Hz (9–24 breaths/minute) are often referred to as "high frequency" (HF) heart rate oscillations which usually correspond to respiration, and are known respiratory sinus arrhythmia (RSA). RSA triggers very powerful reflexes in the body that help it to control the whole autonomic nervous system (including heart rate, blood pressure, and breathing). There also appears to be a high amplitude oscillation within the low frequency (LF) oscillators which range from 0.05–0.15 Hz or approximately 6 breaths/minute. Some studies have associated the LF oscillators range with blood pressure (BP) oscillations. In the present study, there is a special interest in the LF oscillator because it is correlated with measures of a reflex that plays a key role in the regulation of BP [29]. Inside the major arteries of the CVS tiny pressure sensors called baroreceptors convey information to the sinus node of the heart to optimize homeostasis in the blood pressure system. These receptors work on the vagus breaking system to either slow down or speed up heart rate depending on the status of pressure (too much or too little pressure) in the arteries. In other words, the baroreceptors monitor pressure levels and if too high, the vagus breaking system will be stimulated to slow down the heart so that pressure will be decreased. If too little blood pressure occurs, a signal is sent through the sympathetic cardioaccelerator to speed up heart rate and increase BP. As a possible early detector of cardiac disease, baroreflex gain is an important area in which cardiologist are currently directing their attention. Baroreflex gain is quantified as ms/mm hg or the change in IBI (in milliseconds) that co-occurs with changes in blood pressure (in mm Hg). In addition to the HF and LF oscillators, a very low frequency or VLF ranges from 0.005–0.05 Hz which, is sympathetically mediated, and appears to reflect regulation of vascular tone and body temperature [13].

Most individuals can learn RFT biofeedback training easily which involves slowing the breathing rate (around six breaths/min) to each individual's resonant frequency at which the amplitude of HRV (i.e. RSA) is maximized (0.1 Hz) [13]. At the same time, as RSA increases, the spectral distribution of HRV shifts, with a greater percentage of total variability now residing in LF range, including this 0.1-Hz point. The 0.1 Hz is in the LF band which reflects the sympathetic and parasympathetic autonomic control and reflects the action of the baroreflex to control blood pressure.

Although nothing has particularly been done with workers, using resonant frequency heart rate biofeedback shows promise in clinical and non-clinical populations and may be generalized to work settings. Lehrer et al. [13] have used breathing techniques guided by heart rate biofeedback in laboratory settings. They found that when breathing is combined with HRV biofeedback, subject were able to create resonance in the cardio respiratory system between the effects of respiration and those of the baroreflex. Consistent, daily practice of this method also increases total heart rate variability with almost all of the oscillations peaking at a single frequency. One of successful application of this technique in non clinical area has been shown by work of Strack in improving batting performance [19]. Furthermore, Gevirtz and Lehrer [30] provided a review of the underlying principles of resonant frequency training and some of its potential treatment applications.

Therefore, the goal of this study was to test the utility of a novel psychophysiological (HRV Biofeedback) intervention for cognitive performance enhancement in operators. This method combined RFT biofeedback with instructions to breathe diaphragmatically, to inhale through the nose, and to exhale through pursed lips. In addition, subjects are encouraged to do prolonged exhalation. It has been demonstrated that breathing is an important component of performance. During diaphragmatic breathing the double dome shape of the diaphragm extends up under the lungs when at rest. Upon inhalation, the diaphragm descends after contracting and flattening downward allowing the lungs to fill and the belly to expand. Upon exhalation, the diaphragm returns to its normal resting state. This exhalation is generally full and deep, involving the respiratory muscles of the chest and the belly, lower ribcage, and lower back. Gradually, breathing slows down and each breath takes in more oxygen and releases more carbon dioxide [31].

3 Methods

3.1 Subjects

The subjects consisted of 9 female university students, recruited from the University of Malaysia Pahang. The participants received 8 sessions of HRV biofeedback during 4 weeks, two sessions per week. Participants were requested not to introduce any correctives in their daily routines, and during all training sessions, they were to refrain from any drinks that affect central nervous system (strong tea, coffee). The use of any medication was also excluded.

3.2 Apparatus

Physiological measurements were derived from Biofeedback Stress Management Kit developed by Institute of Molecular biology and Biophysics, Russian Academy of Medical Sciences, Siberian Branch to collect electrocardiogram. Statistical analysis was carried out with the aid of SPSS software package

3.3 Experimental Tasks

This study used two independent variables, the groups in which subjects were assigned (RFT biofeedback, control) and the time assessment (pre, post). The effects of RFT training were assessed on two dependent variables: cognitive performance tests (Stroop Color and Word, Memory, and Mental arithmetic) and resonant frequency bandwidths (HF, LF, VLF).

The Stroop Word-Colour test asks subjects to relay to the investigator the color of the word that they are reading. Distracting variables are added by having all of the words read actual color a names that existed in the test [32]. Subjects were given 45 seconds to relay as many colors as possible. The stroop interference scores were recorded at pre and post biofeedback intervention.

For the memory test adapted from study of Traub, G.S. [33], participants were given a list of 20 words to memorize. The goal was to memorize in 1 minute as many of the words according to the words arrangement. They were required to recall the words in 2 minutes. The performance criterion is number of correct responses.

In addition to stroop and memory test, arithmetic test was used in the present study. Mental arithmetic is considered to be typical of day-to-day environmental stressor because it is cognitively-demanding, time-pressured, and high scores are rewarded. These are the three major characteristics of workplace stressors noted by Cinciripinni [34]. Arithmetic sequence problems used in the experiment was adapted from the study of Harrington [35]. Subjects were instructed to determine what number should come next in the arithmetic sequence problems by figuring out the principle of some arithmetical operations. They were given 2 minutes to solve several cases and thereafter maximum 4 minutes to solve all of the problems. A different set of the problems were given at post-test.

3.4 Procedure

Training sessions were conducted at the Biofeedback Laboratory on the University of Malaysia Pahang campus. Each session lasted approximately 30 minutes which consisted of 5 minutes baseline and 20-25 minutes RFT biofeedback. On the first meeting following discussion of the objectives and aims of the study, the participants underwent the cognitive testing. The results were compared with the post-training results at the end of six training sessions afterward.

In the first session, the subjects were introduced to the biofeedback equipment, the training method and protocol as suggested by Lehrer, et al. [13]. Participants were taught to breathe at their resonant frequency with a “quiet mind”. They were instructed to inhale abdominally and exhale through pursed-lips with exhalation longer than inhalation. Heart rate oscillation amplitudes were measured while participants breathed a constant rate at specific frequencies, approximately 5 - 6 cycles / minute. At the end of first session, they were instructed to practice breathing at the resonant frequency on a daily basis. Participants were permitted to choose any time of day in which practice breathing is to take place (e.g. while in class, driving car, studying), however, a minimum of 5-minutes (20 minutes/day total) practice segments was suggested. In the second session and in all subsequent sessions, participants were given biofeedback and step -by-step taught to maximize the peak amplitude of RSA. This was achieved by breathing in phase with heart rate changes and trying to maximize the increases and decreases in heart rates that accompany breathing. This aspect of training was repeated until subjects were able to meet the criteria of maximizing spectral activity near 0.1 Hz while maintaining diaphragmatic breaths. Recall, that 0.1 Hz falls in the LF range.

4 Results

The HRV biofeedback training/session data was analyzed to verify whether participants learned the technique effectively. Results of HRV for the participants were recorded in each of the all sessions for the initial 15 minutes of each 30-minute session. These averages were used to determine what percentage of the total power stems from LF activity. Due to limited number of subjects and violation of ANOVA assumption, non parametric tests were employed to evaluate the effectiveness of RFT biofeedback both in a shift in the HR spectrum towards the LF range and improving cognitive performance.

Percentage of LF activity is illustrated in the table 2. The change in LF activity over 6 sessions across all subjects is also depicted in figure 1.

Table 2. Percentage of LF activity

Subject	Pre	1	2	3	4	5	6
1	29.90	28.05	46.55	76.10	73.20	78.30	87.45
2	23.70	30.50	22.50	50.43	71.37	87.35	92.05
3	28.80	29.80	43.65	54.35	75.07	80.30	85.60
4	24.10	52.83	69.65	80.53	90.73	91.73	91.32
5	39.40	37.45	44.50	60.35	71.00	83.60	85.80
6	22.30	23.45	31.77	49.37	63.13	82.98	89.60
7	26.03	39.73	52.60	62.60	88.93	95.10	96.03
8	11.60	19.90	52.35	57.50	67.45	79.55	82.70
9	17.90	67.90	79.53	87.13	85.13	91.75	92.88
Median	24.10	29.80	46.55	60.35	73.20	83.60	87.45

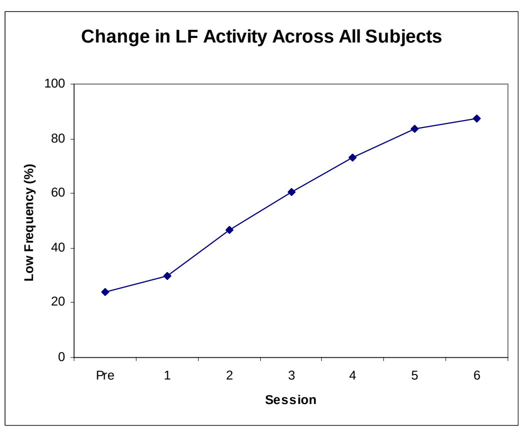

Figure 1. Change in Low Frequency (LF) Activity

Training effectiveness between and within sessions was assessed using Friedman's ANOVA test with repeated measures on percent of total HRV power shifted to the LF range. Results revealed a significant change toward LF range over all training sessions ($\chi^2 = 51.810$, $p < 0.05$). Wilcoxon tests were used to follow up this finding as post hoc test. A Bonferroni correction was applied to the 0.05 level to control the overall *Type I error* *rate* when multiple significance tests were carried out. Thus, all effects are reported at 0.0083 (0.05 divided by 6 pairwise comparisons) level of significance [36]. It appeared that LF oscillation significantly increase from the first week of the training to the second week, Z_{01}= -1.836, r_{01} = -0.433, and the following subsequent weeks, as summarized in table 3.

Table 3. Wilcoxon Test for LF Oscillation Change between Subsequent Sessions

	Sesi 1 – Pre	Sesi 2 – Sesi 1	Sesi 3 – Sesi 2	Sesi 4 – Sesi 3	Sesi 5 – Sesi 4	Sesi 6 – Sesi 5
Z	-1.836[a]	-2.547	-2.666	-2.310	-2.666	-2.073
Exact Sig. (1-tailed)	0.037	0.004	0.002	0.010	0.002	0.020
Size effect (*r*)	-0.433	-0.6003	-0.628	-0.544	-0.628	-0.489

[a] Based on negative ranks

For cognitive performance evaluation, it was hypothesized that the participants would have statistically higher performance in all parameters of cognitive functions after RFT biofeedback. The Wilcoxon-signed rank test showed that with an alpha level 0.05, the effect of RFT biofeedback was statistically significant which shows that of nine participants, eight were able to improve their cognitive performance (table 4). The interference stroop score increased significantly on post training (*Mdn* = 58.4) than on pre training (*Mdn* = 53.5), z = -1.955, $p < 0.05$. For the memory and arithmetic test , the score improvement was also found to be (z = -2.536, $p < 0.05$, and z = -2.12, $p < 0.05$, respectively). Moreover, it is important to report effect size of each cognitive test result as a standardized measure. The stroop score and arithmetic data represented medium effects, (r = -0.46 and r = 0.50 respectively) and a large effect for the memory test data (r = 0.598) [36]. All of these values showed that medium and large effect size could be significant in a small sample.

Table 4. Pre- and Post-test of the Cognitive Performance

	Stroop Interference Score		**Memory test (accuracy)**		**Arithmetic (accuracy)**	
Subject	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
1	36.3	65.2	4	7	0	7
2	58.8	60.4	8	10	1	3
3	63.0	63.6	9	11	2	7
4	48.1	40.8	3	6	4	3
5	56.8	66.7	7	8	3	6
6	46.8	47.2	13	15	1	2
7	54.6	53.8	6	12	2	7
8	53.5	58.4	10	10	4	4
9	46.2	57.7	4	8	2	2
Median	53.50	58.40	7	10	2	4
z	-1.955		-2.536		-2.120	
Exact *Sig* (1-tailed)	0.027		0.004		0.023	
Size effect (*r*)	-0.46		-0.598		-0.50	

On the whole, all participants except subject 4 showed progress in all parameters of operator's cognitive performance. These were in line with the increase of LF activity in most of all sessions. By the end of training, the decrease of the LF activity in participant 4 was accompanied by the absence of positive results in her stroop and arithmetic test.

5 Discussion

The primary objective of the present research was to determine whether training in HRV biofeedback would lead to improvements in cognitive performance. The result of this study indicated that most of all subjects improved their cognitive performance significantly after RFT biofeedback. This finding was coupled with a highly significant shift in total power on the heart rate spectral analysis toward the LF range over all sessions. This confirms that the participants learned how to effectively manipulate and control activity in the autonomic nervous system. They successfully learned the slow diaphragmatic breathing as demonstrated by their mastery of the technique as well. Furthermore, an increase of percentage of LF activity found was in line with performance improvement. It shows that being in a state of “resonance” was linked to enhance performance.

Lehrer et al. [13] have developed a theoretical explanation of the mechanism involved in creating resonance in the body. It appears that the slow paced breathing technique learned through HRV-biofeedback creates a resonance between the cardiovascular and the respiratory systems. It is proposed that the physiological mechanism explaining resonance and autonomic balance involve a complex interplay between heart rate and vascular tone baroreflex loops.

McCraty [14,18] proposes the existence of harmonious interactions of the body’s subsystem coined as “physiological coherence”.He summarized the research that supports the concept that as cardiac afferent neurological input to the brain increases, homeostatic regulation and cognitive processing also increases. He proposes that a combination of rhythmic breathing and the intentional self-induction of a sincere positive emotional state facilitate coherence in the autonomic nervous system. When heart-brain dynamics are modified in this way, the brain’s information processing capabilities may change. These changes lead to potential improvement in faculties such as motor skills, focused attention, and discrimination. Such skills are essential to the work settings and are often under-trained for operators.

Suvorov [4] has shown that the presence of inherent harmonics after sessions of cardiorhythm biofeedback control is one of the qualitative criteria for the improvement of the efficiency of operator activity. This biofeedback control directed to the restoration of lost RSA. The oscillatory regimen of adaptive cardiorhythm bio-regulation is based on psychophysiological mechanisms and carried out by means of individual adaptive algorithms. The presence of inherent harmonics can be observed mostly in young healthy subjects and remains stable for a lengthy period of time. It has been confirmed in a single follow-up study of cardiac rhythm after 1 ½ years.

Therefore, along with the findings of this study, all of these suggest the potential application of HRV biofeedback as a useful strategy for enhancing cognitive functions among human operators. It is also possible, according to Vaschillo, et al. [12], that paced breathing at 5.5 or 6 times/minute allows people to produce clinical effects that are just as strong, without the need for biofeedback equipment. However, further experimental researches are strongly required.Currently our works are on evaluating the effectiveness of such technique among larger sample which were divided into control and biofeedback intervention group. Moreover , a determination of certain mediator between the biofeedback training and enhanced performance is being explored. Previous literatures have demonstrated the performance improvement is linked to reduction of cognitive anxiety through HRV biofeedback. In real work settings, cognitive performance decrement is influenced either by stress and fatigue [21] rather than anxiety.

6 Conclusion

In addition to existing technical and knowledge-based training, a novel psychophysiological approach is developed to solve problems related with human operator’s cognitive performance. The result of the present study provides a promising beginning for HRV (RFT) biofeedback application in work setting, particularly for the improvement of operator’s cognitive performance. This technique showed the potential to be an inexpensive psychophysiological approach to improve autonomic balance and respiratory control. Moreover, it is replicable, standardized, and can be learned rapidly and easily by most operators. Despite HRV biofeedback’s potential values, the results of this study are preliminary and warrant further experimental investigation.

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