International Journal of Biology, Pharmacy
and Allied Sciences (IJBPAS)
'A Bridge Between Laboratory and Reader'

THE EFFECT OF HRV AND EEG BIOFEEDBACK ON NEUROCOGNITIVE FUNCTIONS IN ELECTRIC PLANT OPERATORS

[1]GHAFFAR MALEK KHOSRAVI, [2*]ABBAS POURSHAHBAZ, [3]PARVANEH MOHAMMADKHANI, [4]BEHROOZ DOLATSHAHI

[1]PhD student, Clinical Psychology, Department of Psychology, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

[2]PhD in Clinical Psychology, Department of Psychology, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

[3]PhD in Clinical Psychology, Department of Psychology, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

[4]Asistant Professor of Clinical Psychology, Department of Psychology, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

*Corresponding Author: Abbas Pourshahbaz

ABSTRACT

Cognitive function play a crucial role in task and work performance and they seem to be very important to manage in the daily life. Many strategies are developed to enhance cognitive abilities such as, medication, training, yoga and so on. Recently some interventions based on technology and psychophysiology are established. The aim of this study was to examine the effectiveness of HRV and EEG biofeedback to improve cognitive abilities in workers with high strain job, such as electric plant operators.

This study is an experimental design with group control. 36 volunteers in a power plant were participated in the study. The BSI was a screening test for indicate the presence of psychological problems. Pre assessment was applied by, IVA Continuous Performance Test, and a QEEG assessment.12 subjects in experimental group and 17 subjects in control group completed the study. After 5 sessions HRV biofeedback and 12 sessions EEG biofeedback for experimental group, the assessment was repeated and data statistically were analyzed.

Successful improvement in autonomic balance by HRV biofeedback was observed and whereas no change observed in QEEG patterns, improvement in visual attention and response

control were significant. Also in other modalities such as speed and comprehension no significant enhancement were seen.

It seems that HRV and EEG biofeedback trainings are effective in some cognitive abilities such as attention and impulsivity in line other research, but not all evaluated abilities. The reasons are discussed and type of assessment tools and nature of the work place is known important factors of inconsistencies.

Key Words: HRV biofeedback, EEG biofeedback, IVA Continuous Performance Test, QEEG assessment, Cognitive abilities

INTRODUCTION

Each processes used to organize Information by someone can describe the cognition and we can say that cognition is Information processing facet of behavior (Lezak, Howieson et al.2004). Lezak, Howieson et al (2004) describe the four major classes of cognition corresponding to input or receptive functions, storage, processing and output or expressive functions. Interventions to enhance cognitive function may be compromised anyone of these core capabilities (Bostrom & Sandberg, 2009). Ability to maintain attention or vigilance on a given stimulation source or task is an important index of cognitive performance (Pattyn, Neyt, Henderickx, and Soetens (2008). Schmidt, Hunter, & Outerbridge, (1986) suggested that cognitive ability has strong correlation with job performance because people with higher levels of cognitive ability acquire a greater amount of knowledge and are thus able to better perform a variety of behaviors on the job. Cognitive ability is known as one of the best predictors of job performance, accounting for over 25% of the variance in performance (Schmidt, 2002, Hunter & Hunter, 1984; Schmidt & Hunter, 1998). It can also predict general performance better than all other measures of ability, traits, or dispositions that have been tested (Schmidt & Hunter, 2004). In a study cognitive ability correlated to objectively measured job performance which in turn predicted the overall evaluation by job performance raters (Viswesvaran & Ones ,2000). Campbell& Catano (2004) reported that auditory attention improved the performance among Canadian military personnel in the "Operator Family." Mount et al. (2008) reported that a test of perceptual speed and accuracy improved the task performance, above general mental ability, in a group of warehouse workers. Furthermore cognitive ability should be positively correlated to job satisfaction, due to the tendency for high-ability individuals to occupy jobs with more desirable characteristics. (COOK, 2008). It must be emphasized that while operating

instruments human activity needs concentration or attention and human operator has to adjust between choices (Boy,1998). So cognitive enhancement seems crucial in operational work place.

Improvement of Cognitive function can refer to the empowerment or expansion of main ability of the mind through impoverement or enhancement of internal or external information processing systems (Bostrom & Sandberg, 2009). There are many different forms of cognitive enhancement such as education and training, yoga, meditation, medical and psychological interventions and so on. They have been all used to improve general mental skills such as concentration, memory, and critical thinking as cognitive abilities (Bostrom & Sandberg, 2009). Since cognitive neuroscience has developed, the numbers of prospective internal, biological improvement has constantly increased (Farah et al . 2004). Up to now, it is progress in computing and information technology that has provided the most exiting use of biofeedback or neurofeedback for improving cognitive function in healthy subject (Sutarto, Abdul Wahab, and Zin, 2010). and also fewer which have used both of them in power plant.

The purpose of this study was to examine the effect of psychophysiological interventions including HRV biofeedback and neurofeedback on cognitive abilities in high strain workers such as plant operators.. Biofeedback is a subset of applied psychophysiology in that the physiological signals made by the body are used as a psychophysiological mirror (Peper *et al*., 2008).

Monitoring oneself and then utilizing the information to train and achieve self-regulation is one of the main goals of biofeedback (peper et al. 2008). So the individual may achieve mastership in controlling over his /her cognitive and affecting states and behaviors(Prinzel,Pope, & Freeman,2001). Athletes and executives use biofeedback training to achieve peak performance, and additional uses of biofeedback continue to grow as we explore the mind-body connection in our human existence (Peper et al. 2008).

Heart rate variability (HRV) consists of changes in the time intervals between consecutive heartbeats, which are called interbeat intervals (IBIs) and measured in milliseconds (Task Force, 1996).

HRV is produced by the interaction of multiple regulatory mechanisms that operate on different time scales (Moss, 2004).

When we monitor the beat-to-beat changes in heart rate and display this information in a graphic form for the participant to see and manipulate, we apply HRV biofeedback training (Culbert, 2004). Measurement of

beat-to-beat changes are monitored through changes in pulse rate and can be detected from an electrocardiogram electrode placed on the chest, or a photoplethysmograph optical sensor placed on the finger. Computerized programs can interpret the interbeat interval information into a spectral display of heart rhythm patterns (McCraty, 2002). Several systems influence HRV over a brief time period and contribute to the very low to high frequencies of the HRV spectrum. Breathing rhythms primarily contribute to the low frequencies (LF) (0.04Hz – 0.15Hz)which provides an index of sympathetic effects on the heart , and high frequencies (HF) (0.15Hz – 0.40Hz)that measures the influence of the vagus nerve in modulating the sinoatrial node (peper *et al*., 2008). A healthy heart exhibits complexity in its oscillations and rapidly adjusts to sudden physical and psychological challenges due to its effective interlocking cardiac control systems (Lehrer & Eddie, 2013). Reduced HRV is associated with vulnerability to physical and psychological stressors, and disease (Lehrer, 2007). Since heart rate increases during inhalation and decreases with exhalation (Gevirtz & Lehrer, 2003; Lehrer & Vaschillo, 2008), The baroreceptor reflex (baroreflex) makes the respiration-driven speeding and slowing of the heart via the vagus nerves, called the respiratory sinus

arrhythmia (RSA), possible (Karemaker, 2009). Almost all biofeedback training of HRV focuses upon training the resonant frequency around 0.1Hz that appears to be associated with increased sympathetic-parasympathetic balance. For most trainees, breathing about six breaths per minute while maintaining a positive optimistic attitude increases this resonant frequency(peper et al. 2008). Preliminary evidence indicates that a meditation procedure can activate the prefrontal cortex while evoking increased HRV (Kubota *et al*., 2001).

Neurofeedback or EEG biofeedback is based on two facts: (1) patterns of EEG recorded from the scalp, objectively indicates the brain state, (2) the plasticity of human brain enables it to memorize its desired or rewarded state. In the neurofeedback technique, some current EEG patterns recorded from a subject's scalp (such as an EEG power in a given frequency band, or a ratio of EEG powers in different frequency bands) are presented to the subject through visual, acoustic, or tactile style and finally Changes that are made by subject in the desired direction are rewarded (Kropotov, 2009).

The goal of neurofeedback training is to teach the individual what specific states of cortical arousal feel like and how to activate such states voluntarily (Verenon, 2005).Traditionally, the EEG is divided into

different frequency bands, e.g. delta (<4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz).The position of electrodes and the neurofeedback parameter define a so-called protocol of neurofeedback.

According to the bulldozer principle explained by Kropotov (2009) the aim of neurofeedback in the clinic may be to normalize a pathologically abnormal EEG pattern:" if there is an excess of some EEG parameter in a particular patient and in particular location in the cortex, the aim of the neurofeedback is to train this parameter DOWN, and if there is a lack of some other EEG characteristic, the corresponding neurofeedback parameter is trained UP. The method works like a bulldozer filling in the cavities and excavating the bumps"(p 475 .) To find a proper NFB protocol for each subject, using a brain map derived from a quantitative EEG (QEEG) assessment may be the best guideline. The term quantitative EEG refers to quantitative signal analysis of the digitized electroencephalogram (Coben & Evans,2011). The electroencephalogram is a record of the oscillations of electric potential generated by brain sources and recorded from electrodes on human scalp(Tong & Thakor,2009) QEEG is a collection of quantitative methods designed to process EEG signals and includes spectral and wavelet analysis of EEG(Kropotov,2009). Comparing an

individual pattern of features such as absolute and relative power, coherence and related measures to a reference database is applied in QEEG. (Coben & Evance, 2011). An exciting increase in the number of claims made concerning the likelihood of enhancement some aspects of physical or cognitive performance by using of feedback training is recently seen. (see e.g., Norris & Currieri, 1999, Vernon, 2005).

Papadelis *et al.*, (2007) in a study used a mental imagery training for intervention and reported the significant effect on psychomotor ability as a cognitive performance. In a study McCarty (2002) evaluated the effect of HRV biofeedback on cognitive performance of subjects. In his study he divided 30 subject randomly. He used subjects' reaction time for evaluating cognitive performance and after practicing HRV training for experimental group find a significant decrease in reaction time in this group. Sutarto and Abdul Wahab(2008) and Sutarto et al.(2009) investigated the effect of biofeedback training on the cognitive performance of female manufacturing operators as experimental subjects. They administered three cognitive task including Stroop Color- Word Test, memory and arithmetic test for evaluation of cognitive function. The findings showed a significant improvement in cognitive performance in experimental group. Prinzel et al. (2001)

found that psychophysiological self-regulation improve cognitive resource management skills of operators. Egner and Gruzliaer,(2001) examined the affects of EEG biofeedback on cognitive performance of twenty two healthy volunteers. They used CPT to compare pre- and post- training measures based on omission errors and reaction time. They reported a successful enhancement of commission error which presents improving of sustained attention and reduction of impulsivity. But there were no significant changes for omission and reaction time. In another study conducted by Egner and Gruzliaer,(2003), neurofeedback has enhanced attention and reduced impulsiveness in healthy subjects indicted by less error of both omission and commission errors and reaction time . Vernon(2003) and Egner and Gruzliaer,(2004) reported the same results. Then In a review study Vernon (2005) investigated neurofeedback training literature within sport, cognitive and artistic performance area. He concluded that rationally we can use neurofeedback as a mean to regenerate patterns of brain activity in an effort to improve performance. Hanslmayr et al. (2005) in a single session training study compared two groups for increasing and decreasing a similar brain activity (Responder and non- responder) responders improved their cognitive. Zoefel,

Huster, Herrmann (2011) found that enhancement of cognitive performance was significantly larger for the neurofeedback group than for a control group who did not receive feedback. Thus, enhanced cognitive control went along with an increased upper alpha amplitude that was found in the neurofeedback group only. Recently Wang and Hsieh (2013) investigated the effectiveness of the frontal - midline the activity up training protocol on attention and working memory performance of older and younger healthy participants (N=32) . They included that their protocol improved attention and working memory performance and theta activity in the resting state for normal aging adults. In addition younger participants also benefited from the present protocol in terms of improving their executive function.

reported a study on the use of neurofeedback in conjunction with adaptive automation to decrease the onset of risky state of awareness.

METHODOLOGY

This research was an open label study. It used a combination of convenience selection and random assignment. The subjects were recruited from a power plant producing electricity in Iran. The study was approved by department of clinical psychology of University of Social Welfare and Rehabilitation. Seventy one male

operators were invited to participate in study. Finally thirty six volunteers in existing four work shifts (each shift 8 to 10 persons) accepted the invitation and after signing and returning the consent forms filled the "The Brief Symptom Inventory (BSI)" that is a short version of the SCL-90-R (Derogatis, 1975), and a screening tool for psychological problems for detecting serious psychological disturbance. The items on the BSI define a broad spectrum of physical and psychological symptoms which may have occurred in the preceding seven day period (Derogatis and Melisaratos, 1983). Each item is rated on a 5- point scale of distress from 0 (*Not at all*) to 4 (*Extremely*). Participants didn't have any psychological disorder in terms of test's cutoff base on Persian version standardized by Mamaghani and Javanmard (2007) and Mohammadkhani et al (2010). They also did a computerized test (IVA-AE) for assessment their attention ability and EEG recording for finding an individual intervention protocol.

For evaluating cognitive function we used The Integrated Visual and Auditory (IVA) Continuous Performance Test(CPT). Some authors believe that attentional and inhibition system's complication rises the question of how to adequately and accurately assess the integrity of the components of these systems difficult. CPTs represent one group of patterns for the assessment of attention and, to a lesser degree, impulsivity. It may be the most popular clinical measures of sustained attention and vigilance (DuPaul, Anastopoulos, Shelton, Guevremont, & Metevia, 1992). The basic paradigm for CPTs involves selective attention or vigilance in response to an infrequently occurring stimulus (Eliason & Richman, 1987).

The Integrated Visual and Auditory (IVA) Continuous Performance Test (CPT) was designed primarily to assist in the diagnosis and quantification of the symptoms of ADHD (Sandford and Turner, 2000). It has also been used to measure attention and self control across a variety of neuro developmental and psychiatric conditions as well as serving as an objective device evaluating the effect of treatment. The IVA has been shown to make a important role in neuropsychological assessment (Tinius,2003).

The IVA-AE (Advanced Edition), like the IVA+Plus, is a combined visual and auditory continuous performance test of attention and response control. It is unique in that it is the only CPT designed specifically to help clinicians identify and measure attention problems in the adult population. The IVA-AE is standardized for ages 18 – 50 (N=236, divided by gender).

The task is quite challenging – visual and auditory numbers from 2 to 8 are presented at one-second intervals; the task is to click when you see a 3 or hear a 5. Different numbers are presented simultaneously visually and aurally. (AVI-AE, online manual). In this study visual, auditory and total scores of attention and response control were used for analyses. Since there were some participants over age 50 in the study and because software had no database above this age and doesn't report a quotient for them, we used only the raw numbers reported in a general report sheet by the software. A headphone was used for minimizing the environment noise and a USB mouse make a precise assessment.

For QEEG assessment a Mitsar instrument (model.201) and a full-cap with 19 scalp electrodes dependent to "Ten- Twenty International System" was used to record EEG. Impedance was kept below 5 kΩ. EEG was recorded at two state of eyes opened and closed (five minute each) in a sitting and resting position on a chair. A Neuroguide software then was applied after rejecting artifacts manually to obtain brain map. Since existence more artifact in EEG recorded in eye opened situation the most deviant band wave from norms in absolute power map in eyes closed position were the criteria for making decision to imply neurofeedback protocol for each subject.

After pre assessment two shifts of the four randomly assigned into train (n=18) and control (n=18) groups. Before starting the intervention three participants in experimental group dropped out because moving to other plant and having no time and interest for intervention. Further other three ones in training group and one in control group didn't continue their participation in study because of having no time and interest. Therefore there were 29 participants in the final sample used in analyses: 12 in the train group and 17 in the control group.

Operators in the train group participated in 5 biofeedback and 12 neurofeedback sessions(each session 30 min). In biofeedback sessions respiratory sensor has been placed on abdominal part to detect an abdominal respiration rate and BVP sensor on the index finger to detect heart rate and intervals between pulses. A five minutes baseline was recorded in first session to demonstrate pre training performance. The goals in HRV BFB sessions was to increase Low Frequency (LF) in the session and in turn a sympathetic and parasympathetic balance and a primary calm state. Subjects were asked to inhale and exhale (6 respiration per min) consistent to designed sinusoidal pattern animation presented by software via the monitor and received the audio and video feedback for their success.

the Between each 3 min trial participants were asked to close the eyes and relax their body and imagine a desired nature scene for 3 minute and breath on their way. (4 time in a session). They were asked also to rehearsal this method minimally one time in other situation but they couldn't follow this suggestion . Before and after each session a baseline was recorded to demonstrate their performance and correct the breathing patterns.

In NFB sessions an EEG sensor was connected to scalp and ears via the three electrodes (monopolar montage)and neurofeedback was run in the related software. The reference electrode was placed on left ear and the ground on the right one. The site for the active electrode on the scalp dependent on the one's brain map was different. They generally consisted of frontal and central sites such as FZ, F3, F4, Cz , C3, and C4.Impedance was kept below 5 kΩ in before starting neurofeedback training.. The target band wave also selected due to its deviation rate from norms shown in brain map provided by QEEG. They generally included increasing SMR (12- 15 Hz) and B1(15- 18 Hz) and decreasing Theta(4-8 Hz) and Low Alfa (8- 10 Hz).The goal of QEEG based neurofeedback was to normalize these band waves on a special site in every sessions. The sessions were set in a room in the plant and operators due to their presence in the plant and their readiness (high workload situations, leave or sick leave and emergency events and so on), (2 – 4 session in a month) participated in sessions. The instrument for biofeedback and neurofeedback training was a "5 channel Procomp Infinity" model (Thought Tecnology Ltd; Motreal Quebec)(Version 6) and related sensors connected to a laptop and a monitor for two monitor screens.

RESULT

T-test and Chi square analyses were applied in order to investigate similarity between the groups in pre- intervention variables. Then a t-test analyses for comparison of means between groups in pre- and post-interventions was conducted. All statistical analyses were carried out using SPSS software installed on a pc. The alpha level was $p \leq 0.05$. Result is summarized in table 1 and 2.

Table1: distribution of demographic and screening scores of participant in two group after drop out

Variable	Group	N	Mean	Std. Deviation	t	*p*
Age Year	control	17	32.94	9.877	1.188	.245 .
	Experiment	12	29.17	5.702		
Job experience Year	control	17	7.94	8.474	1.057	.300 .
	Experiment	12	4.83	6.686		
Education	control	17	2.35	.493	-.773	.447

Level	Experiment	12	2.50	.522		.
BSI total Score	control	17	23.5294	14.96712	.132	.896
	Experiment	12	22.7500	16.74474		

There were no significant differences in comparison of means of demographic characters and assessing variables between two groups before and after drop out.

Table 2: Variables changed significantly between train and control groups (t-test)

Variable	Group	N	Mean	Std. Deviation	t	*p*
Visual Attention	Train	12	9.6667	5.94334	2.753	.010
	Control	17	3.4824	5.96846		
Visual Response control	Train	12	8.3833	11.97608	2.622	.014
	Control	17	.2804	3.83810		

As shown in table.2, comparing pre – and post-training measures between train and control group, there is a significant increase in the Visual Attention scores (t =2.753 , *p*= .010)and Visual Response control (t =2.622, *p*= .014) observed on IVA –AE performance. No significant changes for auditory Attention, speed (reaction time) comprehension, sensory motor regulation and auditory Response control were found.

With using a paired samples t-test also a significant changes observed between pre and post HRV BFB training assessment in BVP LF % power mean(t = -3.381, p = .006) and BVP LF total power (t =-3.8 01, p = - .003). Furthermore no significant changes were found in QEEG results in pre and post training.

DISCUSSION

These results represent a successful improvement of visual attentional and response control performance in operators through HRV and EEG biofeedback training. Operators who received the training improved some of their cognitive performance including visual attentional and visual response control. This finding is in line with most of the studies which examine the effect of the HRV biofeedback (Sutarto, 2010,. MaCraty, and Tamsino,2004) or EEG biofeedback (Prinzel et al,2001, . egner and Gruzlier,2003,2004,.Vernon,2005) separately.

Another finding was that HRV variable in pre- and post -training assessment successfully changed . This significant increase in HRV Low Frequency (.15 Hz) shows a successful improving in autonomic system or a sympathetic and parasympathetic balance.

Sutarto, Abdul Wahab , and Zin (2010)endorsed the McCraty and Tomasitno(2004) and McCraty (2002) in this concept that as cardiac afferent neurological input to the brain rises homeostatic regulation and cognitive

processing increases. They hypothesized that association of rhythmic breathing and the purposeful self- induction of a genuine positive emotional state accelerate coherence in the autonomic system. They suggest that when heart- brain dynamics are modified in this way, the brain's information processing capacities may improve. The effectiveness of EEG biofeedback on cognitive performance enhancement has also examined in many studies either with clinically diagnosed individuals or healthy subjects (Vernon, 2005). A contrast in current study is that the attention ability and response control in the auditory aspect and also speed and comprehension demonstrated no significant changes in comparison to control group. It may be due to some reasons. Many researchers didn't use the same tool for assessment cognitive performance. The advantage of current study is using a more complex test such as IVA (Integrated Visual and auditory) for cognitive performance which may have more sensitivity and assess more variables at a time. Another reason could be the nature of the workplace the plant operator work. The classic power plants have some strong engines that make a loud noise while working and this form of noise can affect on auditory system in long time and / or evoke some Inattentional response can

be formed. It also may be due to testing situations that was not completely acoustic and have affected on auditory attention of subject. More precise study is needed to response to these inconsistencies. In addition the changes in QEEG pattern pre and post training were not significant. This finding is not surprising since the EEG neurofeedback didn't concentrate on the training a unique band wave on a unique site of the scalp. So it was predictable that theoretically and statistically a significant increase or decrease in a specific wave activity.

In current study we examined effectiveness of both types of training on cognitive performance Whereas this type of intervention is rarely designed and perhaps be more effective because more supportive literatures, but lack of clear distinction between results of two types of training seems to be important. One of the other limitation in the study is the low number of subjects that became more critical with dropping out of subject. I may be effective in the reliability of the findings. So further studies with more subjects are recommended.

ACKNOWLEDGMENT

university of social welfare and rehabilitation sciences and conducted under support of Power Electric company (Tavanir company). Certainly this project wasn't conducted well without sincerely helps of managers and operators in Rey Power plant.

REFERENCES

[1] Bostrom, N., & Sandberg, A,. (2009).Cognitive Enhancement: Methods, Ethics, Regulatory

[2] Challenges. Sci Eng Ethics. 15:311–341

[3] Campbell LSK, Catano VM. 2004. Using measures of specific abilities to predict training performance in Canadian forces operating occupations. Mil. Psychol. 16:183–201

[4] COOK , A L,. (2008). JOB SATISFACTION AND JOB PERFORMANCE: IS THE RELATIONSHIP SPURIOUS? A Thesis Submitted to the Office of Graduate Studies of Texas A&M University (p 18)

[5] Coben,R,. & Evans,J R,. (2011). Neurofeedback and Neuromodulation Techniques and Applications. Elsevier ,. p 4-5

[6] Culbert, T. P. (2004). The practitioner's guide: Applications of the Freeze-Framer interactive learning system. Boulder Creek, CA: HeartMath

[7] Derogatis, L.R. (1975). *Brief Symptom Inventory*. Baltimore, MD: Clinical Psychometric Research.

[8] Derogatis, L.R. and Melisaratos, N. (1983). The Brief Symptom Inventory: An introductory report. *Psychological Medicine, 13*, 595-605.

[9] DuPaul G.J., Anastopoulos, A.D., Shelton, T.L., Guevremont, D.C., Metevia ,L . (1992). Multimethod assessment of attention deficit hyperactivity disorder: the diagnostic utility of clinic-based tests. Journal of Clinical Child Psychology, 21 (1992), pp. 394–402

[10] Egner, T., & Gruzelier, J. H. (2003). Ecological validity of neurofeedback: modulation of slow-wave EEG enhances musical performance. *NeuroReport,* 14, 225– 1228.

[11] Egner, T., & Gruzelier, J. H. (2004). EEG biofeedback of low beta band components: frequency-specific effects on variables of attention and event-related brain potentials. *Clinical Neurophysiology,* 115, 131– 139.

[12] Eliason, M.J., Richman, L.C. (1987). The continuous

performance test in learning disabled and nondisabled children

[13] Journal of Learning Disabilities, 20 (1987), pp. 614–619.

[14] Farah, M. J., Illes, J., Cook-Deegan, R., Gardner, H., Kandel, E., King, P., et al. (2004). Neurocognitive enhancement: What can we do and what should we do? Nature Reviews Neuroscience, 5(5) ,421–425

[15] Gevirtz, R. N., & Lehrer, P. (2003). Resonant frequency heart rate biofeedback. In M. S.

[16] Hanslmayer S, Klimesch W, Sauseng P, et al. Visual discrimination performance is related to decreased alpha amplitude but increased phase locking. Neurosci. Lett.2005;375:64–68.

[17] Hunter, J.E. & Hunter,R.F. (1984).Validity and utility of alternative predictors of job performance. Psychological Bulletin, 96, 72-98.

[18] Karemaker, J. M. (2009). Counterpoint: Respiratory sinus arrhythmia is due to the baroreflex mechanism. *Journal of Applied Psychology, 106*(5), 1742–1743.

[19] Kubota Y, Sato W, Toichi M, et al(2001). Frontal midline theta rhythm is correlated with cardiac autonomic activities during the performance of an attention demanding meditation procedure. Cogn Brain Res 2001;11:281-7.American Heart Journal Volume 149, Number 6 Nolan et al 1137.e7

[20] Lezak, MD, Howieson, D.B., & Loring, D.W. (2004). Neuropsychological Assessment (4th ed.). New York: Oxford University Press

[21] Lehrer, P. M., & Vaschillo, E. (2008). The future of heart rate variability biofeedback. *Biofeedback, 36*(1), 11-14.

[22] Lehrer, P. M. (2007). Biofeedback training to increase heart rate variability. In P. M.

[23] Lehrer, R. M. Woolfolk, & W. E. Sime (Eds.). *Principles and practice of stress management* (3rd ed.). New York: The Guilford Press.

[24] Lehrer, P. M., & Eddie, D. (2013). Dynamic processes in regulation and some implications for biofeedback and biobehavioral interventions. *Applied Psychophysiology & Biofeedback, 38*, 143-155.

[25] MAMAGHANI , J.,. JAVANMARD ,GH ,.(2007).

standardization of a Brief Symptom Inventory (BSI) for Diagnostic Aims in Consultant and Therapeutic Situations . Journal of Psychology (Text in Persian). Page 129

[26] McCraty, R. (2002). Influence of cardiac afferent input on heartbrain synchronization and cognitive performance. International Journal of Psychophysiology, 45, 71–92

[27] McCraty, R., & Tomasino, D. (2004, November) *Heart Rhythm Coherence Feedback: A New Tool for Stress Reduction, Rehabilitation, and Performance Enhancement*. Paper presented at the First Baltic Forum on Neuronal Regulation and Biofeedback, Riga, Latvia.

[28] Mohamadkhani,p,. Dubson, K,. Amiri M,. Hosseini, F,.(2009). Psychometric properties of the Brief symptom inventory in a sample of recover Iranian depression patients. J clin & health psychol. 2009; 50-72.

[29] Moss, D. (2004). Heart rate variability (HRV) biofeedback. *Psychophysiology Today, 1*, 4-11.

[30] Mount MK,Oh IS, Burns M. 2008. Incremental validity of perceptual speed and accuracy over general mental ability. Pers. Psychol. 61:113–39

[31] Norris, L., & Currieri, M. (1999). Performance enhancement training through neurofeedback. In J. E. Evans & A. Abarbanel (Eds.), Introduction to quantitative EEG and neurofeedback (pp. 224-239). San Diego: Academic Press.

[32] Papadelis, C., Papadeli, K. C., Bamidis, P., & Albani, M. (2007). Effects of imagery training on cognitive performance and use of physiological measures as an assessment tool of mental effort. *Brain and Cognition, 64*, 74–85.

[33] Pattyn, N., Neyt, X., Henderickx, D., & Soetens, E. (2008). Psychophysiological investigation of vigilance decrement: Boredom or cognitive fatigue? *Physiology & Behavior, 93*, 369–378

[34] Peper, Gibney, Tylova, Harvey, and Combatalade's (2008) *Biofeedback Mastery: An Experiential Teaching and Self-Training Manual*. Published by the Association for Applied Psychophysiology and Biofeedback, First Edition. pp 1-2

[35] Prinzel, L. J., Pope, A. T., & Freeman, F. G. (2001). *Application of Physiological Self-Regulation and Adaptive Task Allocation*

Techniques for Controlling Operator Hazardous States of Awareness. (Publication NASA/TM-2001-211015). Langley Research Center, Hampton, Virginia

[36] Schmidt FL, Hunter JE. 1998. The validity and utility of selection methods in personnel psychology: practical and theoretical implications of 85 years of research findings. Psychol. Bull. 124:262–74

[37] Schmidt, F. L. (2002). The role of general cognitive ability and job performance: why there cannot be a debate.*Hum. Perform*. 15, 187–210. doi: 10.1080/08959285.2002.9668091

[38] Schmidt, F.L., Hunter, J.E.&Outerbridge,A.N. (1986). Impact of job experience and ability on job knowledge, work sample, performance, and supervisory ratings of job performance. Journal of Applied Psychology, 71, 432-439.

[39] Schmidt, F. L., & Hunter, J. E. (2004). General mental ability in the world of work: Occupational attainment and job performance. *Journal of Personality and Social Psychology, 86*(1*), 162-173.

[40] Stansfeld, S. A., Fuhrer, R., Head, J., Ferrie, J., & Shipley, M.(1997). Work and psychiatric disorder in the Whitehall II Study. Journal of Psychosomatic Research, 43(1), 73–81.

[41] Sutarto,AP, Wahab,MNA ,Zin, NM (2010) Heart Rate Variability (HRV) biofeedback: A new training approach for operator's performance enhancement - Journal of industrial engineering and Management.

[42] Sutarto, A.P., Abdul Wahab, M.N. (2008, September). *Biofeedback Technique for improving Human Operators' Cognitive Performance.* Paper presented at the Fifth International Cyberspace Conference on Ergonomics, Sarawak, Malaysia.

[43] Sutarto, A.P., Abdul Wahab, M.N., & Mat Zin, N. (2009, October). *Smart Kit for Operators' Performance*. Poster session presented at the International Exposition of Research and Invention of Institutions of Higher Learning 2009, Kuala Lumpur, Malaysia.

[44] Task Force of the European Society of Cardiology and the North American Society of Pacing and

Electrophysiology (1996). Heart rate variability: Standards of measurement, physiological interpretation, and clinical *Circulation, 93*, 1043-1065.

[45] Tinius, T.P. (2003), The Integrated Visual and Auditory Continuous Performance Test as a neuropsychological measure. Archives of Clinical Neuropsychology Volume 18, Issue 5, July 2003, Pages 439–454

[46] Tong S and Thakor N.(2009) (Editors) Advances in quantitative EEG methods and clinical applications, Artech House Press (Boston),

[47] Vernon, David J. (2005). Can Neurofeedback Training Enhance Performance? An Evaluation of the Evidence with Implications for Future Research; Applied Psychophysiology and Biofeedback; December, Volume 30, Issue 4, pp 347-364

[48] Viswesvaran, C., & Ones, D. S. (2000). Perspectives on models of job performance. International Journal of Selection and Assessment, 8(4), 216-226.

[49] Wang ,J-R,. Hsieh,S,. (2013),. Neurofeedback training improves attention and working memory

performance . Clinicall Neuaophysiology ,in press.

[50] Zoefel, B,. Huster , R J,. Herrmann, C S,. (2011). Neurofeedback training of the upper alpha frequency band in EEG improves cognitive performance,. NeuroImage 54 (2011) 1427–1431.