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Stress and EEG

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1. Introduction

Many people suffer from stress in their everyday life. While there is a close relationship between stress and mental health, psychological stress (and associated emotions such as anger, anxiety, and depression), can also have effects on physical health. Indeed, chronic psychological stress can change the responsiveness of central-peripheral regulatory systems (Fuchs & Fluegee 1995; Fuchs, Uno, & Fluegge 1995), potentially rendering them less efficient or adaptive in terms of supporting health. Conditions such as chronic stress, depression, and anxiety have been found to be associated with abnormal autonomic nervous system (ANS) functioning (Cohen et al., 2000; Hughes & Stoney 2000). Accordingly, stress is one of the major factors contributing to chronic disorders (Decker et al., 1996; Lawrence & Kim 2000).

Stress also influences the desire to work, performance at work, and one's general attitude toward life (NIOSH, 1999). Within the industry sector, higher stress levels and stress-related disease lead to decrease in company performance and increase in medical expenses (Cooper, 1996; Manning, et al., 1996). In 2008 in Korea, there were 1,967 deaths associated with occupational cases. Almost half of these deaths (974, or 49.5%) could be ascribed to heart or brain blood vessel disease (Ministry of Labor, 2008). This is not surprising given that stress is implicated in 75% of all heart and brain blood vessel diseases (Belkic, et al., 2004). It is thus apparent that stress can increase social and economic losses and decrease a country's competitiveness (Driskell & Salas, 1996). Therefore, precautionary measures to reduce stress and adequate management of this condition are essential for both individual health and the welfare of society at a broader level.

This chapter reports on relationships among psychological stress, the EEG (Electroencephalogram), ECG, and salivary cortisol in people suffering from chronic stress. We hypothesized that chronic stress will have negative effects on the central-ANS and physiological responsiveness. There are many bio-signal channels by which stress can be potentially quantified, including ECG, EEG, and the skin conductance response (SCR) (Kohlish & Schaefer 1996; Gevins et al., 1998). Even so, determining the stress level of any given individual can be difficult. Related to this is debate concerning the extent to which the EEG can be used to reliably measure stress. However, this chapter presents data showing that there are significant correlations between EEG measures and other indices of stress, including the ECG and salivary cortisol. Also, it revealed relationships between high beta

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frequency EEG activity and each of HRV, measured as the standard deviation of all normal RR intervals (SDNN) and salivary cortisol during several different conditions. Our results suggest that inter-individual differences in stress can be reliably assessed by EEG.

2. The stress response

The human nervous system is very complex and contains two major divisions: central and peripheral. The peripheral nervous system includes the ANS, which has a particular association with negative psychological states such as stress, anxiety, and depression.

The ANS performs and regulates automatic bodily functions associated with breathing, heart rate, digestion, and the hormonal system. The ANS itself has two parts: sympathetic and parasympathetic. The sympathetic and parasympathetic nervous systems initiate the stress and relaxation response, respectively.

There is normally a balance maintained between the activities of the sympathetic and parasympathetic nervous systems. Chronic stress can disturb this balance and thereby cause stress-related health problems to arise.

When one is exposed to a physical or psychological stressor, the brain initiates a stress response, from which a series of chemical reactions ensue. The stress response is a healthy defense mechanism and involves the release of hormones that have numerous biochemical and physiological effects. However, the continued release of these hormones under conditions of chronic stress can have detrimental effects on health.

Indeed, the hormonal response associated with long-lasting stress increases the risk of many diseases, including heart disease, stroke, and angina. Stress hormones can weaken the immune system and thus promote vulnerability to infection. Stress hormones also trigger increases in blood pressure, heart rate, and respiration and raise the risk of stroke, heart attack, and kidney diseases (Noback et al., 1986).

Cognitive and physiological processes of the central nervous system (CNS) associated with stress are known to affect most organs of the human body.

The stress response involves activation of regulatory centers in the CNS that stimulate both the hypothalamic-pituitary-adrenal (HPA) axis and ANS.

The HPA axis is one of the major systems involved in the stress response. It facilitates adaptations to changes in the internal or external conditions of the body. The stress response involves central and peripheral changes that are coordinated by the CNS. The release of glucocorticoids (GCs) such as cortisol is controlled by the paraventricular nucleus of the hypothalamus, in which parvocellular neurons synthesize and release corticotrophin-releasing hormone (CRH) as a response to stress. These neurons also secrete other hormones, including arginine vasopressin. The combined actions of arginine vasopressin and CRH activate the HPA axis. The release of CRH into the pituitary portal system induces the pituitary to release adrenocorticotropic hormone (ACTH), which in turn induces the release of GCs from the adrenal cortex. GCs exert negative feedback on the hypothalamus and pituitary gland that serves to terminate the stress response when no longer required, thereby preventing excessive responses. GCs are involved in many aspects of the stress response; they facilitate adaptation of the body to changing conditions by regulating energy stores, inhibiting nonessential physiological activity, and promoting behavioral responses to stimuli perceived as stressful (Johnson et al., 1992; Bao et al., 2008).

3. Assessing levels of stress

3.1 Psychological assessment

The stress response can be measured and evaluated in terms of perceptual, behavioral, and physical responses. The evaluation of perceptual responses to a stressor involves subjective estimations and perceptions. Indeed, self-report questionnaires are one of the most common instruments used to measure an individual's level of stress (Cohen et al., 1997). Numerous questionnaires have been used in clinical practice and psychiatric research to evaluate stress, including the Perceived Stress Scale (PSS) (Cohen et al., 1983), the Life Events and Coping Inventory (LECI) (Lewis, 1988), and the Stress Response Inventory (SRI) (Koh et al., 2001). The PSS measures the degree to which situations are considered stressful, doing so by addressing events experienced in the preceding month. It was designed to quantify how unpredictable, uncontrollable, and overloaded adults find their lives. The LECI is composed of 125 questions that assess the extent to which children experience stress in association with life events. The SRI is designed for adults, but it differs from the PSS in assessing the mental and physical symptoms associated with psychological stress; it consists of 39 items and produces scores for seven factors: tension, aggression, somatization, anger, depression, fatigue, and frustration.

3.2 Physical assessment

The physical response to stress has two components: these are a physiological response indicative of central-autonomic activity and a biochemical response involving changes in the endocrine and immune systems (Cohen, Kessler & Gordon 1997).

3.2.1 Biochemical response

Stress induces changes in autonomic function and the secretion of hormones that include cortisol, corticosterone, and adrenal catecholamines (Van der Kar & Blair 1999).

The presence of stress hormones such as adrenaline, noradrenaline, and cortisol can be considered indicative of a stress response. Some studies have reported that repeated exposure to intense stress increases the secretion of cortisol (Schulz et al., 1998; Evans et al., 2001). Cortisol levels can be measured in numerous bodily fluids, including serum, urine, and saliva.

There is a daily cycle in cortisol levels, which are normally high in the morning and low at night (Stone et al., 2001). However, repeated exposure to stress decreases the ability to regulate cortisol levels, leading to an elevated level that remains high at night. In such case, the levels may become abnormally low and show very little variation (Dallman, 1993; Pruessner et al., 1999). It has been shown that there are relationships between salivary cortisol levels and physiological variables used to assess stress, including HRV, skin temperature, blood pressure (BP), heart rate (HR), and galvanic skin response (GSR). Accordingly, salivary cortisol is routinely used as a biomarker of psychological stress and associated mental or physical diseases. Exposure to long-lasting stressors often results in elevated cortisol levels (Bigert, Bluhm, & Theorell 2005). Indeed, salivary cortisol is generally considered to be a reliable measure of HPA adaptation to stress (Park, & Kim 2007).

3.2.2 HRV (Heart rate variability)

Stress induces a change in autonomic functioning (Van der Kar & Blair 1999). Blood pressure and heart rate increase during stress, reflecting a predominance of sympathetic

nervous system activity (Ritvanen et al., 2005). HRV is the beat-to-beat variation in heart rate, and it has recently been used as a biomarker of ANS activity associated with mental stress (Zhong et al. 2005). Time domain analysis of HRV involves quantifying the mean or standard deviation of RR intervals. Frequency domain analysis involves calculating the power of the respiratory-dependent high frequency and low frequency components of HRV. While high frequency power is mediated by vagal activity (Hayano et al., 1991), it has been suggested that low frequency power primarily reflects sympathetic modulation (Pomeranz et al., 1985; Malliani et al., 1991). Many studies have investigated abnormalities in ANS functioning associated with stress, with HRV as one of the measures shown to be affected (Salahuddin et al., 2007). Mental stress is reported to evoke a decrease in the high frequency component and an increase in the low frequency component of HRV (Bernardi et al., 2000). Job stress has been shown to induce excessive levels of sympathoadrenal activation, leading to increases in blood pressure and heart rate, the secretion of catecholamines, and the release of lipids and glucose into the bloodstream (Theorel et al. 1993). Abnormalities of ANS functioning (Horsten et al. 1999) that include decreased HRV are associated with mental stress in laboratory experiments (Myrtek et al. 1996; Sloan et al. 1994). Moreover, lower than normal HRV has been found in subjects with depression, high levels of hostility, and anxiety. Low HRV may reflect an inability to generate variable and complex physiological responses, rendering an individual physiologically rigid and vulnerable (Horsten et al. 1999). Sustained autonomic activation can result in arrhythmia or sudden heart attack because of an increase in sympathetic and decrease in parasympathetic activity.

3.2.3 EEG

In healthy people not experiencing stress, there is a balance between the sympathetic and parasympathetic arms of the ANS and flexibility in how these respond. Exposure to threatening situations induces a fight-or-flight response whereby emotional and vigilance systems are activated. Although most current day stress arises from psychosocial factors that are not life threatening, the fight-or-flight response may still be generated, for example, during tests or when called upon to give an impromptu speech (Johannes et al 2007). Studies into brain activity patterns under stressful conditions have focused on stress generated by words, examinations, noise, and mental tasks (Matsunami et al., 2001; Lewis et al., 2007; Tucker 1981; Davidson et al., 1979; Seo et al., 2008a; Seo et al., 2009).

A major aspect of neurophysiological research into emotion concerns hemispheric specialization. While the left hemisphere appears to be more involved in the processing of positive emotions and approach-related behaviors, the right hemisphere is more involved in the processing of negative emotions and withdrawal behaviors (Coan & Allen, 2004; Davidson, 2003). These differences are represented by a model of emotional processing in which the frontal cortex plays a key role. Evidence supporting this model has been obtained from studies concerning asymmetry in prefrontal EEG alpha activity. Positive moods or reactions have been shown to be associated with relatively greater left prefrontal activity (LFA) and negative moods or reactions with relatively greater right prefrontal activity (RFA) (Davidson, Jackson & Kalin, 2000).

The results of recent neuroimaging studies suggest that negative affect typically elicits activation in the right prefrontal cortex, amygdala, and insula, and the left prefrontal cortex is associated with positive emotions (Davidson; 1992). The right prefrontal cortex may be critically involved in the response to stress, since it is a fundamental component of both the

emotional and vigilance networks. Some studies suggest that high levels of right-sided prefrontal activation are associated with a negative affective style and weakened immune system. For example, Davidson has reported that differences in prefrontal activity asymmetry reflect individual differences in affective styles (Bierhaus et al., 2003; Epel et al., 2004). Importantly, the prefrontal cortex may mediate the extent to which psychosocial stress affects mental and physical health (Segerstrom & Miller 2004; Cohen et al., 1993).

There appear to be differences in how activity of the left and right cortical hemispheres affects ANS functioning. Moreover, the extent of this asymmetry has been suggested to vary under conditions of chronic stress (Papousek, 2002). Related effects are reported for stress-related emotions, with preferential right hemispheric activation in the frontopolar region shown to be associated with electrodermal activity (EDA) in anxious subjects (Papousek & Schulter, 2001).

4. Neurofeedback

The side effects and inconvenience associated with long term use of medications has facilitated an interest in alternative therapies and self-regulation for maintaining health.

Alternative therapies such as yoga, meditation, and Ki Gong are widely used to manage stress. These therapies induce relaxation or decrease psychophysiological arousal by reducing the activities of the sympathetic nervous system. Another therapeutic approach involves biofeedback, in which ANS variables such as heart rate, blood pressure, skin tension, and temperature are regulated. Biofeedback has been applied to mental diseases such as anxiety and depression and to psychosomatic diseases such as migraine, tension headache, and hyperpiesia (Sadock B.J. & Sadock V.A. 2004). Neurofeedback is biofeedback using brain waves and has specific applications for brain diseases and associated symptoms (Ahn, 2006; Park, 2006). There have been many recent studies concerning the utility of neurofeedback within clinical medicine. Conditions for which neurofeedback has been most intensively used include alcoholism, epilepsy, ADHD, brain injury, and mood disorders (Peniston E.G., 1999; Mann C.A., 1992; Byers A.P., 1995; Baehr E., 2001). In a more general sense, neurofeedback has been demonstrated to improve concentration, memory, and musical performance (Gruzelier J, 2005).

Subjects undergoing neurofeedback training attempt to regulate their brain waves, wherein special signals are presented to the subject in a suitable form. Via operant conditioning, this feedback facilitates a subject's ability to adopt a desired brain wave state. Neurofeedback training focuses upon two components of the EEG spectrum: synchronized beta waves and alpha waves. Alpha waves reflect a calm, open, and balanced psychological state with a decrease in alpha wave activity during stress. Alpha wave training attempts to alleviate stress by inducing a state of relaxation. This involves removing or reducing habitual tendencies to respond to stressful situations with tension and anxiety.

Beta waves are associated with concentration, thought, and listening. Synchronized brain waves reflect attention or awareness or consciousness in the absence of motor activity. Synchronization at low frequencies (delta and theta) reflects awareness on an unconscious level. Conversely, synchronization of higher frequency alpha and beta waves reflects a state of conscious awareness. Beta training is reported to increase focus, concentration, energy levels, and mental clarity (Paul, 2008). Alpha and beta training supplement one another and can be used in combination to manage stress. Neurofeedback is a noninvasive technique potentially effective in reducing stress. However, there may be a particular benefit to be had

in combining neurofeedback with medications that by themselves have a limited role in managing stress.

5. Experimental methods

5.1 Participants

The participants were 33 healthy, right-handed volunteers (9 females and 24 males) aged 30–40 years old. All participants had normal hearing, and none had a neurological disorder. Informed written consent was provided by all participants before completing questionnaires or undergoing psychophysiological assessment.

5.2 SRI(Stress Response Inventory) and SAM(Self Assessment Manikin)

Stress was assessed with the SRI, which participants completed prior to physiological measurements being obtained.

The SAM (Fig. 1) has been used widely to assess the emotional response of subjects to experimental stimuli. In being pictorial it can be used with people from a diverse range of backgrounds. The SAM quantifies pleasant and unpleasant emotions on a nine-point scale (Margaret et al. 1994).

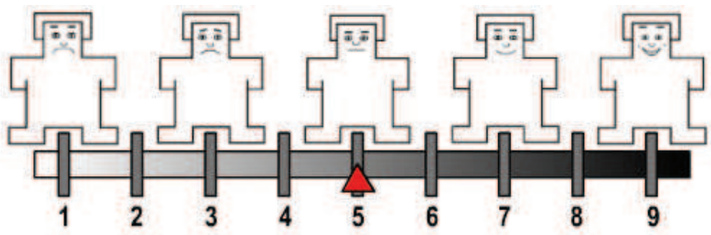


Fig. 1. SAM Valence (negative-positive)

5.3 Procedures

Visual stimuli from the International Affective Picture System (IAPS) were used to evoke emotional responses (Lang, Bradley & Cuthbert 1995). The stimuli were presented as a set of pleasant images and a set of unpleasant images. Each set lasted for 5 min, with individual images presented for 15 s. Participants made a rating with the SAM after each image set. Salivary cortisol was collected after the SRI had been completed, following which participants underwent the sequence of procedures shown in Figure 2: eyes-closed, eyes-open, pleasant images, SAM, rest, unpleasant images, and SAM. EEG and ECG recordings were obtained throughout the experiment. A 5-min portion of the ECG recording was used for short-term HRV analysis.

5.4 Cortisol

Cortisol levels quantify the endocrine response to stress. The collection of blood samples for measuring cortisol levels can be associated with greater inter-individual differences than when saliva samples are used (Park & Kim 2007). Saliva was obtained from our participants between noon and 3 pm. Cortisol levels were determined using a Solid-Phase Radioimmunoassay (RIA) Coat-A-Count Cortisol kit (Siemens, USA), as per the manufacturer's instructions, and a Gamma counter (Packard, USA).

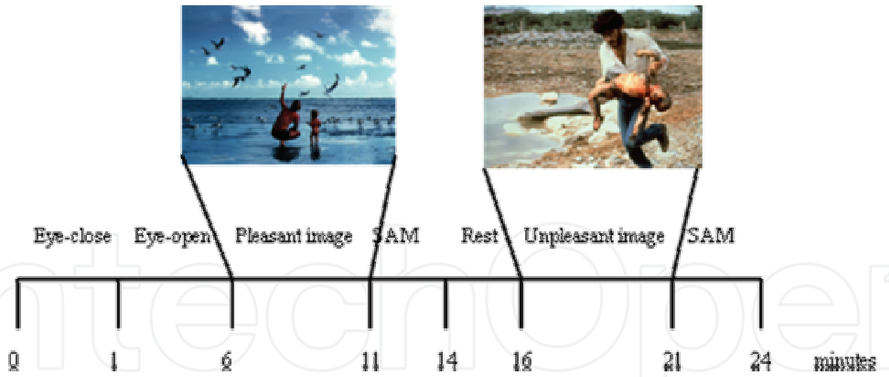


Fig. 2. Experimental sequence

5.5 ECG recording and analysis

The ECG was monitored continuously with a noninvasive system developed by us previously. Limb leads II and III were used, and the sampling rate was 512 Hz. HRV analysis requires accurate detection of the QRS complex. However, this can be difficult because ECG signals are easily corrupted by noise generated by muscular contraction or electrical power lines, and by a drift from baseline associated with respiration or motion artifacts. In addressing this issue, we used a novel QRS detection algorithm based on multi-scale mathematical morphology (3M). This was designed to specifically identify R waves, and with which successive R-R interval series could be reliably determined.

5.6 EEG recording and analysis

The EEG was recorded in each of the four conditions designed to induce different levels of stress: eyes-closed, eyes-open, pleasant images, and unpleasant images. Unpleasant and pleasant images were presented to evoke negative and positive emotions, respectively. Participants rested with their eyes closed for 1 min and with their eyes open for 5 min.

The EEG was recorded with Ag-AgCl disc electrodes from four Modified Combinatiorial Nomenclature (MCN) system sites: FC5, FC6, O1, and O2. These were specifically chosen to facilitate the detection of stress, anxiety, and dysphoria, as reflected by beta activity. The reference and ground sites were Cz and Iz, respectively. A QEEG-4 (LXE1104-RS232, LAXTHA Inc.) device obtained recordings at a sampling rate of 256 Hz. The resolution of the A/D converter was 12 bits, and electrode impedance was maintained as less than 5 kΩ.

EEG data was analyzed with Complexity v2.8 software (LAXTHA Inc.). Recordings were band-pass FFT filtered (4–30 Hz), to eliminate any influence of artifacts in the theta (4–8 Hz), alpha (8–13 Hz), and beta (13–30 Hz) ranges. Ocular artifacts were removed using a PCA-based procedure in Complexity v2.8.

5.7 Statistical analysis

Pearson's correlation was used to determine the strength of relationships among EEG, ECG (SDNN), salivary cortisol, and SRI data. Stress levels groupings of stress, non-stress and general were made with k-means cluster analysis of SDNN and cortisol data. Differences in SDNN and cortisol between these groups were examined with ANOVA. All statistical analyses were performed using SPSS v12.0, and considered to be significant at the level of $p < 0.05$.

6. Results

6.1 Relationships among EEG, ECG, salivary cortisol, and SRI data

Salivary cortisol was negatively correlated with SDNN ($r = -0.498$, $p = 0.07$). However, there was no significant relationship between SDNN and SRI, or between cortisol and SRI. In general, the high stress group showed decreased HRV features compared to the low stress group under chronic stress (Kim, Seo & Salahuddin 2008). Long lasting stress can produce elevated cortisol levels and restrict their typical overnight reduction (Bigert, Bluhm, Theorell 2005).

6.2 EEG and ECG

The relationship between SDNN and relative high beta power for each of the four EEG sites in the eyes-closed condition is shown in Table 1. There was a significant negative correlation between SDNN and relative high beta power at both the anterior temporal sites in this condition. Significant correlations were not found in any of the other conditions or at either of the occipital sites.

Recording site		
	r	**p**
FC5	–0.428	0.013
FC6	–0.346	0.049
O1	0.052	0.772
O2	0.070	0.697

Table 1. Relationships between SDNN and high beta activity in the eyes-closed condition

Table 2 shows the results of the k-means cluster analysis by which stress level groupings based on SDNN data were made.

	Cluster center			**ANOVA**	
	Stress (N = 13)	**Non-Stress (N = 9)**	**General (N = 11)**	**F**	**p**
SDNN	24.64	50.77	36.75	71.077	0.000

Table 2. K-means cluster analysis of SDNN data

The mean high beta power at the anterior temporal sites of each SDNN group is shown in Figure 3. There was a significant difference in high beta activity across the groups at FC5 ($F = 4.271$, $p = 0.023$) but not at FC6 ($F = 2.262$, $p = 0.122$). The stress group (with relatively low SDNN) had the highest level of beta activity.

6.3 Relationships between salivary cortisol and EEG data

The relationship between salivary cortisol level and relative high beta power at each of the four EEG sites in the eyes-closed condition is summarized in Table 4. In this condition, there was a significant positive correlation between the cortisol level and relative high beta power at both the anterior temporal sites, and a tendency toward a similar relationship at one of the occipital sites (O2). Significant relationships were not found in any of the other conditions.

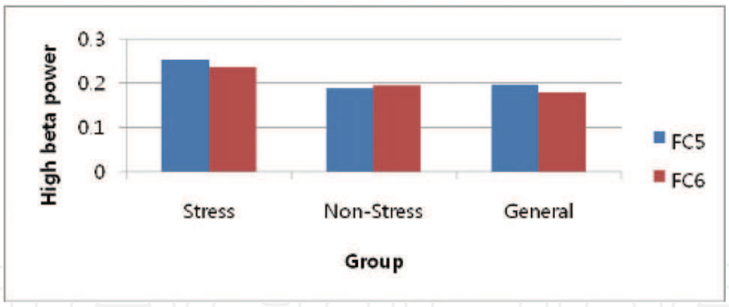


Fig. 3. Relative high beta power in each of the three SDNN-based stress level groups

Recording site		
	r	p
FC5	0.454	0.008
FC6	0.439	0.011
O1	0.247	0.165
O2	0.334	0.057

Table 3. Relationships between cortisol and high beta activity in the eyes-closed condition

Table 4 shows the results of the k-means cluster analysis by which stress level groupings based on cortisol data were made.

	Cluster center			ANOVA	
	Stress (N = 8)	Non-Stress (N = 10)	General (N = 15)	F	p
Cortisol (ug/dL)	0.32	0.11	0.21	71.378	0.000

Table 4. K-means cluster analysis of cortisol data

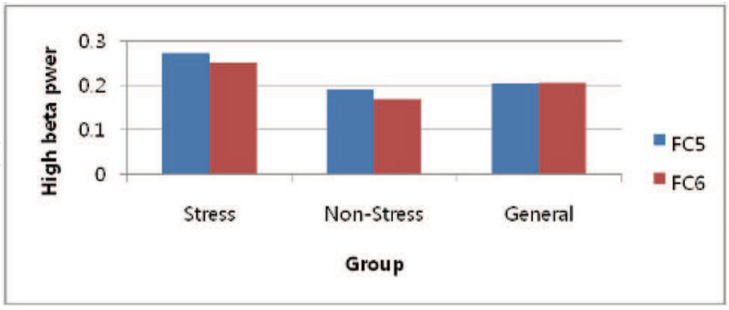


Fig. 4. Relative high beta power in each of the three cortisol-based stress level groups

The mean high beta power at the anterior temporal sites of each cortisol group is shown in Figure 4. There was a significant difference in high beta activity across the groups at both FC5 ($F = 5.556$, $p = 0.009$) and FC6 ($F = 3.635$, $p = 0.039$) sites. The stress group (with relatively high cortisol levels) had the highest level of beta activity.

The relationship between salivary cortisol level and relative high beta power at each of the four EEG sites in the eyes-closed condition is summarized in Table 4. In this condition, there was a significant positive correlation between the cortisol level and relative high beta power at

both the anterior temporal sites, and a tendency toward a similar relationship at one of the occipital sites (O2). Significant relationships were not found in any of the other conditions.

7. Discussion

There are three major results to report from the present study. The first of these is a significant correlation between HRV and salivary cortisol (but not between HRV and SRI scores). Second, significant correlations exist between relative high beta EEG power at anterior temporal sites and each of HRV and salivary cortisol during an eyes-closed resting condition. The third finding is a difference in the relative high beta power across stress level groups determined on the basis of SDNN and cortisol data. In both instances, the stress group participants had the highest level of beta activity.

Chronic stress leads to increase in the variability of central-autonomic responses and decrease in physiological adaptability and immunity (Fuchs & Fluegee 1995; Fuchs, Uno & Fluegge 1995; Cohen et al., 2000; Hughes & Stoney 2000). There have been many studies using biosignals to quantify the stress associated with mental tasks or work load in healthy subjects (Jeon et al., 2002). These studies have established that biomarker profiles can distinguish between people experiencing chronic stress and those who are not, with sufferers of chronic stress typically having lower HRV and higher cortisol levels. The findings of the present study are thus consistent with those of previous research.

Although many researchers have reported EEG abnormalities as being associated with stress and negative emotions, the extent to which stress can be reliably evaluated from the EEG has been unclear. Recent EEG research on emotion has focused on relationships between dorsolateral prefrontal asymmetry and a dispositional tendency toward positive or negative affects (Davidson 2004). However, some researchers have suggested a need to pay more attention to frontopolar regions of the prefrontal cortex (Papousek & Schulter 2002). Thompson has indicated that the EEG of someone under stress displays decreases in both alpha (11–12 Hz) and sensorimotor rhythm (SMR, 12–15 Hz) activity, and increases in EEG amplitude in the 19–22 Hz and high beta (23–35 Hz) ranges at both Cz and FCz sites (Michael & Lynda 2007). Emotional intensity, particularly relating to anxiety, correlates with 19–22 Hz band activity, while activity within the 23–36 Hz band reflects an active brain state. Accortt has reported a relationship between premenstrual distress and frontal EEG alpha, an effect especially pronounced at the anterior temporal sites (Accortt & Allen 2006). It has also been found that beta rhythms are predominant under resting conditions in bilateral superior temporal and somato-motor regions of the cortex (Mantlnl et al., 2007), both of which are implicated in emotional processes (Hagemann et al., 1998; Davidson et al., 1990).

In the present study, we found a correlation between HRV and high beta activity at anterior temporal sites (FC5, FC6) during the eyes-closed condition. We also found a correlation between salivary cortisol and high beta activity in this condition. These results show that participants with relatively low HRV had relatively high levels of beta activity in premotor regions of the cortex. Participants with a higher level of salivary cortisol also had a higher level of beta activity. These results suggest that there are close relationships among EEG, ECG, and salivary cortisol indicative of chronic stress. Chronic stress was particularly associated with high levels of relative beta power at anterior temporal sites.

We assigned participants to stress level groups on the basis of SDNN and salivary cortisol data. Greater stress was associated with lower HRV (i.e., lower SDNN values) and a higher level of cortisol. The group with the highest stress level showed the highest level of beta activity during the eyes-closed condition. However, there were no significant correlations

among EEG, ECG, and salivary cortisol data during any of the other conditions: eyes-open, pleasant images, and unpleasant images. These correlations need to be analyzed because of the difference in individual responses to stimuli. Participants experiencing chronic stress showed less HRV than those who were not. Range of variance of HRV features according to stimuli was little.

Finally, the present study demonstrated that there are consistent relationships among EEG, ECG, and salivary cortisol data associated with chronic stress. In addition to confirming the results of previous studies, our results suggest that chronic stress may be reliably assessed by relative high beta EEG power at anterior temporal sites. Indeed, this variable could even be seen as a diathesis for the dysphoria associated with chronic stress.

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Starting a journey on the new path of converging information technologies is the aim of the present book. Extended on 27 chapters, the book provides the reader with some leading-edge research results regarding algorithms and information models, software frameworks, multimedia, information security, communication networks, and applications. Information technologies are only at the dawn of a massive transformation and adaptation to the complex demands of the new upcoming information society. It is not possible to achieve a thorough view of the field in one book. Nonetheless, the editor hopes that the book can at least offer the first step into the convergence domain of information technologies, and the reader will find it instructive and stimulating.

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