The Effect of Photo-Stimulation on the Autonomic Nervous System
As Measured by Entrainment Ratios of Heart Rate Variability

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ABSTRACT

The Effect of Photo-Stimulation on the Autonomic Nervous System As Measured by the Ratio of Entrainment of Heart Rate Variability

A study was undertaken to evaluate the effect of photo-stimulation on the autonomic nervous system as measured by entrainment ratios of heart rate variability (HRV). Sixty subjects were recruited through both a primary care clinical practice setting and personal contacts. Exclusion criteria included known seizure disorder or activity and use of certain medications, specifically beta blockers and calcium channel blockers. After completing a health screening tool and signing an informed consent, eligible subjects were randomized into control verses intervention group by means of drawing a piece of paper from a can that had printed on it either the word "star" [signifying control group assignment] or the word "balloon" [signifying intervention group assignment]. The can contained a total of sixty pieces of paper, thirty with the word star and thirty with the word balloon on them. A baseline recording of HRV of fifteen minutes duration, utilizing the Freeze Framer™ program was obtained on each subject. Following the baseline recording, the intervention group used a brain wave synchronizer (BWS), a form of photo-stimulation, set at the lowest frequency (theta) and the lowest illumination with their eyes closed for fifteen minutes while their HRV was measured for another fifteen minute session. The hypothesis tested was: Utilization of BWS for fifteen minutes, as a passive method of balancing the autonomic nervous system (ANS), will result in a shift to higher ratio levels of entrainment of HRV. Analysis of the data does not support acceptance of the hypothesis. While some subjects in the intervention group achieved a shift to higher levels of entrainment of HRV, the majority did not.

CHAPTER I

INTRODUCTION

Today's informed health care consumer has become dissatisfied with the health care system that exists in the United States. Astute consumers see that the system is focused on "illness" care, trying to get the horse back in the barn after it has been let out, rather than on "preventive" care, trying to keep the horse in the barn – so to speak. With the apparent failure of the current conventional medical system, there has been an increased interest in the use of alternative forms of health care in America. According to Eisenberg, et al., (1998), there has been an increase in visits to alternative therapists from four hundred twenty-seven million in 1990 to six hundred twenty-nine million in 1997. The primary reason given for visits to alternative therapists was for treatment of chronic illnesses. The number of visits to alternative therapists exceeds the total number of visits to all U.S. primary care physicians (Eisenberg, et al., 1998).

As a primary care provider my greatest clinical challenges come in the care of patients with chronic illnesses. While high tech, high cost, drug driven health care approaches continue to fail many patients who present as multi-dimensional, chronic health crises, frustration sets in for both provider and patient when the "conventional" system comes up short. All too often providers are either uninformed or too skeptical to look beyond the confines of their conventional health care education to find answers for those patients who suffer the most.

Compounding the failure of the system is the fact that often it is difficult for the chronically ill population to see and/or acknowledge their role in their health care and healing journey. Even when courageous practitioners are willing to go beyond the confines of the “envelope” of conventional medicine and recommend alternative health care approaches in an attempt to facilitate healing for individuals with chronic illness, the patient is not always willing to be an active participant in their own healing process. Patients may have arrived at this point as a result of a lack of faith in the conventional system that has failed them time and time again, or a lack of insight into the psychological, emotional or spiritual “distress” component of their illness. Partnering of the patient in the healing process is fundamental in alternative health care approaches.

Reflected in current literature are studies which explore the concept of “intent” in health care processes. Research reflecting this concept was conducted by McCraty, Atkinson, and Tomasino (2001), in both the laboratory and the field, which demonstrated that use of a positive emotion-focused technique of heart rhythm coherence feedback training resulted in beneficial psychological and physiological health care outcomes across diverse populations. Can positive health care outcomes be facilitated without the deliberate evocation of “intent” by the patient?

It has been postulated that “stress” plays a major role in the development of contemporary chronic illness (Anderberg, 2001). The physiological responses to stress are varied yet predictable and have been well defined and investigated for nearly a century. Altered health states, particularly those noted in chronic illnesses, are resultant from the imbalances of the body systems as a result of the physiologic effects of stress.

Many researchers have demonstrated that activities performed with “intent” have powerful balancing capabilities on body systems, particularly the autonomic nervous system. The aim of this study is to determine if a “passive” mechanism for achieving physiological balance can be achieved with the use of photo-stimulation as a mechanism of brain wave synchronization. McCraty, Tiller, and Atkinson (1996) demonstrated that "intentional" entrainment of HRV resulted in a reflexive entrainment or "frequency pulling" of brain wave activity. Is a reflexive entrainment or "frequency pulling" of HRV achievable through "passive" use of a BWS?

CHAPTER II

REVIEW OF THE LITERATURE

The following pages contain a review of the literature regarding the concepts central to this project. Exploration will be made regarding the functioning of the autonomic nervous system, the concept of stress, and physiologic responses to stress noted in the autonomic nervous system. To encourage the reader, techniques performed with "intent" proven to combat the negative physiologic effects of stress are presented as well, followed by a discussion of the additive value of the power of personal belief systems in maximizing outcomes.

Concepts relative to a widely accepted, and extensively used, measure of autonomic nervous system balance are explored. An alternative health care approach, "passive" in nature yet validated through research for balancing certain aspects of physiology, is presented to the reader. At the conclusion of this chapter is presented information found in the literature of published research that relates to this project.

The Hypothalamus and the Autonomic Nervous System

The Hypothalamus

The main function of the hypothalamus is homeostasis, or maintaining the "status quo" of the body. Factors such as blood pressure, body temperature, fluid and electrolyte balance, and body weight are held to a precise value referred to as the "set point". Although this set point can migrate over time, from day to day it remains remarkably fixed. To achieve this task, the hypothalamus must receive input about the state of the body and must be able to initiate compensatory changes when processes drift from homeostasis. Input systems include the following:

- Nucleus of the solitary tract – this nucleus collects all of the visceral sensory information from the vagus and relays it to the hypothalamus and other targets. Information includes blood pressure and gut distention.
- Reticular formation – this catch all nucleus in the brainstem receives a variety of inputs from the spinal cord. Among these inputs is information about skin temperature which is in turn relayed to the hypothalamus.
- Retina – some fibers from the optic nerve go directly to a small nucleus within the hypothalamus called the suprachiasmatic nucleus. This nucleus regulates circadian rhythms and couples the rhythms to dark and light cycles.
- Circumventricular organs – these nuclei are located along the ventricles and are unique in that they lack a blood-brain barrier. This allows them to monitor substances in the blood that would normally be shielded from neural tissue. Examples include sensitivity to changes in osmolarity and toxins in the blood which project to the hypothalamus.
- Limbic and olfactory systems – structures such as the amygdala, the hippocampus, and the olfactory cortex project to the hypothalamus. These structures help to regulate behaviors such as eating and reproduction.
- Intrinsic receptors – the hypothalamus contains intrinsic thermoreceptors to monitor temperature and osmoreceptors to monitor ionic balance.

Once the hypothalamus is alerted to a problem, how does it fix it? Essentially there are two main outputs:

- Neural signals to the autonomic system – the hypothalamus projects to the medulla, where the cells that drive the autonomic systems are located. These include the parasympathetic vagal nuclei and a group of cells that descend to the sympathetic system in the spinal cord. With access to these systems, the hypothalamus can control heart rate, vasoconstriction, digestion and sweating.
- Endocrine signals to/through the pituitary – the endocrine signal is a chemical signal that travels via the bloodstream. Large hypothalamic cells around the third ventricle send their axons directly to the posterior pituitary where the axon terminals release oxytocin and vasopressin into the bloodstream. Smaller cells in the same area send their axons only as far as the base of the pituitary where they empty releasing factors into the capillary system of the anterior pituitary. These releasing factors induce the anterior pituitary to secrete one of six hormones, including adrenocorticotropic hormone (ACTH) and thyroid stimulating hormone (TSH). Ultimately the hypothalamus can control every endocrine gland in the body and alter blood pressure (through vasopressin and vasoconstriction), body temperature, metabolism (through TSH), and epinephrine levels (through ACTH) [http://hypothalamus.wustl.edu/course/hypoANS.html].

<u>The Autonomic Nervous System</u>

The autonomic nervous system (ANS), in a sense, is an entire “little brain” unto itself. The name comes from “autonomous” and it serves to regulate bodily functions without our awareness or control. The ANS is predominantly an efferent system transmitting impulses from the central nervous system (CNS) [especially the hypothalamus and the medulla oblongata] to the peripheral organ systems. Effects of the ANS include control of heart rate, force of heart contraction, constriction and dilation of blood vessels, contraction and relaxation of smooth muscle in various organs, visual accommodation, pupil size and secretions from the exocrine and endocrine glands. Autonomic nerves constitute all of the efferent fibers that leave the CNS, except those which innervate skeletal muscle. Afferent autonomic fibers transmit information from the periphery to the CNS. Afferent fibers are concerned with the mediation of visceral sensation and the regulation of vasomotor and respiratory reflexes, notably the baroreceptors and the chemoreceptors in the carotid sinus and aortic arch which are important in the control of heart rate, blood pressure and respiratory activity. Usually afferent fibers are carried to the CNS by major autonomic nerves such as the vagus, splanchnic or pelvic nerves. Afferent fibers from blood vessels may be carried by somatic nerves (Bakewell, 1995).

The ANS is primarily involved in reflex arcs, involving the autonomic or somatic afferent limb, and then autonomic and somatic efferent limbs. For example, afferent fibers may transmit stimuli from pain receptors, mechanoreceptors and chemoreceptors in the heart, lungs, gastrointestinal tract and so on. Resultant may be a reflex response involving efferent fibers yielding contraction of smooth muscle in certain organs (e.g. blood vessels, eyes, lungs, bladder, gastrointestinal tract, etc.) and influencing the function of the heart and glands. The efferent limbs of these reflexes may also involve the somatic nervous system (e.g. coughing and vomiting). Simple reflexes are completed entirely within the organ concerned, whereas more complex reflexes are controlled by the higher autonomic centers in the CNS, particularly the hypothalamus (Bakewell, 1995).

On the basis of anatomical and functional differences, the ANS is divided into two separate divisions called the parasympathetic and sympathetic systems. Both systems consist of myelinated preganglionic fibers which make synaptic connections with unmyelinated postganglionic fibers which then innervate the effector organ. These synapses usually occur in clusters called ganglia. Most organs are innervated by fibers from both divisions of the ANS, and the influence is usually opposing (e.g. the vagus slows the heart, while the sympathetic nerves increase heart rate and contractility), although it may be parallel (e.g. the salivary glands) (Bakewell, 1995).

Parasympathetic Nervous System

The preganglionic outflow of the parasympathetic nervous system (PNS) arises from the cell bodies of the motor nuclei of cranial nerves II, VII, IX and X in the brain stem and from the second , third and fourth sacral segments of the spinal cord. Therefore, it is often known as the cranio-sacral outflow. Preganglionic fibers run almost to the organ which is innervated and synapse in ganglia close to or within that organ which gives rise to postganglionic fibers which then innervate the relevant tissue. Cranial nerves III, VII and IX affect the pupil and salivary gland secretion while cranial nerve X (the vagus nerve) carries fibers to the heart, lungs, stomach, upper intestines and ureters. The sacral fibers form the pelvic plexuses which innervate the distal colon, rectum, bladder and reproductive organs (Bakewell, 1995).

Physiologically speaking, the PNS is concerned with conservation and restoration of energy. Stimulation of the PNS produces a reduction in heart rate and blood pressure, and facilitates digestion and absorption of nutrients, and consequently the excretion of waste products. Often these responses are referred to as the “rest and digest” phenomenon (Bakewell, 1995).

The chemical transmitter at both pre- and postganglionic synapses in the PNS is acetylcholine (ACH). ACH is also the neurotransmitter at the sympathetic preganglionic synapses, some sympathetic postganglionic synapses, the neuromuscular junction (somatic nervous system), and at some sites in the CNS. Nerve fibers that release ACH from their endings are described as cholinergic fibers. The synthesis of ACH occurs in the cytoplasm of nerve endings and is stored in vesicles in the pre-synaptic terminal. Arrival of pre-synaptic action potential causes an influx of calcium ions and the release of the ACH contents of several hundred vesicles into the synaptic space. The ACH then binds to specific receptors on the postsynaptic membrane and increases the membrane permeability to sodium, potassium and calcium ions creating a post-synaptic excitatory potential. Action of ACH can be terminated by hydrolysis with an enzyme, namely acetyl cholinesterase (Bakewell, 1995).

ACH receptors have been classified pharmacologically by the actions of the alkaloids – muscarine and nicotine. The action of ACH at the preganglionic synapses in both parasympathetic and sympathetic systems is mimicked by nicotine. All autonomic ganglia are therefore termed nicotinic. Nicotinic transmission occurs also at the neuromuscular junction, in the CNS, the adrenal medulla and at some sympathetic sites. However the actions of ACH at the parasympathetic postganglionic nerve ending is mimicked by muscarine. Muscarine transmission also occurs at certain sites in the CNS (Bakewell, 1995).

Sympathetic Nervous System

In contrast to the PNS, the sympathetic nervous system (SNS) enables the body to be prepared for fear, flight or fight. SNS responses include an increase in heart rate, blood pressure and cardiac output. Additionally blood flow is diverted from the skin and splanchnic vessels to those supplying skeletal muscle, increased pupil size, bronchial dilation, contraction of sphincters and metabolic changes which include mobilization of glycogen and fat (Bakewell, 1995).

The cell bodies of the sympathetic preganglionic fibers are in the lateral horns of the spinal segments T1 – L2, known as the thoracic-lumbar outflow. The preganglionic fibers travel a short distance in the mixed spinal nerve and then branch off as myelinated white rami to enter the sympathetic ganglia. The ganglia are arranged in two paravertebral chains which lie anterolateral to the vertebral bodies and extend form the cervical to the sacral region. They are called the sympathetic ganglionic chains. The short preganglionic fibers which enter the chain share a synapse with a postsynaptic fiber either at the same dermatome level, or at a higher or lower level. Longer postganglionic fibers usually return to the adjacent spinal nerve via unmyelinated rami and are conveyed to the effector organ (Bakewell, 1995).

Some preganglionic fibers do not synapse in the sympathetic chains but terminate in separate cervical or abdominal ganglia, or travel in the greater splanchnic nerve and directly synapse with chromaffin cells in the adrenal medulla. As previously discussed, ACH is the neurotransmitter, via a nicotinic receptor, at the preganglionic synapse. The adrenal medulla is innervated by preganglionic fibers and therefore epinephrine (also referred to in the literature as adrenaline – derived from the root word "adrenal") is released from the gland by stimulation of nicotinic ACH receptors (Bakewell, 1995).

At most postganglionic sympathetic endings, the chemical transmitter is norepinephrine (also referred to in the literature as noradrenalin). Norepinephrine is present in the pre-synaptic terminal as well as in the adrenal medulla. However, in sweat glands postganglionic sympathetic fibers release ACH and the transmission is nicotinic.

Epinephrine and norepinephrine are both catecholamines. Both are synthesized from the essential amino acid phenylalanine by a series of steps, which includes the production of dopamine. The terminal branches of sympathetic postganglionic fibers have swellings which give them the appearance of a string of beads. These swellings form the synaptic contact with the effector organ and are also serve as the site for synthesis and storage of norepinephrine. With the arrival of a nerve impulse, norepinephrine is released from granules in the pre-synaptic terminal into the synaptic space. The action of norepinephrine is terminated by diffusion from the site of action, reuptake back into the pre-synaptic nerve ending (where it is inactivated by the enzyme monoamine oxidase), or metabolism locally by the enzyme catechol-o-methyl-transferase (Bakewell, 1995).

The synthesis and storage of catecholamines in the adrenal medulla is similar to that of the sympathetic postganglionic nerve endings, but due to the presence of an additional enzyme the majority of norepinephrine is converted into epinephrine. The adrenal medulla responds to nerve impulses in the sympathetic cholinergic ganglionic fibers by transforming the neural impulses into hormonal secretion. During situations evoking physical or psychological stress, larger quantities of catecholamines are released. The actions of catecholamines are mediated by specific post-synaptic cell surface receptors (Bakewell, 1985).

Pharmacologic subdivision of these receptors into two groups (alpha and beta) was first recommended by Ahlquist in 1948. The recommendation was based on the effects of epinephrine at peripheral sympathetic sites. Receptors have been further subdivided on functional and anatomical bases. Thus beta1 adrenergic effects in the heart (increased force and rate of contraction) have been differentiated from beta2 adrenergic effects in the lungs and vasculature (smooth muscle relaxation in the bronchi and blood vessels). Similarly alpha receptor mediated effects such as vasoconstriction have been termed as alpha1 effects, to differentiate them from the feedback inhibition by norepinephrine by its own release from pre-synaptic terminals, which is mediated by alpha2 adrenoreceptors on the pre-synaptic membrane. However, further research now shows that the classification is not as simple as this. For example, many organs have both beta1 and beta2 adrenoreceptors (e.g. in the heart there is one beta2 receptor to every three beta1 receptors). Receptors also show differing responses to epinephrine and norepinephrine. At beta1 receptors in the heart, epinephrine and norepinephrine appear to have an equal effect. However beta2 receptors in smooth muscle are more sensitive to circulating epinephrine than they are to norepinephrine (Bakewell, 1995).

<u>Commentary</u>

The state of the body at any given time represents a balance between the two divisions of the ANS. Although the ANS is considered to be an “involuntary” system, this is not entirely true. An apparent amount of conscious control can be exerted over the ANS as has long been demonstrated by practitioners of Yoga and Zen Buddhism. During periods of meditation a number of ANS functions are altered to include heart rate and oxygen consumption. These changes are not simply a reflection of the decreased physical activity during meditation because the degree of change observed exceeds the degree of change observed during sleep or hibernation. Also skin temperature changes have been noted during meditation while core body temperatures remain constant (Benson, 1975).

In the health care setting value has always been placed on the ability of the patient to grasp even a simple understanding of the concepts presented above. With the level of complexity of the material, one can see that this is not a simple task. An analogy of the body as a reservoir of biochemical resources, or "biochemical soup" has been adopted as an aid to facilitating understanding. Using this analogy allows the patient to gain an understanding of the reality of finite resources available to maintain balance in the complex physiologic system we call the human body. Exploring how each presenting symptom dips into the resource "soup" provides a visual mechanism for patients to understand how on "low symptom" days their body can maintain balance fairly well and why on "high symptom" days resources are exhausted and imbalances manifest in multiple body systems. A visual image of the too many body systems "dipping" their spoon into the soup demonstrates to the patient that the contents of the bowl are finite, just like their biochemical resources are finite as well.

The Concept of Stress

Defining Stress

What is Stress? Ask a hundred people and you are likely to get a hundred different answers. According to Webster (2001), stress is defined as an applied force or system of forces that tend to strain or deform a body. One can experience physical, psychological, emotional and spiritual stress. Stress can be both a subjective and an objective phenomenon. Perception plays a large role in the subjective experience of stress. From an objective standpoint, the multiple physiologic effects of stress can be measured. The ability to measure the impact of stress, regardless the genesis, has been a major focus of research for nearly a century.

Present day investigations regarding the impact of stress have evolved from the classic work of Cannon and Selye, who described stress in terms of physiologic and biochemical responses noted in an organism under threat (Leidy, 1989). Cannon presented an evolutionary view that strong emotions such as anger and fear elicit physiologic responses that prepare the body to flee, flight, or face injury – the famous fight-or-flight phenomenon (Cannon, 1929).

According to Selye, stress is the non-specifically induced biologic response of the organism to any demand (Selye, 1976). While the genesis of the stressor may differ, the stress response itself, referred to as the General Adaptation Syndrome (GAS), is manifested in a specific and characteristic pattern of systemic biologic change. Seemingly universal in nature, the GAS as outlined by Selye, does not exclude the uniqueness and individuality in stress reactions. Stress is a consequence of the interaction that takes place between the stimulus and the response, a biologic interpretation of stress which is consistent with the term as it is used in physics to denote the force-resistance interaction (Mason, 1975; Selye, 1975).

In Selye's model, it is not necessarily the characteristics of the stressor that play a predominant role in determining the nature of the stress response and subsequent health outcomes. Secondary to the influence of internal conditioning factors, what generally may be called a 'normally well tolerated degree of stress' (Selye, 1975) can become pathogenic for individuals with vulnerable body systems, leading to diseases of adaptation.

According to Selye (1975), qualitatively different stimuli of equal potency (ability to elicit adrenocorticotropic hormone and corticoid production) do not necessarily cause the same syndrome in different individuals. Further, even the same degree of stress induced by the same stimulus may provoke different lesions in different individuals. While the GAS is comprised of commonly experienced systemic characteristics which occur regardless of cause, unique individual sensitivities influence the intensity and progression of the GAS, as well as the location and extent of specific stress manifestations and health outcomes (Selye, 1976).

Stress Responses

The focal point of Selye's theoretical and empirical work was the pituitary/adrenal-cortical aspect of the stress response described in the context of GAS. Selye defined this syndrome as a pattern of all nonspecific changes as they develop throughout time during continued exposure to a stressor (Selye, 1976). GAS is seen as a purposeful, coordinated, effort among inter-dependent biologic systems to defend the body against potential disease (Selye, 1976). GAS involves three phases of adaptation and resistance consisting of an initial/acute alarm reaction followed by a stage of resistance and concluding in a state of exhaustion (Selye, 1976).

The three phases of stress response have been defined based on experimental observations. In the alarm reaction phase one experiences a deviation in functional norms and a decline in vitality (Toussaint, et al., 2000) as well as, depression of the sympathetic nervous system, altered hematology of the blood , altered electrolytes and excess protein catabolism (Selye, 1976; Chrousos, 1998). If the stressor persists the organism enters the stage of resistance. The stage of resistance is characterized by a level of rise in resistance to the stressor and a comparable fight-or-flight reaction associated with stimulation of the sympathetic nervous system (Cannon, 1929). During this stage the sympatho-adrenal medullar system is activated, with a resultant rise in epinephrine and norepinephrine. Hemodynamic consequences include coronary artery dilation, increased myocardial contractility, and increased heart rate and increased cardiac output. Selective visceral vasoconstriction diverts blood flow away from digestive organs to the brain, heart and skeletal muscle. Aldosterone secretion from the adrenal cortex and anti-diuretic hormone from the posterior pituitary results in an increased blood volume and elevation of systolic blood pressure through retention of sodium and water (Leidy, 1989; Chrousos, 1998).

Alterations in immune responses take place during the stage of resistance also. Cortisol secreted in increased quantities from the adrenal cortex has a suppressive effect on lymphocyte and antibody formation (Leidy, 1989; Chrousos, 1998). Macrophage activity as well as the activation and conduct of the complement system are adversely affected by altered plasma concentration of corticosteroids (Munck, Guyre & Holbrook, 1984; Syvalahti, 1987; Chrousos, 1998). B-cells are susceptible to destruction by the corticosteroids and the role of the stress responsive thymus in maturation of T-cells is altered as well (Stein, Keller & Schleifer, 1985; Chrousos, 1998).

Greater quantities of glucocorticoids results in higher levels of fibrinogen, and increase in the production and adhesiveness of platelets and more rapid clotting times. Ventricular fibrillation thresholds are lowered in the presence of higher circulating levels of catecholamines (Engel, 1978; Chrousos, 1998). The sympathetic nervous system activation results in increased skeletal muscle tone and contractility (Leidy, 1989).

According to Selye (1976), every individual possesses a genetically determined amount of adaptive energy which may be spent with thrifty discretion [hence a longer life] or reckless abandon [shorter, more colorful existence]. Excess expenditure on reckless abandon will surely lead to the third phase of GAS, the stage of exhaustion. Selye's conception of the exhaustion stage is physiologically comparable to an inverted alarm reaction. It begins with resistance which gives way to manifestations of shock and ends in intense systemic damage, general system failure and death. The timing and locality of the breakdown, which varies from person to person, is dependent upon the interaction between the primary stressor, the presence of concurrent stressors, and the location of the weak links in the system (Leidy, 1989).

Modern day researchers have challenged Selye's concept of non-specificity. Pacak, et al. (1998), under took a study to test Selye's concept. These researchers compared the magnitude of responses to different stress intensities, assuming that the magnitudes vary with stress intensity; predicted was that, at different stress intensities ratios of neuroendocrine responses would be the same. Rats were used for the experiment and the conditions of hemorrhage, intravenous insulin administration, subcutaneous formaldehyde administration, exposure to cold and immobilization were achieved. Measurements of ACTH, norepinephrine and epinephrine were taken after exposure to the stressor. Exposure to cold evoked large norepinephrine responses, insulin evoked large epinephrine responses and hemorrhage evoked small norepinephrine and epinephrine responses. Creating a condition of immobilization resulted in large increases in ACTH, norepinephrine and epinephrine. When conditions of twenty-five and ten percent hemorrhage were induced the ACTH response to the larger hemorrhage was twice that of the smaller hemorrhage. The ACTH response to a four percent formaldehyde solution was twice the response of a one percent formaldehyde solution and the epinephrine response of the stronger formaldehyde was four times that of the weaker solution. Based on these findings, the researchers concluded that their results were inconsistent with Selye's doctrine of non specificity and the existence of a unitary stress syndrome; they proposed that their findings were more consistent with the concept that each stressor has its own neurochemical and peripheral neuroendocrine signature. Coming to this conclusion signifies the researchers' lack of understanding of Selye's premise that qualitatively different stimuli of equal potency do not necessarily cause the same responses. Nor would one expect doubling the intensity of physiologic stressor would result in the same level of response.

Stress and Chronic Illness

During recent decades countless numbers of researchers have looked at the physiologic effects of stress. Research has not only focused on physiologic stress but on psychological stress as well. The biologic stress response is the same whether the stressor is physical, psychological, emotional or spiritual. Many researchers have speculated as to the genesis of chronic illness. Is chronic illness genetically predisposed or simply exhaustion of the organism's ability to adequately adapt to multiple stressors?

The concept of stress encompasses the exposure of an organism or individual to a threatening stimulus or an overwhelming event. Autonomic activation in response to stressors may be beneficial up to a point, but excessive autonomic activation may have hidden costs. Autonomic and neuroendocrine activation in response to stressors mobilizes metabolic resources to support the requirements of fight or flight. However, the stressors of contemporary society often do not require or even allow behavioral fight or flight creating autonomic and neuroendocrine reactions to acute psychological stressors such that they substantially exceed metabolic requirements (Cacioppo, et al., 1998). A design for the stress physiology that worked well in the Stone Age may have maladaptive aspects that manifested as civilizations emerged and life expectancy increased well beyond the reproductive years. According to the disposable soma theory of aging, it may be "disadvantageous to increase maintenance beyond a level sufficient to keep the organism in good shape through its natural life expectancy in the wild, because the extra cost will eat into resources that in terms of natural selection are better used to boost other functions that will enhance fitness" (Lithgow & Kirkwood, 1996, pg. 80).

There are many indications that stress within the family and in the work place are strong predictors for developing stress-related disorders. The relatively new diagnoses of burnout, chronic fatigue syndrome and fibromyalgia probably represent different ways of reacting to an overwhelming situation. The boundary between these diseases on the one hand and depression and heart disease on the other hand is often blurred. These new diagnoses may delineate preliminary stages of more serious diseases such as angina pectoris or myocardial infarction (Anderberg, 2001).

DeVente, et al. (2003), investigated the differences between burnout patients and healthy controls regarding basal physiological values and physiological stress responses. Measures of the sympathetic-adrenergic-meduallary (SAM) axis and the hypothalamic-pituitary-adrenal (HPA) axis were examined. Twenty-two burnout patients and twenty-three healthy controls were compared using means of heart rate (HR) and blood pressure (BP) as measures of the SAM axis and means of salivary cortisol levels as a measure of the HPA axis. Additionally, morning cortisol levels were measured for both groups. Subjects participated in a laboratory session involving mental arithmetic and speech tasks. Researchers discovered that burnout patients demonstrated higher resting HR levels and morning cortisol levels than healthy controls suggesting that the SAM and HPA axes are disturbed among burnout patients.

Lucini, Norbiato, Clerici and Pagani (2002), tested the hypothesis that real-life stress conditions produce changes in autonomic cardiac and vascular regulation that might differ in magnitude. University students, a well established model of mild, real-life stress, were examined shortly before a university examination and again three months later during a university holiday. Autonomic cardiovascular regulation was assessed by a noninvasive technique based on autoregressive analysis of RR interval variability (RRV) and systolic arterial pressure variability (SAPV). The overall level of stress in the two samplings was gauged from the elevated salivary cortisol and altered cytokine profile. During the stress day sampling the RR interval was reduced and arterial pressure increased significantly; simultaneously the normalized low frequency component of RRV (a marker of sympathetic modulation of the sinoatrial node) was increased and the index alpha (a measure of baroreflex gain) was reduced. Concomitantly the autonomic response to sympathetic excitation produced by standing was altered: cardiac response was impaired and vascular responsiveness increased. Markers of autonomic regulation of the sinoatrial node correlated significantly with cortisol levels, both at rest and also considering standing induced changes. The data support the concept that mild, real-life stress increases arterial pressure and alters cardiovascular homeostasis. These changes, assessable with spectral analysis of cardiovascular variability might contribute, in susceptible individuals, to the link between psychological stress and increased cardiovascular risk for hypertension.

A group of researchers, Williams, et al. (2001), undertook a study with the objective to evaluate the impact of indices of central nervous system (CNS) serotonin function on cardiovascular reactivity to mental stress. Lumbar puncture was performed on fifty-four healthy volunteers to obtain cerebrospinal fluid (CSF) to ascertain the major serotonin metabolite, 5-hydroxyindoleacetic acid (5HIAA) levels. Genotypes were determined with respect to a functional polymorphism of the serotonin transporter gene promoter region (5HTTLPR). Subjects then underwent mental stress testing. Persons with one or two long 5HTTLPR alleles had CSF levels of 5HIAA that were fifty percent higher than those persons with the short 5HTTLPR genotype. Persons with the higher CSF levels of 5HIAA also exhibited greater blood pressure and heart rate responses to a mental stress protocol. The researchers concluded that the 5HTTLPR polymorphism affects CNS serotonin function, and they are consistent with the general hypothesis that CNS serotonin function is involved in the regulation of potentially health damaging biobehavioral characteristics. In particular, the long 5HTTLPR allele through its association with increased cardiovascular reactivity could contribute to increased risk of cardiovascular disease.

Gender differences in response to psychological stress were explored by Traustadottir, Bosch and Matt (2003). Researchers set out to answer the question: Do gender differences in the neuroendocrine and cardiovascular response to psychological stress contribute to the gender differences in the prevalence of diseases associated with the HPA axis reactivity such as cardiovascular disease (CVD), diabetes (DM) and hypertension (HTN)? Eight men and eight women between the ages of fifty-five to seventy-five were exposed to the Matt Stress Reactivity Protocol which is a psychological challenge. Researchers measured plasma ACTH, cortisol, heart rate (HR) and blood pressure (BP) pre and post protocol exposure. Exposure to the stress protocol elicited significant increases in HR, both systolic and diastolic BP, ACTH and cortisol (all $p<0.01$). Males had significantly greater cortisol and diastolic BP responses compared to females ($p<0.05$). Additionally, a positive correlation between the ACTH and cortisol responses was only found in the males ($r=0.71$, $p<0.05$). There were no group differences observed in HR, systolic BP or ACTH responses. The researchers concluded that for the age group of individuals studied, males respond to psychological stress with greater increases in cortisol as compared to females. The observed greater activation of the HPA axis could translate into an elevated risk for CVD, DM and HTN which may be related to the higher prevalence of these diseases in males.

The gender issue was looked at by another group of researchers, Matthews, Gump and Owens (2001). These researchers tested the influence of chronic stress on cardiovascular and neuroendocrine responses to and recovery from acute stressors and whether the effects are gender specific. Thirty-one healthy, middle aged males and thirty-one healthy, middle aged females were exposed to acute stress by performing mental arithmetic and public speaking tasks. Subjects then relaxed for a period of one hour post the acute stress exposure while their cardiovascular and neuroendocrine function was measured. Participants with higher levels of chronic stress showed lower systolic BP and epinephrine, and marginally lower levels of norepinephrine responses to the tasks. Additionally participants with higher levels of chronic stress show lower levels of cortisol and marginally lower norepinephrine responses during recovery. Relative to females, males had higher diastolic BP responses to the tasks and high systolic BP, diastolic BP and epinephrine responses during recovery. The researchers conclude that gender differences in cardiovascular disease in middle aged persons may be due to gender differences in the inability to recover quickly, in addition to enhanced acute stress response.

Commentary

In contemporary society stress has become a part of everyday life. As outlined above, there exists a complex series of physiologic responses to stress. Research studies have identified both gender and genetic issues in relation to the reactions to and recovery from stressors. Patients will certainly benefit from techniques that are aimed at reducing or reversing the adverse effects of stress responses. Primary care providers need to equip themselves with knowledge and techniques aimed at combating the effects of stress.

Combating the Physiologic Effects of Stress

"An astute physician is lamenting the times:

'But the present world is a different one. Grief, calamity, and evil cause inner bitterness . . . there is disobedience and rebellion . . . Evil influences strike from early morning until late at night . . . they injure the mind and reduce its intelligence and they also injure muscles and the flesh.'

This chronicler lived 4,600 years ago in China, even though his observations appear contemporary. Human beings have always felt subjected to stress and often seem to look longingly backward to more peaceful times. Yet with each generation, complexity and additional stress are added to our lives. The truth is that most of the persistent problems of this planet are even further from solution than when the Chinese doctor decried them. The technology of the past forty-six centuries and especially that of the last century which was supposed to make life easier for people, often seems to intensify the stress in our day-to-day existence." (Benson, 1975, pg. 11)

The Relaxation Response

Although most health care professionals would agree that stress does affect the body, they tend not to be attuned to the psychological, non-medical literature about stress. Concerned mostly with bodily signs and symptoms, providers treat stress by prescribing medication when no specific diseases are present. All too often a prescription for "tranquilizing" drugs is dispensed rather than delving into the psychological roots of the problem (Benson, 1975).

As previously explored, humans react in a predictable manner to acute and chronic stressful situations which trigger inborn responses that have been a part of our physiologic makeup for perhaps millions of years – the famous "fight or flight" response. Any situation that demands we adjust our behavior can elicit this response. In today's society very few situations warrant the magnitude of this response. When elicited unnecessarily, which is most of the time, the "fight or flight" response may ultimately lead to dire diseases (Benson, 1975).

The continual need to adjust to new situations brings on the detrimental "fight or flight" response, and if we live with stressful events that trigger the response, one naturally questions if we know how to check the dangerous results that inevitably follow. Taking this line of reasoning a step further, is there an innate physiologic response that is diametrically different? Yes, each of us possesses a natural and innate protective mechanism against "overstress" which allows us to turn off harmful bodily effects and to counter the effects of the "fight or flight" response. The counter response brings on bodily changes that decrease heart rate, lower metabolism, decrease the rate of breathing, and bring the body back into a healthier balance; this is the Relaxation Response (RR) (Benson, 1975).

The relaxation response has always existed contextually in religious teachings. Use has been most widespread in Eastern cultures where it has been an essential part of daily existence. Prayers and related mental processes have measurable, definable physiologic effects on the body. However the physiology of the RR has only recently been defined. Evoking the RR is very simple when following a few simple instructions that incorporate four essential elements:

- A quiet environment.
- A mental device such as a word or a phrase which should be repeated in a specific fashion over and over again.
- Adoption of a passive attitude, which is perhaps the most important element.
- A comfortable position.

Appropriate practice of these four elements for ten to twenty minutes once or twice daily can markedly increase your well being (Benson, 1975).

As previously cited the “fight or flight” response was first described by Walter B. Cannon, a professor of physiology at the Harvard Medical School at the turn of the twentieth century, as an “emergency reaction”. The hypothalamus controls evocation of the “fight or flight” response. In the past the “fight or flight” response had considerable evolutionary significance. Individuals with this response survived more effectively thus passing it on to their heirs. Modern society does not accept the fighting or running. The response is turned on but we do not use it appropriately (Benson, 1975).

The “fight or flight” response happens in an integrated fashion controlled by the hypothalamus and occurs in a coordinated, simultaneous manner. When evoked, it brings into play the SNS which is a part of the ANS. As outlined previously, the SNS acts by secreting specific hormones – epinephrine and norepinephrine. As previously cited in this text, increased epinephrine activity results in the physiological changes of increased blood pressure, increased heart rate, and increased body metabolism (Benson, 1975).

Can we influence our own physiologic reaction to stress through individually controlled mental practices? Researchers have addressed this question. Dr. B. F. Skinner, of Harvard University, addressed this problem through behavioral experiments. Skinner’s research revealed that voluntary behavior of an animal could be controlled. Dr. Neil E. Miller took Skinner’s research a step further into the autonomic nervous system. Miller sought to explore if it was possible to not only control voluntary behavior but involuntary behavior as well. Miller’s work showed that control of involuntary bodily processes was possible through biofeedback. Proponents of biofeedback believe that mentally recognizing a biologic function allows one to gain control of that function, even involuntary responses. Through biofeedback, also known as visceral learning, one can control processes of the ANS (Benson, 1975).

Most biofeedback approaches involve the use of specialized equipment. Biofeedback techniques utilizing equipment can only focus on one biologic process at a time. These issues are perceived to be drawbacks for the use of biofeedback techniques. Although Miller demonstrated experimentally that involuntary responses could be deliberately altered, subsequent research has shown that the same results can be achieved by methods other than biofeedback (Benson, 1975).

Centuries before research proved biofeedback to be an effective tool in gaining control over the involuntary actions of the ANS, dramatic claims for control of physiologic functions had come to us from the East. According to the claims, control over physiological functions was attainable through ancient meditation techniques. Meditation techniques studied by modern day researchers have proven to decrease oxygen consumption, respiratory rate, heart rate, blood pressure (in patients with hypertension), and produce changes in the electrical activity of the brain. Yoga, Zen, and other forms of meditation have made their way into Western life. Transcendental Meditation (TM) is one of the most widely practiced forms of meditation (Benson, 1975).

Practitioners of TM were studied at both The University of California, Los Angeles and at Harvard. The experiments demonstrated that the major physiologic change associated with meditation is a decrease in the rate of metabolism; such a state is termed hypometabolism and represents a restful state. During meditation, as in sleep, bodily energy resources are less taxed. Humans rarely achieve a hypometabolic state associated with an oxygen consumption that is lower than that which occurs when quietly sitting in a chair or lying down. In fact, there are very few conditions that can lead to hypometabolism; sleep is one, and hibernation is another. Initially it was thought that this decreased consumption of oxygen during TM might be due to an unknown hibernation-like response in humans. A way of detecting a hibernation state is measurement of core body temperature (rectal measurement); during hibernation this temperature decreases. Measurement of core body temperatures of meditators reveals they do not enter a hibernation-like state, as their rectal temperatures do not decrease during the practice of meditation (Benson, 1975).

Swiss Nobel Prize winning physiologist, Dr. Walter Hess, produced changes associated with the “fight or flight” response by stimulating a part of the cat’s brain within the hypothalamus. In another part of the hypothalamus, Dr. Hess demonstrated a response whose physiologic changes were similar to those measured during the practice of meditation, that is, a response opposite the “fight or flight” response. Dr. Hess termed this reaction the trophotropic response. The trophotropic response was described by Hess as being a protective mechanism against overstress and promoting restorative processes. The trophotropic response described by Hess in the cat is believed, by Benson, to be the RR in man. Hence, both these opposite responses are associated with physiologic changes occurring concomitantly in a coordinated fashion and appear to be controlled by the hypothalamus. Since the “fight or flight” response and the RR response are in opposition, Benson feels regular use of the RR will offset the harmful effects of the inappropriate elicitation of the “fight or flight” response (Benson, 1975).

There are several techniques, most of which are used as relaxation therapy, that evoke the same physiologic changes as the RR. These techniques include autogenic training, progressive relaxation, hypnosis with suggested deep relaxation, and scentic cycles (Benson, 1975). Let us briefly explore these techniques.

Autogenic training is based on six mental exercises devised by a German neurologist, Dr. H. H. Schultz. Having noted that hypnotized subjects experienced feelings of relaxation, heaviness, and a sensation of warmth, Schultz devised a technique of passive repetition of physiologically oriented statements. It was emphasized that exercises be carried out in a quiet room with reduced lighting and that the patient should be in a relaxed position with restrictive clothing loosened. The patient is instructed to concentrate in a goal-directed, focused fashion referred to as a "passive concentration" by Schultz. Autogenic training is to be practiced several times a day until an individual can shift voluntarily to a less stressful, or trophotropic state. Satisfactory practice of autogenic therapy results in patients achieving a neutral autogenic state. The skeletal muscles are relaxed and the knee jerk response is diminished. These findings are consistent with Jacobson's technique of Progressive Relaxation (Benson, 1975; Shealy, 1986).

Progressive relaxation, as described by Edmund Jacobson, M.D., emphasizes the relaxation of voluntary skeletal muscles. Jacobson taught patients to recognize the contractions of muscles in order that they would be able to note the opposite which was relaxation. The purpose of these tensing exercises was to demonstrate to the patient that relaxation requires no effort. Increased control over skeletal muscle is sought until an individual is able to induce very low levels of muscle tension in the major muscle groups. Jacobson demonstrated that the knee jerk reflex becomes significantly diminished in deep relaxation. Additionally, Jacobson found that in the presence of advancing relaxation cerebral activity of attention diminished (Benson, 1975; Shealy, 1986).

Hypnosis is a widely utilized technique for “relaxation”, but is still poorly understood. This technique may be defined as an altered state of consciousness artificially induced and characterized by increased receptiveness to suggestion. During hypnosis, when deep relaxation is achieved the physiologic changes of the RR may be evoked (Benson, 1975).

A gifted pianist and psychophysiological researcher, Dr. Manfred Clynes, devised scentic cycles. Scentic cycles demonstrate the close relation between emotional states and predictable physiologic changes. A scentic cycle is composed of eight “scentic states”, or self induced emotional states. Physiologic changes consistent with the RR have been noted during the imagined scentic cycles of reverence, love, and grief (Benson, 1975).

Physiologic changes of the RR are associated with what is called an altered state of consciousness, termed “altered state” simply because it is not commonly experienced and because it typically does not occur spontaneously. The altered state of consciousness experienced with the RR has been routinely experienced in Eastern and Western cultures throughout the ages. Subjective feelings associated with an altered state have been described as ecstatic, clairvoyant, beautiful, and totally relaxing. Others have reported peace of mind, ease with the world, and a sense of well being like that experienced after a period of exercise but without the fatigue. Most describe their experiences as pleasant (Benson, 1975).

Research studies have been conducted utilizing the RR as the primary intervention. Use of the RR was found to be a valuable adjunct for treating hypertension. However researchers concluded that use of the RR alone would unlikely serve as adequate therapy for moderate to severe high blood pressure. Elicit drug use is another area in which the use of the RR has been studied. Results revealed that regular evocation of the RR in the study population led to decreased drug use. Decreased alcohol intake and cigarette smoking have been observed in studies evaluating the efficacy of the RR. Other studies have shown that cardiac dysrhythmias and anxiety were reduced with the RR. However, evocation of the RR did not prove to be beneficial in patients with migraine headaches (Benson, 1975).

The Relaxation Response serves as a natural mechanism to counteract increased SNS activity associated with the "fight or flight" response. The RR should be useful in alleviating disease states where increased SNS activity is a primary factor in the development of the disease or is a less than desirable co-morbid factor of the disease. Prevention of stress-related diseases carries with it enormous significance, not only for the individual and the individual's family, in terms of their own physical and mental well-being, but also significant for society as a whole through major monetary savings in health care expenditures. The case for use of the RR by healthy, but stressed individuals is straightforward. It is a natural, no-cost gift that anyone can turn on and use. By bridging the traditional gaps between psychology, physiology, medicine, and history, it has been established that the RR is an innate mechanism within us (Benson, 1975).

Commentary

While it may be comforting to know there exists a process or a technique that can be utilized to minimize or negate the effects of stress, what good is the knowledge if no one is interested in utilizing it? For many, knowledge does not necessarily result in action despite the fact an individual can identify a known benefit from the action. What then may be the missing motivator to action for these people? Perhaps it may have something to do with personal belief systems. For some it may be possible to have knowledge of something but not to believe in it and for others it may be possible to believe in things that they have no knowledge of. Astute health care professionals will survey the patient's personal belief systems when assisting the patient in the development of a treatment plan.

The Faith Factor

Scientific research is demonstrating more clearly that what we can touch, taste, and measure may frequently have to take a backseat to what we perceive or believe to be real. It is how one interprets reality or how the body sees the concrete world around us that is important. A personally held and exspoused belief is "perception is reality to the person who perceives it."

Combining the Relaxation Response technique with an individual's belief system is what Benson (1984) calls the Faith Factor (FF). Benson admits that the concept of the FF is not an entirely original concept. It is a new kind of "package" that contains two powerful and familiar spiritual vehicles; meditation and a deeply held set of philosophical or religious convictions. Benson hopes that his exploration and description of the FF serves as a bridge between the two disciplines:

- Traditional faith and meditative practices.
- Scientific observation.

Western health care providers, for years, have been aware of the phenomenon of the curative power of personal belief. Any extensive study of this phenomenon has tended to be neglected. Instead the phenomenon has preferentially been lumped into a catch-all classification referred to as the "placebo effect". The word placebo comes from a Latin root word that literally means "I shall please." In contemporary conventional medicine, it refers to a medicine or procedure that has no known active, curative ingredient and is given solely for the purpose of calming or "pleasing" the patient. We are learning, hopefully, that our past definitions and understanding of the placebo effect are inadequate. Most researchers have tried to eliminate it from the repertoire of practical medicine without stopping to examine the why, when, and how it works. Studies of new drugs are designed to minimize or remove the placebo effect so that the "true" effectiveness of the drug can emerge. If the effects of the new drug were not different from those of a placebo, the new drug is considered "ineffective" even if both the new drug and the placebo produced beneficial changes (Benson & Proctor, 1984).

Ignoring and minimizing the power of the placebo effect results in a loss of one of the most powerful therapeutic forces available to man. The placebo effect can present us with some of the most dramatic examples of the power of the mind over the body and of the use of personal belief to heal a wide variety of physical ailments. Eastern medicine, most notably Tibetan Buddhist medicine, acknowledges that effectiveness of any treatment is dependent on three things:

- The belief of the patient.
- The belief of the doctor.
- The karma (the spiritual force generated by their mutual actions) between the doctor and the patient.

Western health care providers, without using the same terminology or relying on an Eastern belief system, routinely but often unconsciously make use of these same three factors when helping their patients. Because Western understanding of the placebo effect is so rudimentary, many health care providers cannot explain why one patient improves while another remains ill. In fact, we know from research into this subject that seventy-five percent of the patients health care providers see cannot be helped by specific medicines or surgical procedures. However, many patients are helped simply because they visit their health care professional, believe in that individual, and get assurances from them. Therefore, health care providers that gain the confidence and trust of patients are much more likely to treat illnesses with success than a health care provider who cannot. If the patient and the provider start off with a belief in a common spiritual or nonphysical curative power, then remarkable things are possible (Benson & Proctor, 1984).

Fully understanding the power of our mind in helping us reach optimum health, we can reinforce our belief in the capacity of the body to heal itself. The primary objective is to develop a positive, powerful attitude which provides a strong sense of control so that the best health we are capable of flows naturally from our brains into our bodies. The best means to achieve this end is the linkage between:

- A strong personal belief system, which encourages the possibility of achieving and maintaining good health.
- Enhancement of the healing power of this belief through the Relaxation Response.

This combination is what Benson (1984) called the Faith Factor.

Measuring Balance in the Autonomic Nervous System

Defining Heart Rate Variability

Over two decades ago a seminal report suggesting the clinical utility of the assessment of heart rate variability (HRV) was published. Regulations, modulations and physiological variability of cardiac cycles have been researched extensively. Presently the evaluation of (HRV) is an established tool for the assessment of the cardiac autonomic status (van Ravenswaaij-Arts, et al., 1993; Bigger, 1995, chap. 101; Malik, 2000, chap. 84). Recognition of the need for standardization of HRV measurement led to the formulation of two major task forces whose reports offer general guidelines and suggestions both for experimental and clinical applications and for further research (Malik, 2000, chap. 84).

Though the term HRV suggests that it is the variability of heart rate that is being measured, it is actually the variability of cardiac cycles that is being investigated in most cases. The term HRV has become used so universally that it is generally adopted when dealing with the variability of cardiac periods. Because of the non-linear inverse relationship between heart rate and cardiac cycles, some complex measures of HRV, for example, proportion of spectral components derived from cardiac cycles, do not parallel those derived from heart rate samples (Malik, 2000, chap. 84).

Measuring Heart Rate Variability

Measurement of RR intervals, in principle, allows assessment of HRV using any electrocardiogram (ECG) of sufficient duration. In doing so the following rules have to be observed:

- The signal-to-noise ratio of the ECG should allow all QRS complexes to be properly identified.
- The digital sampling of the ECG signal must be regular, and sufficiently robust algorithms must be used to localize the fiducial points of the individual QRS complexes; this particularly means that when recording the ECG on an analogue medium (e.g. a magnetic tape), the signal must be accompanied by a time track record used by the analyzing equipment.
- The morphology and rhythm characteristics of all QRS complexes should be classified in order to distinguish between cardiac cycles of sinus rhythm and other origins.
- Only RR intervals between normal sinus rhythm beats (the so called normal-to-normal, or NN, intervals) should be considered, and none of such intervals should be excluded – meaning that coupling intervals of atrial and ventricular ectopics as well as their compensatory pauses are excluded, but all other NN intervals are used, including all those preceding a coupling and following a compensatory pause.

(Malik, 2000, chap. 84)

Analysis of the sequence of NN intervals can be accomplished in many different ways. Those methods most commonly used for the assessment of HRV are the time domain, the frequency domain and the non-linear methods.

Time domain methods of measurement.

The time domain methods treat the NN interval sequence as an unordered set of intervals (or pairs of intervals) measurement and utilize different ways to express the variance of such data. Numerous approaches have been proposed to estimate the variance of the NN interval data and its surrogates. Since many of these methods lead to essentially equivalent results, only selected methods have been proposed as the "gold standard" time domain. Standard approaches include the so-called statistical methods, which are based on the formula of standard deviation and provide results in units of time (van Ravenswaaij-Arts, et al., 1993; Bigger, 1995, chap. 101; Malik, 2000, chap. 84).

The SDNN measure is the standard deviation of the durations of all NN intervals, and the SDANN is the standard deviation of the duration of NN intervals averaged over all subsections of the original ECG that do not overlap (although different subsections can be considered, five minute segments are used as a standard), and the RMSSD measure is the root of the averaged squares of differences between neighboring NN intervals (which is a surrogate of the standard deviation of the differences between neighboring NN intervals). The RMSSD measure is essentially equivalent to the frequency used measure pNN50, which is the percentage of NN intervals differing by more than 50 milliseconds from the immediately preceding NN interval. Compared with pNN50, the RMSSD values have better statistical properties. Although the SDNN and RMSSD methods can be applied to nearly any ECG, the SDANN method is usually used only with long term (i.e. twenty-four hour) ECG recordings. The length of the ECG recording is an important determinant of the HRV. In increasing the length of ECG recording SDNN, SDANN and RMSSD values increase. Therefore it is not appropriate to compare HRV data obtained from ECG recordings of different durations (Malik, 2000, chap. 84).

All of the time domain methods for determining HRV depend crucially on the quality of the NN intervals. It is usually not difficult to achieve a high quality of NN intervals with short term ECG recordings, the automatic analysis of which can be visually verified to include the localization and morphological and rhythm classification of every single QRS complex. Achieving a high quality of NN interval sequence derived from long term ECG recording is frequently problematic, especially with recordings obtained in the standard clinical environment and when resources do not allow the ECG analyzing technician to verify carefully all NN intervals found by the automatic equipment. Even with advanced Holtor equipment systems a precise analysis of long term ECG recording can be time consuming in terms of operator involvement when some QRS patterns of low voltage are not automatically identified or when tall T waves and recording artifacts are misclassified as QRS complexes. When such long term ECG recordings are analyzed the statistical values of HRV can be substantially incorrect (Malik, 2000, chap. 84). To overcome this difficulty the geometrical methods for HRV have been proposed. The geometrical methods use the NN interval sequence to construct a geometrical form and express HRV by assessing a certain parameter or shape of that form. The incorrect NN intervals are usually outliers of the geometrical form and can then be easily excluded from the HRV assessment. Of the geometrical methods, most application experience exists with the HRV triangular index method. This method constructs a sample density histogram of all NN intervals and approximates its baseline width (a surrogate of the standard deviation of NN intervals) by computing the proportion between the total number of NN intervals (i.e., the area of the histogram) and the number of intervals of modal durations (i.e., the height of the histogram). Proposed as one of the gold standard approaches to the analysis of long term ECG recordings, depends critically on the size of the bins used to construct the histogram. Used with the bins of 1/128 s

(~ 7.8msec), which correspond to the usual sampling rate of Holtor equipment, and when applied to appropriately edited NN interval sequence, the HRV triangular index method yields values fairly consistent to SDNN (one unit or HRV triangular index ~ 2.5msec of SDNN) (Malik, 2000, chap. 84).

Frequency domain methods of measurement.

Frequency domain methods for the assessment of HRV are explored next. Power spectral density analysis provides the basic information of how power (i.e., variance) distributes as a function of frequency. Independent of the method employed, only an estimate of the actual spectral density of the signal is attainable. Methods for calculation of the power spectral density can be classified as non-parametrical and parametrical. In most circumstances both methods provide comparable results. Non-parametrical methods are advantageous because of the simplicity of the algorithm employed (fast Fourier transform – FFT- in most of the cases) and the rapid processing speed employed in this method. The advantages of the parametrical methods are smoother spectral components that are distinguishable independent of pre-selected frequency bands, easy post processing of the spectrum with an automatic calculation of low-frequency and high-frequency power components with an easy identification of the central frequency of each component and an accurate estimation of power spectral density even on a small number of samples on which the signal is supposed to maintain stability. The disadvantage of parametrical methods is the need for verification of the suitability of the chosen model and of its complexity (i.e. the order of the model) (Malik, 2000, chap. 84).

In frequency domain analysis three main spectral components are distinguished in a spectrum calculated from short term ECG recordings of at least two minutes. These are the very low frequency (VLF; below 0.04Hz), low frequency (LF; 0.04 to 0.15Hz), and high frequency (HF; 0.15Hz to 0.4Hz) components. Distribution of the power and the central frequency of LF and HF are not fixed but may vary in relation to changes in autonomic modulations of the cardiac cycle. The non-harmonic component, which does not have coherent properties and is affected by algorithms of baseline or trend removal, is commonly accepted as a major constituent of VLF. VLF assessed from short term ECG recordings is dubious and should be avoided when interpreting the spectral analysis of HRV from short term ECG recordings. The measurement of VLF, LF and HR power components is typically made in absolute values of power (msec2). LF and HF may also be measured in normalized units which represent the relative value of each power component in proportion to the total power minus the VLF component. The representation of LF and HF in normalized units has been proposed to signify the balanced behavior of the two branches of the autonomic nervous system. The normalization tends to minimize the effect of changes in total power on the values of LF and HF components. Nevertheless, normalized units need always be quoted with absolute values of LF and HF power in order to describe completely the distribution of power in spectral components (van Ravenswaaij-Arts, 1993; Bigger, 1995, chap. 101; Malik, 2000, chap. 84).

Spectral analysis can also be used to analyze the sequence of NN intervals for the entire twenty-four hour period. When used in this analysis, the results then include an ultra low frequency (ULF; below 0.0033Hz) component in addition to the VLF, LF and HF components. The slope of the twenty-four hour spectrum can be assessed on a log-log scale by linear fitting the spectral values (Malik, 2000, chap. 84).

The problem of stability needs to be considered carefully with long term ECG recordings. If responsible mechanisms for cardiac cycle modulations of a certain frequency remain stable for the entire ECG recording period, the corresponding frequency component of HRV can be used as a measure of the modulations. If the modulations are not stable, the interpretation of the results of frequency component of HRV is less well defined. Physiological mechanism of cardiac cycle modulations responsible for LF and HF power components cannot be considered stationary during the twenty-four hour period when the modulations are not stable. Thus spectral analysis performed on the entire twenty-four hour period, along with results from shorter segments averaged over the entire twenty-four hour period provides averages of modulation attributable to the LF and HF components. Such averages obscure the detailed information regarding autonomic modulation of NN intervals that is available in shorter recordings. The components of HRV provide measurement of the degree of autonomic modulations rather than the level of autonomic tone. Averages of modulations do not represent an averaged level of tone (Malik, 2000, chap. 84).

Non-Linear analysis methods.

Non-linear phenomena are involved in the genesis of HRV. These phenomena are determined by the complex interactions of hemodynamic, electrophysiological, and humoral variables, as well as the autonomic and central nervous system regulations.
It has been proposed that analysis of HRV based on the dynamics of non-linear dynamics may elicit valuable information for the physiological interpretation of HRV. Parameters that have been used to measure non-linear properties of HRV include 1/f scaling of Fourier spectra, H scaling exponent, and coarse graining spectral analysis. Proposed for

data representation have been Poincare sections, low dimension attractor plots, singular value decomposition and attractor trajectories. Other quantitative descriptions employed have been the D2 correlation dimension, Lyapunov exponents and Kolmogorov entropy (Malik, 2000, chap. 84).

Poincare plots, maps of dots with coordinates corresponding to durations of pairs of successive NN intervals, have attracted some attention among clinical investigators because of the easiness of the classification of the patterns of the plots. Some investigators propose classification based on categories from a torpedo or cigar shape to a comet and butterfly shape of the plots. The problem with this classification is that it is highly subjective and has not been tested in a blinded prospective fashion. Therefore, the practical application of Poincare plots is restricted to the assessment of the quality of NN interval sequence because the plots make outliers and artifacts very visible (Malik, 2000, chap. 84).

Standardization of HRV assessment is needed in respect to the duration of analyzed ECG recordings and of the conditions under which the recordings are obtained. The measurements provided by the time domain methods increase with the duration of the recordings, and the physiological relevance of the LF and HF spectral components depends on the stability of underlying autonomic modulations. Recognizing these issues, standards of two different analytical modes have been proposed that should be adopted in most cases. Studies of physiological aspects of cardiac autonomic status are best served by spectral analysis of short, preferably five minute, ECG recordings that are obtained under stationary conditions (i.e., conditions during which the physiological processes regulating the heart rate remain in a steady state). To the contrary, optimum assessment of cardiac autonomic responsiveness to environmental stimuli is based on the nominal twenty-four hour ECG recordings (i.e., recordings obtained over 24 hours that contain 18 hours of analyzable data which include portions of both day and night recordings). Time domain methods of analysis are preferred for these long term ECG recordings. Although NN interval sequences from long term ECG recordings can be analyzed via frequency domain methods, the stability of the underlying modulations cannot be maintained over a prolonged period of time. Thus physiological interpretation of individual spectral components acquired from long term ECG recordings is questionable and frequency domain analysis offers only the same information that can be obtained by time domain methods (Malik, 2000, chap. 84).

In both short and long term ECG recordings the conditions of recording significantly influence the mechanisms regulating heart rate and should therefore be controlled and monitored. It is inappropriate to compare spectral HRV components in short term ECG recordings from one group of subjects while sitting and another group of subjects while standing. Similarly it would be inappropriate to compare twenty-four hour ECG measures of HRV from hospitalized subjects with those from ambulatory control subjects (Malik, 2000, chap. 84).

Physiological Interpretation of HRV

Short term ECG recordings.

During resting conditions the RR interval variations represent a fine tuning of the beat-to-beat control mechanisms. Vagal afferent stimulation leads to reflex excitation of vagal efferent activity and the inhibition of sympathetic efferent activity. Stimulation of sympathetic afferent activity mediates the opposite reflex. Efferent vagal activity appears to be under tonic restraint by cardiac afferent sympathetic activity. Efferent sympathetic and vagal activities directed to the sinus node are characterized by a discharge that is synchronous with each cardiac cycle, which can be modulated by central and peripheral oscillators. These oscillators produce rhythmic fluctuations in efferent neural discharge that manifest as short term or long term oscillations in the cardiac cycle. Analysis of these oscillations may permit inferences on the state and function of:

- The central oscillators.
- The sympathetic and vagal efferent activity.
- Humoral factors.
- The sinus node.

(Malik, 2000, chap. 84)

Understanding the modulatory effects of neural mechanisms on the sinus node has been enhanced by spectral analysis of HRV. Efferent vagal activity is a major contributor to the HF component as seen in clinical and experimental observations of autonomic maneuvers such as electrical vagal stimulation, muscurinic receptor blockade, and vagotomy. More controversial is the interpretation of the LF component, considered by some as a marker of sympathetic modulation (especially when expressing it in normalized units) and by others as a parameter that includes both sympathetic and vagal influences. The discrepancy is due to the fact that in some conditions associated with sympathetic excitation a decrease in the absolute power of the LF component is observed. It is important to recall that during sympathetic activation the resulting tachycardia is usually accompanied by a reduction in total power, whereas the reverse occurs during vagal activation. When spectral components are expressed in absolute units (msec2), the changes in total power influence LF and HF in the same direction and prevent the appreciation of the fractional distribution of energy. This explains why in supine patients under controlled respiration, administration of atropine reduces both LF and HF and explains why during exercise LF is markedly reduced. LF and HF can increase under different circumstances. When expressed in normalized units LF was found to increase during 90 degree tilt, standing, mental stress, moderate exercise in healthy subjects, moderate hypotension, physical activity and occlusion of coronary artery or common carotid artery in conscious dogs. Conversely an increase in HF was induced by controlled respiration, cold stimulation of the face and rotational stimuli. Both LF and HF, when expressed in normalized units, correlate with the passive head up tilt. The same correlation was not seen when expressing the same HRV components in absolute values of spectral power. Measurements of HRV components in absolute terms and normalized units have different physiological meaning and the two different expressions should complement each other (Malik, 2000, chap. 84).

Long term ECG recordings.

Spectral analysis of short segments of long term ECG recordings reveals that in normal subjects, LF and HF expressed in normal units exhibit circadian pattern and reciprocal fluctuations; with higher LF values during the day and higher HF values during the night. These patterns are no longer detectable when a single spectrum of the entire twenty-four recording is used for analysis. In long term recordings, only five percent of the total power is accounted for by the LF and HF components. The ULF and VLF components account for the remaining ninety-five percent of the total power, despite the fact that their physiological correlates are still not known. It is speculated that these components do not relate to specific regulatory mechanisms but rather they are the expressions of the dynamic nature of LF and HF components that change in response to demands of the changing environment. However, some physiologic stimuli have been shown to contribute to VLF components; these include hemorrhage, aortic constriction, acidosis, vasocactive agents and asphyxia. Global measures of HRV over a twenty-four period provide sensitive measures of cardiac autonomic responsiveness to environmental stimuli and allow estimation of the ability of the cardiac autonomic status to adapt to physiological demands (Malik, 2000, chap. 84).

Clinical Use of Heart Rate Variability

HRV is a valuable tool to investigate the sympathetic and parasympathetic function of the autonomic nervous system. Various cardiovascular and other physiological pathologies, as well as different forms of mental and physical load are associated with altered heart rate variability, offering the possibility of analyzing HRV measurements for predicting disease outcome and assessing stress (Hejjel & Gal, 2001). HRV measurements are easy to perform, are noninvasive and have good reproducibility under standardized conditions (van Ravenswaaij-Arts, 1993). HRV analysis is readily applicable in adult medicine, taking into consideration physiological influences such as age, gender, effects of medication and position [i.e., standing verses supine] (Malpas & Purdie, 1990; van Ravenswaaij-Arts, et al., 1993; Ahmed, Kadish, Parker & Goldberger, 1994; Bigger, 1995, chap. 101; The Framingham Heart Study, 1996; Fauchier, et al., 1998; Umetani, Singer, McCraty & Atkinson, 1998; Malik, 2000, chap. 84). In conventional medical circles the only purported benefit of HRV measurement is thought to be in risk stratification after acute myocardial infarction and in the early diagnosis of diabetic neuropathy (van Ravenswaaij-Arts, et al., 1993; Bigger, 1995, chap. 101; Malik, 1998; Malik, 2000, chap. 84). In the psychological domain, the analysis of HRV is found to be a powerful measure of the neurocardiac function that reflects heart-brain interactions and the subsequent autonomic nervous system dynamics (Childre & McCraty, 2001). Thus HRV provides a reliable measure of autonomic nervous system dynamics that is particularly sensitive to changes in the psychophysiological state (McCraty, 2002). Emotional experiences play a role in determining sympathovagal balance independent of heart rate and respiration suggesting that positive emotions lead to alterations in heart rate variability that may be beneficial in the treatment of hypertension and reduce the risk of sudden death in patients with congestive heart failure and coronary artery disease (Tiller, McCraty & Atkinson, 1996).

Evaluating and Facilitating Balance in the Autonomic Nervous System

Entrainment of Heart Rate Variability

A number of physiological systems have been identified as exhibiting nonlinear oscillatory systems. These oscillatory systems include the pacemaker cells of the heart, the insulin secreting cells in the pancreas, the neural networks in the brain, the brain stem respiratory and vasomotor center, as well as the neuro networks of the intestines (McCraty, et al., 1996). Although these physiological systems clearly perform different functions, for each the concept of synchronization or “entrainment” underlies its dynamic behavior. Coupling of nonlinear oscillatory systems causes the two oscillators to lock into a common frequency. As the frequency difference between the two nonlinear systems is reduced, a point is reached where the “coupled system” consists of a single dominant frequency; this is called "frequency selective entrainment" (McCraty, et al., 1996). If the amplitude of one of the oscillators is insufficient to result in a full entrainment, but the amplitude is capable of pulling or displacing the frequency of the other oscillator the phenomenon is referred to as "frequency-pulling" (McCraty, et al., 1996). Examples of entrainment between physiologic oscillatory systems have been observed in electromyography signals from the smooth muscle of the arterial system and the gut, as well as, the interaction between respiration and heart rate variability (McCraty, et al., 1996).

Research findings of Childre and McCraty (2001) have linked positive emotion with a distinct mode of physiological functioning termed physiological coherence. "Coherence" is used as an umbrella term to describe a physiological mode that encompasses distinct but related phenomena including synchronization, entrainment, and resonance emerging from the harmonious interactions of the body's subsystems (McCraty, 2002). Correlates of physiological coherence include a smooth, sine-wave pattern in the heart rhythms, a shift in autonomic balance toward increased parasympathetic activity, increased heart-brain synchronization (alpha rhythms become entrained to the ECG), increased vascular resonance, and entrainment among diverse oscillatory systems (i.e., heart rhythm patterns, respiratory, craniosacral and blood pressure rhythms) and improved cognitive performance (McCraty, et al., 1996; McCraty, 2002; Richards, McCraty & Atkinson, 2002).

Clinical Studies on Achievement of Psychophysiological Coherence

Psychophysiological coherence is the term that describes physiological coherence that is driven by a positive psychological state (McCraty, 2000). Beneficial psychological and health outcomes have been reported with the use of positive emotion-focused techniques and heart rhythm coherence feedback training across diverse populations in both laboratory and field studies (McCraty, et al., 2001). Results suggest that techniques which increase physiologic coherence are effective in producing sustained improvements in many aspects of psychological and physical health, in general well being and in cognitive performance.

One study examined a heart lock-in technique focused on appreciation resulted in a significant increase of levels of secretory IgA (McCraty, et al., 1996). In another study a thirty-two percent reduction in cortisol and a hundred percent increase in DHEA were noted after one month of practicing a heart lock-in technique (McCraty, et al., 1998). Blood pressure reductions were observed in a hypertensive population (McCraty, et al., 2001). Blood pressure and stress were found to be reduced in another study utilizing a positive emotion-focused technique program implemented as part of a workplace-based stress management program (McCraty, Atkinson & Tomasino, 2003). Reduced depression and improved functional capacity was noted in congestive heart failure patients (Luskin, et al., 2002). Positive emotion-focused techniques and heart rhythm feedback are used by mental health professionals for the treatment of emotional disorders to include anxiety, panic disorder, depression, and post-traumatic stress disorder (McCraty, 2002).

Commentary

Measurement of the ANS appears to be as complex as the function of the ANS. Nonetheless it is a valuable clinical tool for delineating patients at risk for certain health alterations and for evaluating the balance of the ANS. Researchers have shown that activities and techniques of "intent" result in improved balance in the ANS and improved health care outcomes. Additionally, researchers have demonstrated these same activities and techniques of "intent" can result in synchronization/entrainment of physiologic systems not directly affected by the technique but by "reflex" activity resultant from evoking a system of complex biologic oscillators. Can activities or techniques that are "passive" in nature, such as brain wave synchronization, evoke that system of biologic oscillators and result in a reflex activity in systems not directly affected by the technique?

Photo-Stimulation

Defining Photo-Stimulation

What is photo-stimulation? A review of the literature reveals a wide range of definitions of this term. In many sources photo-stimulation is also referred to as light therapy. Light therapy can include the use of colors, frequency and intensity of light.

The Egyptians were the first to use color for healing and the Greeks were the first to document the theory and practice of solar therapy. In 1840, Johann Wolfgang Von Goether, a philosopher and poet, wrote the first definitive book on color therapy. In the 1960s, Albert Szent-Gyorgyi became a Nobel Prize Winner for discovering that enzymes and hormones are colored and very sensitive to light (Liberman, 1991).

Knowledge that light-induced photocurrents can activate specific areas of the brain, has led many light-therapy researchers to the development of a variety of light-treatment systems that project different colors and intensities of light into the eyes in order to treat certain neurological disorders (Gerber, 2000). German researcher, Dr. Fritz Popp, confirmed that cells give off biophotons – or biologically generated packets of light which appear to be in the ultraviolet (UV) frequency range. These UV biophotons may be a part of a light based communication system that relays important biological information between cells within the body. Given that our cells may utilize light to communicate, it seems plausible that human beings could be affected by therapies utilizing light or by the sources of light frequencies in their environment (Gerber, 2000).

Shortly after the development of electroencephalography (EEG) it was discovered that certain brain wave activity followed repetitive light and sound frequencies (Toman, 1941). Alpha frequency (8-13 Hz) is a posterior wave activity that begins in the occipital region – the visual cortex region – and moves forward to the temporal and parietal regions. Although it can move forward to the frontal region, alpha is found in a reduced amount in this location as compared to the other three cortical regions. Theta frequency (4 – 7 Hz), know as rhythmic slow activity (RSA), is prominent in the hippocampus region of the brain which is anterior to the alpha region. Delta frequency (1-3 Hz) originates from deep brain structures and is prominent during deep sleep (Morse, 1993).

Clinical Uses of Photo-Stimulation

The first uses of rhythmical photo-stimulation were to evoke paroxysmal EEG discharges. Photo-stimulation was used primarily to evaluate epileptic and other seizure disorders. Brain wave synchronizers (BWS) were developed using photo-stimulation dark goggles for the purpose of rapid induction of a relaxation state. As early as 1948, studies using BWS as a means of inducing relaxation and hypnosis were conducted. Increases in alpha, theta and some delta frequency, together with synchronization in various cortical areas have been observed by investigators to be indicative of deep relaxation. BWS also induces these phenomena (Orme-Johnson, 1973; Morse, Martin, Furst & Dubin, 1977; West, 1980; Shealy, 1996, chap. 7).

The first commercially available BWS was demonstrated by Schneider in 1958 (Kroger and Schneider, 1959). The BWS unit consisted of a photic stimulator similar to those used to test for convulsive disorders. However, Schneider's unit, which consisted of a single light placed two to three feet from the patient's eyes, had variable frequencies ranging from low delta (0-1 Hz) to alpha (approx. 13 Hz). The traditional photic stimulator used to evoke seizures is set at higher frequencies, general 15-25 Hz. Frequency control with these BWS was managed either by the therapist or the subject. Kroger and Schneider used audiotapes or verbal phrases in conjunction with their BWS with approximately two thousand five hundred subjects. Over ninety percent of the subjects treated had induced light to deep hypnotic trance with the use of the BWS. Schneider noted that each individual became entrained at a specific frequency which resulted in a wide range of responses.

In those early years, BWS were used to help in labor and delivery, aid in anesthesiology, and for control of hypertension (Morse, 1993). Popularity of the BWS increased over time. In 1966, Bernard Margolis, D.D.S., reported that patient controlled frequency BWS was a valuable tool for allaying fears and apprehension (Cox, Shealy, Cady & Liss, 1996). Margolis found that relative to BWS, as compared to routine treatment: (a) patients used less local anesthesia; (b) gagging was easier to control; (c) central nervous system (CNS) depression did not occur; and (d) post procedure healing appeared to be more rapid (Morse, 1993; Cox, et al., 1996). In later years Jack Schwartz developed a new type of BWS that utilized alternating light from right to left eye at alpha

(8-13 Hz) or beta (>13 Hz). From 1975 through 1990, C. Norman Shealy, M.D., Ph.D., used BWS units to include Schneider and Schwartz type devices, as well as goggles he developed to synchronize both hemispheres which employed simultaneous flashing of right and left lights at alpha or theta frequency, in over five thousand chronic pain patients to facilitate relaxation and detachment from their preoccupation with pain (Morse, 1993). In a retrospective study of ninety-two patients, Shealy compared: (a) cranial electrical stimulation (CES); (b) several different light frequency BWS units; (c) Hemi-Sync tapes designed by Bob Monroe to synchronize brain wave activity and focus of attention; (d) self-hypnosis tapes; and (e) relaxation-type music. Considering all of the parameters reviewed: (a) one percent of patients preferred self-hypnosis alone; (b) ten percent preferred BWS alone; (c) eighty percent preferred a combination of BWS and self-hypnosis; and (d) five percent preferred neither BWS nor self-hypnosis (Morse, 1993; Cox, et al., 1996). In 1990, Dr. Shealy developed the Shealy Relaxmate™ which employs variable frequency of 3.1 Hz to 12 Hz utilizing red LED reflected against a blue background to produce a visual analog of violet (Cox, et al., 1996).

Physiologic Effects of Photo-Stimulation

Research studies have been conducted aimed at evaluating the physiologic effects of photo-stimulation. Use of the flickering light form of photo-stimulation results in synchronization or “entrainment’ of brain wave activity to the same frequency of the stimulus (Cox, et al., 1996). Photo-acoustic stimulation is a powerful stimulator for the central nervous system resulting in a state of relaxation, relief from simple anxiety and reduction of salivary secretion in the oral cavity (Fabian & Fabian, 2000; Morse, 2000). In a study conducted by Shealy, et al. (1996) color photo-stimulation was found to affect both neuro-hormones and neuro-chemicals, with the most pronounced effect on neuro-hormones.

Use of flickering light photo-stimulation in the treatment of headaches has been addressed in the literature. Slow wave (1-3 Hz) photo-stimulation applied for a period of only five minutes was shown to relieve muscle contraction headache but not migraine (Solomon, 1985). Anderson (1989) undertook a study to evaluate the use of variable frequency (0.5 -50 Hz) photo-stimulation for treatment of migraine headaches in subjects for whom pharmacologic therapy had not achieved satisfactory control. Median duration of use of the photo-stimulation goggles was thirty minutes. Frequency and intensity of the photo-stimulation were set to subject preference. The median duration of migraine headaches using the goggles was thirty-five minutes which was found to be statistically significant ($p<0.02$). Follow up with two subjects over eighteen months appeared to reveal a trend toward increasing intervals between migraines. A survey of migraine sufferers, who used the same photo-stimulation goggles studied by Anderson, was conducted by Norton (2000). The result showed that forty-four percent of migraine sufferers reported that the frequency of their migraines was “less”.

A study of the use of photo-stimulation for the treatment of premenstrual syndrome (PMS) was undertaken by Anderson, Legg and Ridout (1997). Seventeen women with confirmed, severe, and long standing PMS used photo-stimulation for a median of seventeen minutes daily for up to four menstrual cycles. At the conclusion of the treatment prospectively recorded median luteal symptom scores were reduced by seventy-six percent, with clinically and statistically significant reductions in depression, anxiety, affective lability, irritability, poor concentration, fatigue, food cravings, bloating and breast pain. According to Norton (1997), another study of women with PMS revealed that during the time symptoms were experienced EEG measurement showed an increase in delta activity and slower evoked response than when they were mid-cycle. This finding suggests that PMS may be characterized as a slow brainwave disorder similar to attention deficit disorder and minor head injury.

Two Studies Germaine to this Dissertation

McCraty, et al. (1996) studied five individuals trained in the Freeze-Frame (FF) technique. Subjects were seated in comfortable, high back chairs (to minimize postural changes), fitted with ECG and EEG electrodes, respiration belt, and ear and finger pulse transducer sensors. Prior to each session subjects were informed of the tasks they were to perform and asked to refrain from talking, falling asleep, exaggerated body movements and intentionally altering their respiration. The subjects were monitored one at a time using a fifteen minute baseline period followed by a five minute FF period. As the heart approaches entrainment, both the sympathetic and parasympathetic branches of the autonomic nervous system shift their power into the mid frequency range (~0.1 Hz) in the HRV power spectrum which is associated with the baroreceptor feedback loop between the heart and the brain. Frequency pulling is observed in the respiratory system towards this mid range frequency until frequency locking of the HRV waveform and respiration rate occurs. Thereafter the signal amplitude in the ~0.1 Hz range of the brainwaves begins to increase significantly. Strong cross correlation was found to exist between these pairs of biological oscillators.

Zagulova, et al. (2001), subjected twenty healthy female volunteers to ten audiovisual stimulation (AVS) sessions utilizing a Voyager XL™ apparatus. The AVS relaxation programs started in the beta range, then decreased to the alpha range and finally to the theta range. Before the end of the program, the rate of AVS stimulation increased to slow beta range (12-14 Hz) in order to accelerate adaptation to normal activity after relaxation. ECGs and individual anxiety were assessed before the AVS and the next day after the final session. The effect of AVS induced structural changes in the heart rhythm.

Noting that current views purport the heart rate is closely related to psychic status, Zugulova, et al. (2001) also compared the vegetative and psychic effects of AVS on the subjects by measuring changes in spectral parameters with the heart rhythm simultaneously while assessing individual and reactive anxiety. AVS was found to decrease both individual and reactive anxiety. These data agree with general views of interrelation between psychoemotional stress on the one hand, and high activity of sympathetic and ergotropic systems, on the other. Therefore, AVS induces parallel changes at the psychic and vegetative states.

CHAPTER III

METHODOLOGY

A quantitative research design was utilized for this project. The study was organized in such a manner that it met the criteria to be considered a true experiment. Potential subjects were recruited and screened by an interviewer until a total of sixty subjects were successfully enrolled in the study.

Sampling

Sampling refers to the process of selecting a portion of the population to represent the entire population. Quantitative research designs should identify the eligibility and/or exclusion criteria for inclusion in the study. Exclusion criteria for this study included known seizure disorder and current medication regimes that included beta blockers and calcium channel blockers. Sampling strategies are grouped into two categories:

- Probability sampling. This technique uses some form of random selection in choosing the sample. Probability samples are generally preferred because greater confidence can be placed in the representativeness of the sample.
- Non-probability sampling. With this technique the samples are selected by nonrandom methods.

(Polit & Hungler, 1997)

For this study a non-probability sampling technique was utilized. Specifically, a convenience sampling method was utilized. Convenience sampling entails the use of the most conveniently available people for the study (Polit & Hungler, 1997). Subjects for the study were recruited from a convenience population of patients of a primary care clinic and through personal contacts by the researcher. Potential subjects were screened for appropriateness of inclusion in the study by filling out a Subject Profile form which solicited demographic and health information (Appendix A). The researcher reviewed the Subject Profile with all potential subjects and a determination made if the subject could be accepted into the study. Once accepted for inclusion in the study, subjects were provided with an Informed Consent (Appendix B) to review and sign. Subjects were offered a copy of their signed consent form for their personal records.

Study Design

The nature of the concepts and constructs to be examined in this study are best explored in a quantitative research design. An experimental design is chosen. An experiment differs from a non-experiment in that in an experiment the researcher is an active agent in the work rather than an observer. The following three properties are found in the study design, resulting in a true experiment:

- Randomization. The experimenter assigns participants to a control or experimental group on a random basis.
- Control. The experimenter introduces one or more controls over the experimental situation, including the use of a control group.
- Manipulation. The experimenter does something to at least some of the participants in the study.

(Polit & Hungler, 1997)

Randomization

Random assignment of subjects insures that each participant has an equal chance of being included in any group. With random assignment there is no systematic bias in the groups with respect to attributes that may affect the dependent variable under investigation. Subjects who are randomly assigned to groups are expected to be comparable with respect to a wide range of human characteristics such as age, gender, race, education, physical condition, and psychological adjustment. Randomization results in groups that tend to be equivalent with respect to an infinite number of biologic, psychological, and social traits at the outset of the study. Any differences that emerge after random assignment of subjects can therefore be attributed to the experimental treatment (Polit & Hungler, 1997).

Random assignment of subjects in the study was accomplished through a self "drawing" technique. Once an individual had been accepted for inclusion in the study they were asked to draw a piece of paper from a tall coffee can. A total of sixty small strips of paper were used for this process. On thirty of the strips of paper the word "star" was written and on the other thirty strips of paper the word "balloon" was written. Subjects drawing a piece of paper with the word "star" on it were assigned to the control group and subjects drawing a piece of paper with the word "balloon" on it were placed in the intervention group. Group assignment was recorded appropriately on the subject profile form.

Control

The second requirement for experimental research is a control group. The term control group refers to a group of participants whose performance on a dependent variable is used as the basis for evaluating the performance of the experimental group – the group that receives the treatment of interest to the researcher, on the same dependent variable (Polit & Hungler, 1997). The intervention under investigation was not applied to the control group.

Subjects in the control group were placed on a massage table in a darkened room. A pulse sensor was appropriately placed on the index finger of the left hand of all subjects at the beginning of the study. To facilitate appropriate sensing of the pulse wave, subjects were instructed to keep their left hand by their side and avoid movement of the left hand for the duration of the study. The Freeze Framer™ program was used to measure a baseline fifteen minute monitoring session of HRV. Since no intervention was applied to the control group, a second fifteen minute monitoring session of HRV was obtained. Subjects in the control group were instructed to keep their eyes closed through both recording sessions and instructed to simply do whatever they would do if they had a specific aim of relaxing.

Manipulation

In experimental research, the investigator manipulates the independent variable by administering a treatment, or intervention, to subjects in the intervention group while withholding the intervention from the control group. The investigator has control over and consciously varies the independent variable and then observes its effect on the dependent variable of interest (Polit & Hungler, 1997). The intervention in this study was the placement of a BWS over the eyes of subjects in the intervention group for a period of fifteen minutes while measuring their HRV via the Freeze Framer™ program.

Subjects in the intervention group were placed on a massage table in a darkened room. A pulse sensor was appropriately placed on the index finger of the left hand of all subjects at the beginning of the study. To facilitate appropriate sensing of the pulse wave, subjects were instructed to keep their left hand by their side and avoid movement of the left hand for the duration of the study. The Freeze Framer™ program was used to measure a baseline fifteen minute monitoring session of HRV. Subjects in the intervention group were instructed to keep their eyes closed through the baseline recording session and instructed to simply do whatever they would do if they had a specific aim of relaxing.

At the conclusion of recording of the baseline fifteen minute HRV monitoring session, the researcher placed a BWS - namely the Shealy Relaxmate™, over the closed eyes of the subjects. The lowest frequency (theta) was selected along with the lowest level of intensity by the researcher prior to placement on the subject. Subjects were instructed to keep their eyes closed during the fifteen minute intervention session.

Data Collection

Like research design, there are many alternative approaches to data collection. A primary decision for investigators concerns the basic form of the data collection method. Three approaches are most often utilized in clinical research: self-reports, observation, and biophysiolgic measures. Regardless of the specific approach used, data collection methods vary along several important dimensions:

- Structure. Research data are often collected in a highly structured manner: exactly the same information is gathered from all participants in a comparable, specific way. For some studies, however, it may be appropriate to be flexible and impose a minimum structure and to provide participants with opportunities to reveal relevant information in a naturalistic way.
- Quantifiability. Data that will be subjected to statistical analysis must be gathered in such a manner that it can be quantified. Structured data collection methods tend to yield data that are more easily quantified.

- Obtrusiveness. Data collection methods differ in terms of the degree to which participants are aware of their status as a research subject. When participants are aware of their role in a study, their behavior and responses may not be normal.
- Objectivity. Some data collection methods require more subjective judgment than others. Quantitative researchers strive for methods that are as objective as possible.

(Polit & Hungler, 1997)

A biophysiologic measure was utilized for this study. Specifically, that measure was of HRV. HRV measurement was obtained and recorded via the Freeze Framer™ program. The program is a product available from Planetary™, which is a division of HeartMath, LLC. Two computers with the capacity to load and run the program were used for this study. One computer was a Toshiba™ notebook model and the other computer was a Compaq™ desktop model. Recordings from both subject sessions were numbered and saved to the hard drive of the respective computer. At the conclusion of data collection from all sixty subjects, data sets were printed out. Data was sorted into control and intervention sets. The data points from both groups were then placed into an Excel™ spreadsheet to facilitate transport into SPSS™ a statistical data analysis program.

While not the primary method of collection for the study, self-reporting data was also collected from study subjects. For the intervention group, at the conclusion of the BWS session subjects were queried in regard to their subjective experience of the BWS. Information was then noted on the respective participant's Subject Profile.

This data was collected for anecdotal purposes. Additionally, self-reporting data was obtained from two subjects in the control group who were noted at the conclusion of their HRV recording sessions to have demonstrated high levels of entrainment of HRV.

Data Analysis

Application of statistical measures allows the researcher to reduce, summarize, organize, evaluate, interpret and communicate numeric information. A quantitative measure can be classified according to its level of measurement. There are four major classes, or levels of measurement:

- Nominal measurement. This is the lowest level of measurement and involves using numbers to simply classify characteristics into categories.
- Ordinal measurement. This measurement permits the numeric ranking of objects on the basis of their standings relative to each other on a specified attribute.
- Interval measurement. This measurement occurs when the researcher can specify both the rank order of objects on an attribute and the distance between those objects.
- Ratio measurement. This is the highest level of measurement. Ratio scales have a rational, meaningful zero.

(Polit & Hungler, 1997)

Analysis of variance (ANOVA) is a parametric statistical procedure used to test the significance of mean group differences. The statistic computed in an ANOVA test is the

F ratio. A multivariate analysis of variance (MANOVA) is the extension of ANOVA to more than one dependent variable (Polit & Hungler, 1997).

The level of measurement achieved in this study was the ratio level. MANOVA was the procedure used to test the significance of mean group differences. Since analysis with a multivariate procedure did not result in achievement of a statistically significant level of significance, findings from this study will also be explored utilizing simple descriptive statistics in an attempt to explore trends noted with evaluation of the data set.

CHAPTER IV

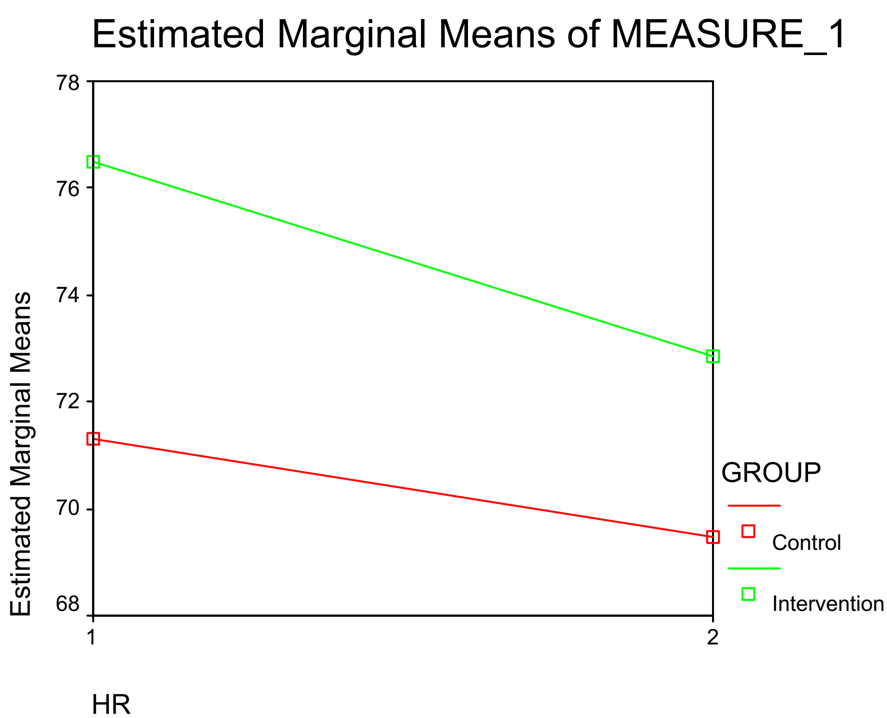
RESULTS

A quantitative research design was used for this study. The study design included the elements of randomization, control and manipulation. Hence this study meets the criteria of being a true experiment. The scientific hypothesis tested was: Utilization of BWS for fifteen minutes, as a passive method of balancing the autonomic nervous system, will result in a shift to higher ratio levels of entrainment of HRV. The dependent variables of the study are the three ratio levels of entrainment of HRV - low, medium, and high. The independent variable, or the intervention, of the study is the application of BWS which is a form of photo-stimulation.

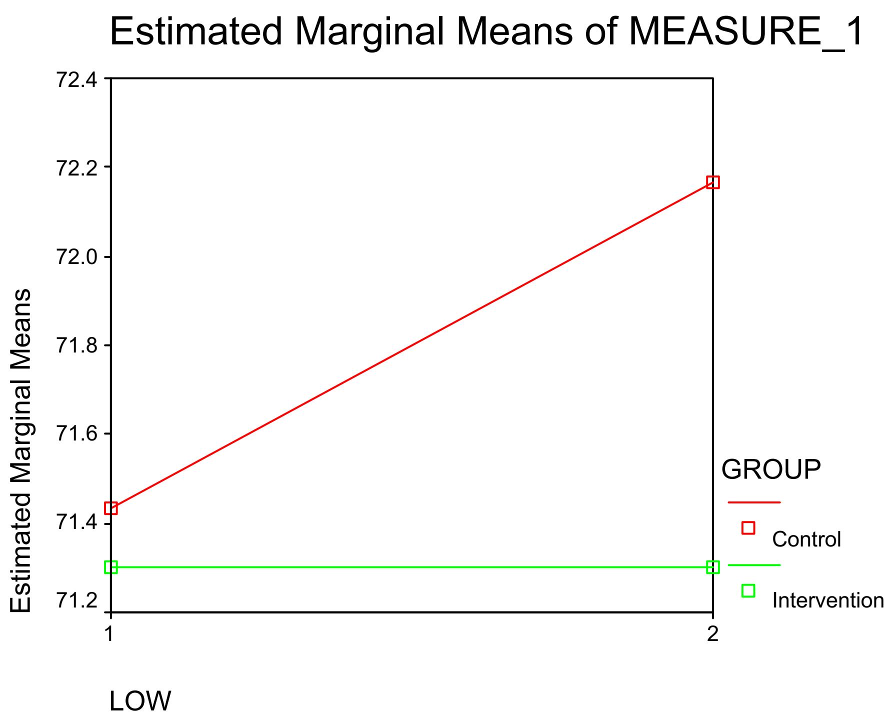
Utilizing the parametric statistical procedure of MANOVA, analysis of data failed to demonstrate a statistical significance of mean group differences for all dependent variables of the study. Hence, the results do not support acceptance of the hypothesis tested.

Although not intended to be included as a dependent variable initially for this study, a review of the graph below regarding mean measurements of heart rate (HR) reveals an interesting finding. Noted for both groups is a decrease in the mean heart rate during the baseline recording session and the mean heart rate noted during the intervention session. An approximate decrease of four beats per minute of the mean heart rate noted in the intervention group represents an approximate decrease of five percent. The control groups mean heart rate decreased two beats per minute, representing an approximate three percent decrease. Is the greater percentage decrease in mean heart rate in the intervention group simply a matter of chance, or could it be reflective of a trend toward the phenomena of a decreased heart rate observed in other methods used to balance the

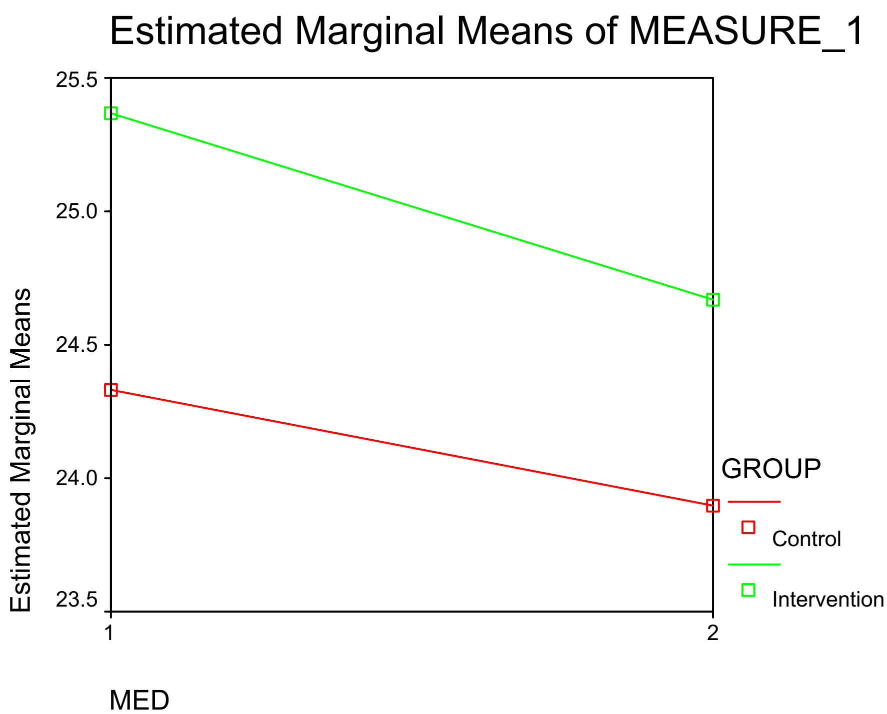
ANS as presented earlier in this paper? If this finding is a trend, then use of BWS is consistent with the findings of prior research into methods used to combat the effects of stress by reducing heart rate. See the graph below.



Review of the difference between the mean low ratio levels of entrainment of HRV from the baseline session to the intervention session for subjects in the intervention group reveals no change. This finding is notable when compared to the difference in mean low ratio level of entrainment of HRV between the two sessions in the control group. The control group trend was toward an increase in the mean low ratio level of entrainment of HRV. To achieve the goal of combating the effects of stress on the ANS, a decrease in the mean low ratio level of entrainment needs to be accomplished. Decreasing the low ratio level of entrainment of HRV would result in a shift to increased mean medium, and perhaps increased mean high, ratio levels of entrainment of HRV. Higher ratio levels of entrainment of HRV reflect greater balance of the ANS. See the graph below.

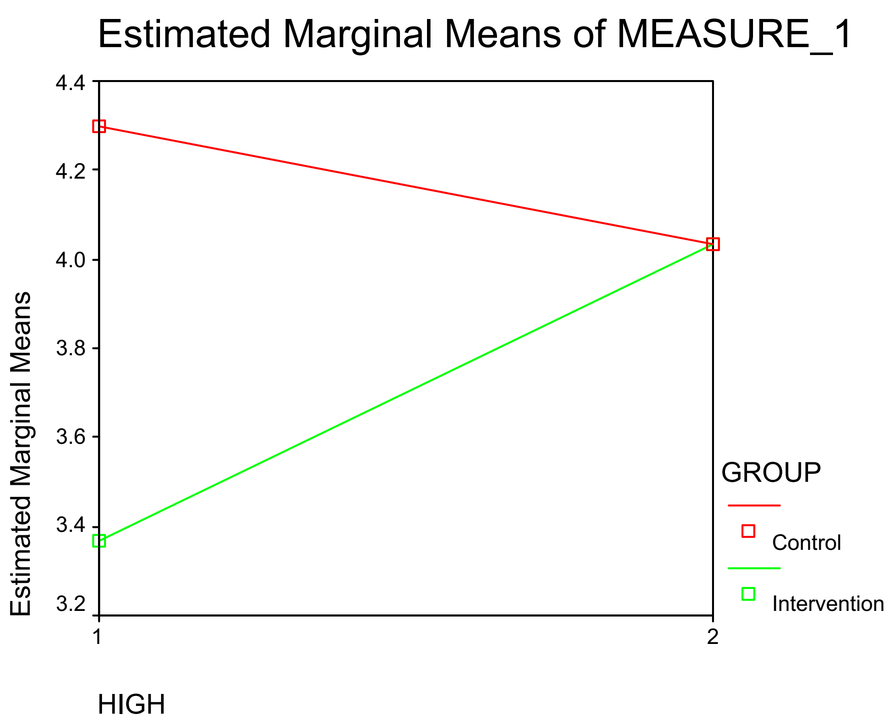


Review of the change in the mean medium ratio level of entrainment of HRV both within the groups and between the groups does not reveal any striking information. The change in mean medium ratio level of entrainment of HRV demonstrated within the groups from baseline to second recording session was approximately two percent for each group. The difference between the mean medium ratio levels of entrainment of HRV between the groups from baseline to second recording session only changed by two tenths of a percent. See the graph below.



Review of the graph representing the difference between the mean high ratio levels of entrainment of HRV in the intervention group from baseline recording to intervention recording is striking. There is noted a twenty-three percent increase in the mean high ratio level of entrainment of HRV during the intervention session. Although a statistical level of significance did not result from data analysis, the percent increase noted is important in that it indicates a trend toward increased mean high ratio levels of entrainment of HRV which reflects a trend of increased balance of the ANS. In the control group there is noted a decrease in the mean high ratio level of entrainment of

HRV. This decrease correlates with the increase noted in the control group of the mean low ratio level of entrainment of HRV. Despite the trend noted in the intervention group, at the conclusion of the study period the mean high ratio level of entrainment of HRV was equivalent in both groups. See the graph below.



Failure of statistical significance to be achieved in both the control group and the intervention group suggests two conclusions:

- Lying on a massage table for two consecutive fifteen minute sessions, doing whatever they typically do when they have a specific aim of relaxing, does not result in a shift to higher ratio levels of entrainment of HRV.
- Lying on a massage table for a fifteen minute session, doing whatever they typically do when they have a specific aim of relaxing, followed by a fifteen

minute session of BWS, does not result in a shift to higher ratio levels of entrainment of HRV.

Please refer to the entire data set for this study (Appendix C).

Individual review of data sets from both the control and the intervention groups does reveal some interesting findings. The highest ratio levels of HRV entrainment were actually observed in the control group for a two subjects who reported praying during their two fifteen minute sessions (appendix D). One subject in the intervention group demonstrated the desired response from BWS, resulting in a nearly thirty percent shift into higher ratio levels of HRV (Appendix E). A shift of this magnitude was not noted in any subjects in the control group nor in the majority of subjects in the intervention group. A subject in the intervention group, who demonstrated a heart rate in excess of one hundred beats per minute during the baseline recording, experienced a significant decrease of their heart rate in response to BWS (Appendix F). Most subjects in the intervention group reported that the use of BWS did result in a feeling being “relaxed”. However for some subjects in the intervention group, use of the BWS was anxiety producing.

CHAPTER V

DISCUSSION

One of the major limitations of this study was the setting. While subjects were placed on a massage table in a darkened room, the property the study was conducted at is located on a busy street corner. Despite the fact that subjects were placed in the two rooms of the property at the greatest distance from the busy street, and depending on the time of day the subject participated, it was difficult even with heavy fabric covering the windows and outside the entrance doors to the rooms to filter out all the noise. Encroachment of the testing environment from ambient noise may have adversely affected the outcome of a study aimed at achieving relaxation and balance in the autonomic nervous system. A similar concern was noted by Jacobson (1974) for which Celotex™ panels were placed along the walls of the room in an attempt to better "sound proof" the testing environment.

Another limiting factor may be the introduction of the BWS itself to subjects in the intervention group. Only three subjects randomized into the intervention group had any prior knowledge or experience with BWS. Being in a testing environment and being exposed to a new device, as unusual as a BWS, alone could be anxiety producing enough to have a contradictory effect.

A third draw back to the study was the need for the researcher to enter the testing environment at the end of the baseline recording session in order to restart the Freeze-Framer™ program for the second session. It would be beneficial if the computer could be placed outside the room for testing purposes, however length of the cord on the pulse wave sensor did not allow for such a placement. It would also be beneficial if the BWS had a fifteen minute delay timer that could be set at the beginning of the first session such that it would begin to operate at the beginning of the second session preventing the need for the researcher to have to enter the room and place the BWS on the subject. Again this same concern was expressed by Jacobson (1974). He noted that the presence of the investigator was often disquieting. Subjects were instructed not to bother about the comings and goings of others, but just to keep on relaxing or to relax all the more when disturbed in this or any other manner.

In so much as most of the subjects in the intervention group reported that use of the BWS led to a feeling of being relaxed, I believe there is merit in replicating this study and controlling for the environmental problems described above. Additionally, the study should be restructured to allow subjects randomly assigned to the intervention group the opportunity to experience the BWS on several occasions before conducting the study. Doing so may eliminate the potential anxiety producing scenario of experiencing an unfamiliar intervention which is assuredly counterproductive to testing the hypothesis. Additionally, the amount of time for application of BWS may need to be increased to thirty minutes in order to fully synchronize brain wave activity in such a manner that would result in a reflexive entrainment of HRV.

In so much as the highest ratio of HRV entrainment was observed in control group subjects who prayed, the concept of "intent" must not be overlooked in analyzing the results of this study or planning future studies. While these subjects may not have had the specific intent of high ratio level of HRV entrainment, they did have the "heart" intention of a positive emotion-focused activity. Perhaps future studies should be undertaken to evaluate the effect of prayer on the ratio level of HRV entrainment.

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APPENDICES

Appendix A

Subject Profile

Subject Profile

Date of Interview _________
Interviewer _______________
Subject's name ________________________________ Age ________ DOB ___________
Race of subject _______________ Are you a native English speaker? ☐ Yes ☐ No

In the following questions regarding health answer the question in reference to you and your immediate family members. Use the following to complete the form.
(I) Self; (M) Mother; (F) father; (S) sister; (B) brother; (EF) extended family

Cardiovascular Problems [High BP, Stroke, Heart Attack, Blockage, CHF, Abn Rhythm]
____
____
____

Seizure Disorder ____

Your current medications:
____
____
____

Have you taken any stimulants, depressants, or over the counter medications in the last 48 hours? ☐ Yes ☐ No
If yes, please list them below:
____

I have reviewed all above information as provided to interviewer and believe to be correct to the best of my knowledge.

Name print _______________________ sign _______________________ date _________

For staff use only below this line.

Accepted ☐ Yes ☐ No ______________ Study Number ___________________

Study Group ☐ Star ☐ Balloon

Denied, reason ____
Interviewer's signature: _______________________ Date _____________ Time ________

Appendix B

Informed Consent

Informed Consent

Holos University Graduate Seminary supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You should be aware that even if you agree to participate, you are free to change your mind at any time prior to the collection of information without penalty.

The purpose of this study is to examine the effect of photo-stimulation on relaxation as measured by entrainment of heart rate variability.

You should know the following:

Your personal information will be kept confidential and may only be accessed by a group of four faculty members at Holos University Graduate Seminary for use in student dissertation study by one graduate student, Julie Penick.

Your personal information will remain in a locked file cabinet.

Your personal information will not be shared with anyone, any agency or other study group.

Your personal data will be collected and added to data collected from all study subjects. It is this aggregated data that will be the reported as the study findings.

Your name will not be associated in any way with the research findings.

Time frame for subject participation is approximately thirty minutes.

Your participation is solicited although strictly voluntary. Your consent will expire a year from the date on which it was signed. If you would like any additional information concerning this study before or after it is complete, please feel free to contact us by phone or mail.

Julie Penick, MSN
Principal Investigator
1211 E. Woodland
Springfield, MO 65804
(417) 887-2838

C. Norman Shealy, M.D., Ph.D.
Faculty Chair
Holos University Graduate Seminary
Fair Grove, MO
(417) 267-4625

____Date___________
Signature of Subject agreeing to participate

Print Your Name Here: ____
With my signature I affirm that I am at least 18 years of age, understand and have received a copy of the consent form to keep.

Appendix C

Data Set

General Linear Model

Notes

Output Created		29-JUL-2003 11:40:37
Comments		
Input	Data	C:\Documents and Settings\pthomli\Desktop\Stat projects\Penick Dissertation Data.sav
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	61
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM hr1 hr2 BY group /WSFACTOR = hr 2 Polynomial /METHOD = SSTYPE(3) /PLOT = PROFILE(hr*group) /CRITERIA = ALPHA(.05) /WSDESIGN = hr /DESIGN = group .
Resources	Elapsed Time	0:00:00.03

Within-Subjects Factors

Measure: MEASURE_1

HR	Dependent Variable
1	HR1
2	HR2

Between-Subjects Factors

		Value Label	N
GROUP	.00	Control	30
	1.00	Intervention	30

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
HR	Pillai's Trace	.159	10.947(a)	1.000	58.000	.002
	Wilks' Lambda	.841	10.947(a)	1.000	58.000	.002
	Hotelling's Trace	.189	10.947(a)	1.000	58.000	.002
	Roy's Largest Root	.189	10.947(a)	1.000	58.000	.002
HR * GROUP	Pillai's Trace	.020	1.187(a)	1.000	58.000	.280
	Wilks' Lambda	.980	1.187(a)	1.000	58.000	.280
	Hotelling's Trace	.020	1.187(a)	1.000	58.000	.280
	Roy's Largest Root	.020	1.187(a)	1.000	58.000	.280

a Exact statistic
b Design: Intercept+GROUP Within Subjects Design: HR

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-boun
HR	1.000	.000	0	.	1.000	1.000	1.0

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept+GROUP Within Subjects Design: HR

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
HR	Sphericity Assumed	224.133	1	224.133	10.947	.002
	Greenhouse-Geisser	224.133	1.000	224.133	10.947	.002
	Huynh-Feldt	224.133	1.000	224.133	10.947	.002
	Lower-bound	224.133	1.000	224.133	10.947	.002
HR * GROUP	Sphericity Assumed	24.300	1	24.300	1.187	.280
	Greenhouse-Geisser	24.300	1.000	24.300	1.187	.280
	Huynh-Feldt	24.300	1.000	24.300	1.187	.280
	Lower-bound	24.300	1.000	24.300	1.187	.280
Error(HR)	Sphericity Assumed	1187.567	58	20.475		
	Greenhouse-Geisser	1187.567	58.000	20.475		
	Huynh-Feldt	1187.567	58.000	20.475		
	Lower-bound	1187.567	58.000	20.475		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

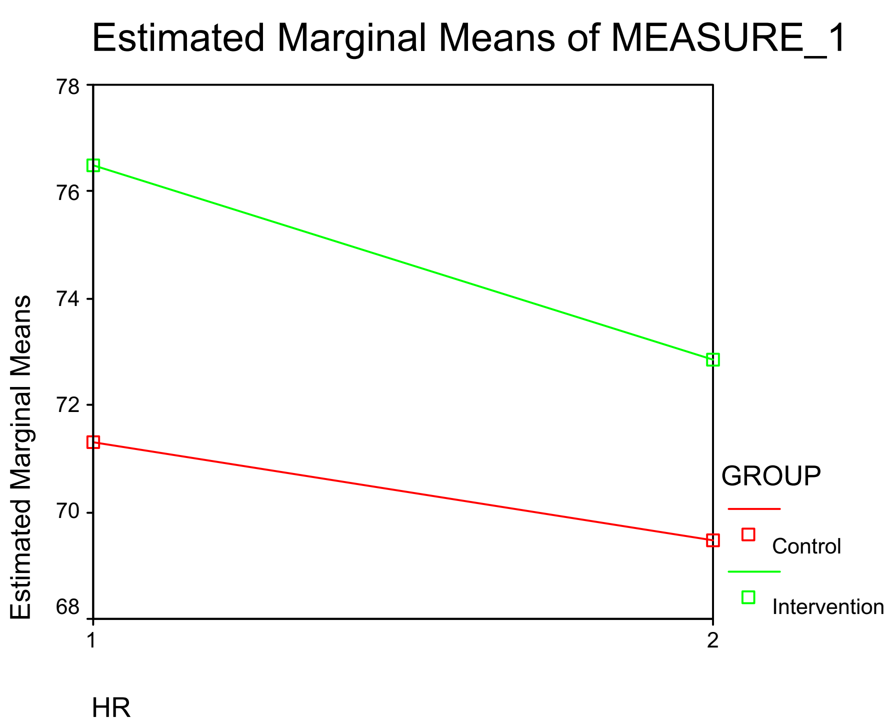
Source	HR	Type III Sum of Squares	df	Mean Square	F	Sig.
HR	Linear	224.133	1	224.133	10.947	.002
HR * GROUP	Linear	24.300	1	24.300	1.187	.280
Error(HR)	Linear	1187.567	58	20.475		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	631330.133	1	631330.133	2382.507	.000
GROUP	554.700	1	554.700	2.093	.153
Error	15369.167	58	264.986		

Profile Plots



General Linear Model

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM low_1 low_2 BY group /WSFACTOR = low 2 Polynomial /METHOD = SSTYPE(3) /PLOT = PROFILE(low*group) /CRITERIA = ALPHA(.05) /WSDESIGN = low /DESIGN = group .
Resources	Elapsed Time	0:00:00.02

Within-Subjects Factors

Measure: MEASURE_1

LOW	Dependent Variable
1	LOW_1
2	LOW_2

Between-Subjects Factors

		Value Label	N
GROUP	.00	Control	30
	1.00	Intervention	30

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
LOW	Pillai's Trace	.001	.033(a)	1.000	58.000	.857
	Wilks' Lambda	.999	.033(a)	1.000	58.000	.857
	Hotelling's Trace	.001	.033(a)	1.000	58.000	.857
	Roy's Largest Root	.001	.033(a)	1.000	58.000	.857
LOW * GROUP	Pillai's Trace	.001	.033(a)	1.000	58.000	.857
	Wilks' Lambda	.999	.033(a)	1.000	58.000	.857
	Hotelling's Trace	.001	.033(a)	1.000	58.000	.857
	Roy's Largest Root	.001	.033(a)	1.000	58.000	.857

a Exact statistic
b Design: Intercept+GROUP Within Subjects Design: LOW

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-boun
LOW	1.000	.000	0	.	1.000	1.000	1.0

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept+GROUP Within Subjects Design: LOW

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
LOW	Sphericity Assumed	4.033	1	4.033	.033	.857
	Greenhouse-Geisser	4.033	1.000	4.033	.033	.857
	Huynh-Feldt	4.033	1.000	4.033	.033	.857
	Lower-bound	4.033	1.000	4.033	.033	.857
LOW * GROUP	Sphericity Assumed	4.033	1	4.033	.033	.857
	Greenhouse-Geisser	4.033	1.000	4.033	.033	.857
	Huynh-Feldt	4.033	1.000	4.033	.033	.857
	Lower-bound	4.033	1.000	4.033	.033	.857
Error(LOW)	Sphericity Assumed	7163.933	58	123.516		
	Greenhouse-Geisser	7163.933	58.000	123.516		
	Huynh-Feldt	7163.933	58.000	123.516		
	Lower-bound	7163.933	58.000	123.516		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

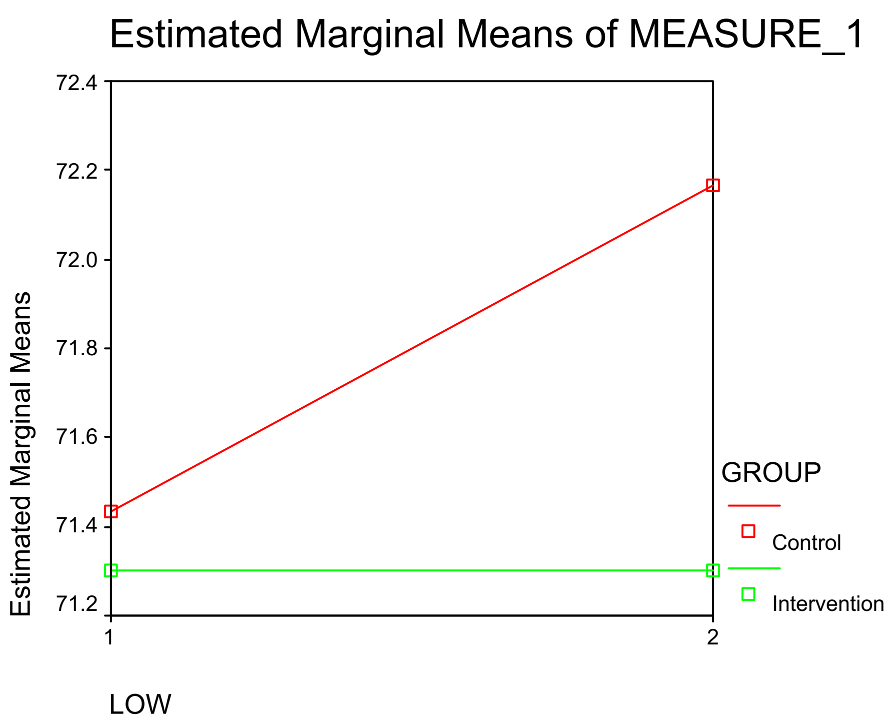
Source	LOW	Type III Sum of Squares	df	Mean Square	F	Sig.
LOW	Linear	4.033	1	4.033	.033	.857
LOW * GROUP	Linear	4.033	1	4.033	.033	.857
Error(LOW)	Linear	7163.933	58	123.516		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	614328.300	1	614328.300	1064.878	.000
GROUP	7.500	1	7.500	.013	.910
Error	33460.200	58	576.900		

Profile Plots



General Linear Model

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM med_1 med_2 BY group /WSFACTOR = med 2 Polynomial /METHOD = SSTYPE(3) /PLOT = PROFILE(med*group) /CRITERIA = ALPHA(.05) /WSDESIGN = med /DESIGN = group .
Resources	Elapsed Time	0:00:00.02

Within-Subjects Factors

Measure: MEASURE_1

MED	Dependent Variable
1	MED_1
2	MED_2

Between-Subjects Factors

		Value Label	N
GROUP	.00	Control	30
	1.00	Intervention	30

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
MED	Pillai's Trace	.002	.112(a)	1.000	58.000	.739
	Wilks' Lambda	.998	.112(a)	1.000	58.000	.739
	Hotelling's Trace	.002	.112(a)	1.000	58.000	.739
	Roy's Largest Root	.002	.112(a)	1.000	58.000	.739
MED * GROUP	Pillai's Trace	.000	.006(a)	1.000	58.000	.938
	Wilks' Lambda	1.000	.006(a)	1.000	58.000	.938
	Hotelling's Trace	.000	.006(a)	1.000	58.000	.938
	Roy's Largest Root	.000	.006(a)	1.000	58.000	.938

a Exact statistic
b Design: Intercept+GROUP Within Subjects Design: MED

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-boun
MED	1.000	.000	0	.	1.000	1.000	1.0

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept+GROUP Within Subjects Design: MED

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
MED	Sphericity Assumed	9.633	1	9.633	.112	.739
	Greenhouse-Geisser	9.633	1.000	9.633	.112	.739
	Huynh-Feldt	9.633	1.000	9.633	.112	.739
	Lower-bound	9.633	1.000	9.633	.112	.739
MED * GROUP	Sphericity Assumed	.533	1	.533	.006	.938
	Greenhouse-Geisser	.533	1.000	.533	.006	.938
	Huynh-Feldt	.533	1.000	.533	.006	.938
	Lower-bound	.533	1.000	.533	.006	.938
Error(MED)	Sphericity Assumed	5000.833	58	86.221		
	Greenhouse-Geisser	5000.833	58.000	86.221		
	Huynh-Feldt	5000.833	58.000	86.221		
	Lower-bound	5000.833	58.000	86.221		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

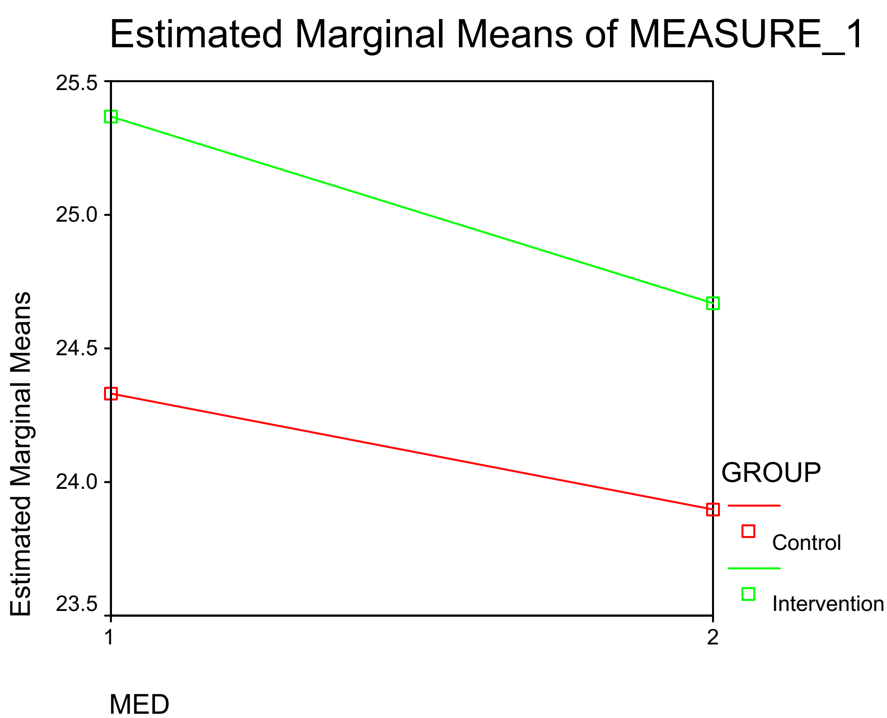
Source	MED	Type III Sum of Squares	df	Mean Square	F	Sig.
MED	Linear	9.633	1	9.633	.112	.739
MED * GROUP	Linear	.533	1	.533	.006	.938
Error(MED)	Linear	5000.833	58	86.221		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	72422.533	1	72422.533	215.343	.000
GROUP	24.300	1	24.300	.072	.789
Error	19506.167	58	336.313		

Profile Plots



General Linear Model

Notes

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	N of Rows in Working Data File	61
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM high_1 high_2 BY group /WSFACTOR = high 2 Polynomial /METHOD = SSTYPE(3) /PLOT = PROFILE(high*group) /CRITERIA = ALPHA(.05) /WSDESIGN = high /DESIGN = group .
Resources	Elapsed Time	0:00:00.02

Within-Subjects Factors

Measure: MEASURE_1

HIGH	Dependent Variable
1	HIGH_1
2	HIGH_2

Between-Subjects Factors

		Value Label	N
GROUP	.00	Control	30
	1.00	Intervention	30

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
HIGH	Pillai's Trace	.002	.090(a)	1.000	58.000	.766
	Wilks' Lambda	.998	.090(a)	1.000	58.000	.766
	Hotelling's Trace	.002	.090(a)	1.000	58.000	.766
	Roy's Largest Root	.002	.090(a)	1.000	58.000	.766
HIGH * GROUP	Pillai's Trace	.008	.489(a)	1.000	58.000	.487
	Wilks' Lambda	.992	.489(a)	1.000	58.000	.487
	Hotelling's Trace	.008	.489(a)	1.000	58.000	.487
	Roy's Largest Root	.008	.489(a)	1.000	58.000	.487

a Exact statistic
b Design: Intercept+GROUP Within Subjects Design: HIGH

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-boun
HIGH	1.000	.000	0	.	1.000	1.000	1.0

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept+GROUP Within Subjects Design: HIGH

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	Df	Mean Square	F	Sig.
HIGH	Sphericity Assumed	1.200	1	1.200	.090	.766
	Greenhouse-Geisser	1.200	1.000	1.200	.090	.766
	Huynh-Feldt	1.200	1.000	1.200	.090	.766
	Lower-bound	1.200	1.000	1.200	.090	.766
HIGH * GROUP	Sphericity Assumed	6.533	1	6.533	.489	.487
	Greenhouse-Geisser	6.533	1.000	6.533	.489	.487
	Huynh-Feldt	6.533	1.000	6.533	.489	.487
	Lower-bound	6.533	1.000	6.533	.489	.487
Error(HIGH)	Sphericity Assumed	775.267	58	13.367		
	Greenhouse-Geisser	775.267	58.000	13.367		
	Huynh-Feldt	775.267	58.000	13.367		
	Lower-bound	775.267	58.000	13.367		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

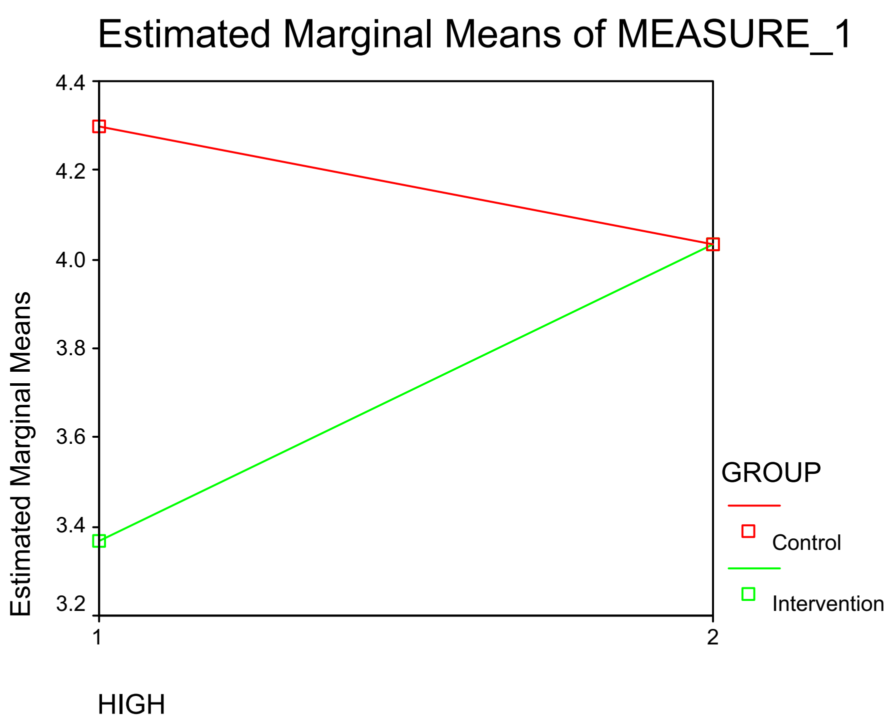
Source	HIGH	Type III Sum of Squares	df	Mean Square	F	Sig.
HIGH	Linear	1.200	1	1.200	.090	.766
HIGH * GROUP	Linear	6.533	1	6.533	.489	.487
Error(HIGH)	Linear	775.267	58	13.367		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1856.533	1	1856.533	27.055	.000
GROUP	6.533	1	6.533	.095	.759
Error	3979.933	58	68.620		

Profile Plots



Appendix D

Control Group Data Sets - Praying Subjects

Appendix E

Intervention Group Subject – Desired Response

Appendix F

Intervention Group Subject – Heart Rate Response