Measuring the Relationship Between Reflexive and Intentional ANS Response

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
In
Psychology

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April 30, 2008
Blacksburg, Virginia

Keywords: Autonomic Nervous System, Coactivation, Inhibition, Volition

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ABSTRACT

The dynamic behaviors of a complex organism are explained via voluntary and involuntary action. One underpinning of this system is organized and facilitated by the autonomic nervous system, integrating information from conscious and non-conscious centers in a seemingly hierarchical fashion. As a result, voluntary actions have the ability to inhibit reflexive actions via an inhibitory circuit. 111 subjects performed four diverse autonomic tasks consisting of voluntary and involuntary combinations. Analysis supports the proposed hierarchical model. Each task evoked specific autonomic states. Voluntary tasks influenced autonomic actions more than involuntary tasks. And working memory capacity mediated voluntary control.

ACKNOWLEDGMENTS

I must first direct my gratitude towards my parents. They are the impetus to all my accomplishments. In this same vain I thank all my relatives and friends, both dead and living. We are all the residue of things prior to us. Next, I must thank my esteemed colleagues at Virginia Tech. Bruce, you have given me freedom and guidance, it is an event of synchronicity that I have come to study under you. To my brothers of the Mind-Body Order, may we continue to innovate and discover. And a very special thanks to the laboratory assistants, your efforts greatly assuaged the pain inherent in such a project.

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Introduction

Psychologists, biologists, anthropologists, philosophers, chemists, and even economists have long debated the impetus of action—to put it simply, what makes organisms, especially humans, do what they do? The actions of complex organisms are the result of complex, dynamic relationships. However, the complexity of motivating variables can be simplified into two prominent categories: reflexive and intentional behavior.

Reflexive actions are by definition unconscious responses (Bratman, 1999; James, 1890; Velleman, 2000). An organism that is unaware of the motivations generating the response is engaging in involuntary behavior. Reflexive actions are the result of entrained biological and psychological processes that are highly predictable. The synthesis of proteins, cellular respiration, endocrine responses, digestion and even aspects of driving are examples of reflexive action. In contrast, intentional, or voluntary, responses require the organism to actively choose a response via conscious deliberation (James, 1890). An agent's behaviors that are based on beliefs and performed with awareness are considered to be purposeful (Anscombe, 1963; Bourdieu, 1977; Bratman, 1999; Davidson, 1980; Mele, 1992; Sahlins, 1977; Velleman, 2000). Actively choosing to hold one's breath, read a book, or exercise can be considered intentional actions.

The idea of reflexive and intentional actions is an old one. Pioneers in the field of psychology, like William James, Sigmund Freud, and B.F. Skinner considered involuntary forces a primary motivator of action. They also recognized the necessary role of intention in suppressing involuntary action (Freud, 1927; James, 1890; Skinner, 1953). Contemporary researchers have explored these same concepts and have discovered that humans and other animals can repress reflexive behavior in favor of cortically mediated actions (Curtis & D'Esposito, 2003; Simons, Ohman, & Lang, 1979; Ohman, 1992). Research also shows that these repressive qualities are readily apparent in autonomic functions (Jennings, 1992a, b; Porges, 1992; Van Der Veen, Van Der Molen, & Jennings, 2000). The current study attempts to advance this line of investigation by viewing actions as components of an encompassing mind-body system and by quantitatively measuring the mind-body system via the autonomic nervous system.

The Organism as a System

Systems theory proposes an *anti-reductionistic model* of phenomena. The study of single components in an active system overlooks both the interactions between elements and the context within which the system is operating. The behavior of a system is described as an *emergent property*—a dynamic interaction between the system's components (Miller, 1976, 2006; von Bertalanffy, 1968, 1969). Emphasis is shifted from the objects themselves to the ongoing communication between them. Organisms can therefore be considered complex networks of bio-oscillators that operate as open systems which are continuously exchanging information and energy with other systems (Gatlin, 1972; Glass, 2001; Miller, 1976; Miller & Thomas, 1977; West & Goldberger, 1987).

Behavior in this view is influenced by an organism's experience over time. Highly predictable behaviors, such as reflexive actions, are the result of highly canalized experience. Reflexive actions allow an organism to react quickly to specific and general conditions; however, reflexes can be limiting and disadvantageous. Multiple responses to specific or general conditions allow an organism to react with various behaviors to various conditions (Globus & Arpaia, 1994; Goldberger, 1990). Evolutionary processes have generated further variability of response via the phenomena of conscious intent. Volition is therefore one more component contributing to an organism's behavior.

Intent requires an organism to actively choose a response. From a systems view, the behaviors of humans (and other complex organisms) are the reciprocal product and impetus of ongoing voluntary and involuntary processes. Both volitional and reflexive variables (inputs) are constantly contributing to the organism's state or behavior (output). Further, both inputs and outputs are reciprocally contributing to subsequent intentional and reflexive states. This voluntary/reflexive system will be referred to as the *mind-body system*.

Exploring the Mind-Body System via the ANS

The mind-body system constructs actions through the dynamic functions of voluntary and involuntary experience. The result of interconnected and residual dynamics creates complex behaviors, well defined in dynamic systems theories (Globus & Arpaia, 1994; Lewis, 2005; Miller, 1976, 2006; von Bertalanffy, 1968, 1969). The prime component of the proposed mind-body system is the autonomic nervous system (ANS). The next section explores why the ANS provides an excellent tool for investigating the mind-body system.

The Autonomic Nervous System

The ANS was first designated as such by John Langley (1921) to describe an intricate network of peripheral nerves, ganglia and associated regulatory systems. He proposed these cranial and cervical structures to control the smooth muscles and glands of the viscera. Early conceptions of the ANS as an "automatic" system, immune from conscious infiltration, are apparent in the name. Walter Cannon viewed the ANS as a system responsible for sustaining life. Cannon (1939) termed this process 'homeostasis' and put forth the idea that the survival of organisms is dependent upon their ability to maintain an optimal functional state. This functional state arises from feed-back regulated autonomic reflexes responding to change in visceral demand that elicit automatic adjustments to restore homeostatic balance.

Because humans are not always conscious of visceral modulations or autonomic actions, Langley's "autonomic" conceptions dominated subsequent research as scientists focused on unconscious ANS action. However, research soon emerged that recognized the input of cognitive structures and the recognition of the ANS as a sensory system. The ANS is now understood to be organized via the diencephalon, mesencephalon, rhombencephalon and spinal cord responsible for simplistic reflexes and the telencephalon generating complex cognitive and behavioral processes. The advent of the ANS as sensory system also allows visceral afferent information to contribute to higher processing centers (For review see Appenzeller, 1999; Berntson & Cacioppo, 2000).

Autonomic Divisions

Traditionally the ANS is divided into two discrete branches: the sympathetic (SNS) and the parasympathetic nervous systems (PNS). The divisions of the ANS have distinct central origins, anatomy and functions. The sympathetic system generally prepares the organism to metabolize energy. The parasympathetic division generally allows an organism to conserve and store energy.

The sympathetic nervous system. An organism must have the ability to respond to various situations in appropriate ways to ensure survival. The SNS serves one strategy by mobilizing the organism. Some specific consequences of sympathetic activation increases metabolism, heart rate, respiration and skin conductance (Appenzeller, 1999). Cannon (1939) referred to this heightened state of activation as the "fight—or—flight" response, preparing the body to use energy in an effort to avoid or confront a stressful situation.

The parasympathetic nervous system. The PNS is generally viewed reciprocally to the SNS serving to conserve energy, promote feeding/digestion and assist in reproduction. In general, parasympathetic actions relax smooth muscle, slow down heart rate, engage peristalsis in the digestive track, and foster calm and social behavioral states. An integral component of the PNS is the vagus nerve which is proposed to have two distinct pathways originating in the unmyelinated Dorsal Motor Nucleus and myelinated Nucleus Ambiguus (Bueno et al.,1989; Porges, 1995b, 2003, 2006).

Modes of Autonomic Control

This simple distinction of the activities promoted between the components of the ANS belies the incredible complexity of neurotransmitter, neuromodulatory, and neurohormonal interactions that the ANS is capable of. The ANS is a flexible system allowing maximal response to environmental events (Berntson, Cacioppo & Quigely, 1993; Berntson, Cacioppo, Quigley & Fabro, 1994). However, three major modes of behavior are apparent in how the ANS operates: The ANS can effectively increase, decrease or not change autonomic functions.

Coupled reciprocal activity and coactivation. A common mode of autonomic activity between the PNS and SNS is *coupled reciprocal activation* (CRA). CRA is recognized as a negative correlation between the two branches, as one increases in activity the other decreases. CRA exhibits the widest dynamic range of control and yields the greatest target organ reactivity. Reciprocal modes also yield a high degree of directional stability as states tend to persist (Berntson et al., 1994).

In addition to CRA, the ANS can effectively stimulate both sympathetic and parasympathetic activity simultaneously at a target organ. *Coactivation* of both autonomic systems has been historically recognized as a possibility of autonomic activity (Cannon, 1939). It is now clear that autonomic coactivation, as demonstrated by direct neural stimulation, neurophysiological recordings, and psychophysiological measurements, can be generated by basic cardiovascular reflexes as well as behavioral and cognitive processes (Berntson, Cacioppo, & Quigley, 1991; Fukuda, Sato, Suzuki, & Trzebski, 1989; Iwata & LeDoux, 1988; Koizumi, Kollai, & Terui, 1986; Levy & Zieske, 1969; Levy 1984; Obrist, Wood, & Perez-Reyes, 1965; Quigley & Berntson, 1990; Uijtdehaage & Thayer, 2000).

The ANS provides a window of access for investigating the mind-body system. First, the ongoing implicit and explicit processes of the mind-body system are present in the behavior of the ANS. Second, the distinct behaviors of the ANS (SNS & PNS) provide opportunity to investigate the specific dynamics of involuntary and voluntary processes.

How is the Integration of Mind and Body Possible?

Human actions depend on reflexive and voluntary motivations which generate the mind-body system. The autonomic nervous system has been proposed to represent the behavior of this system. However, the question as to exactly how the mind-body system integrates reflexive and intentional motivations into expressed behavior still remains. The next sections will explore the possible neuroanatomical underpinnings of the mind-body system.

Mind-Body Integration

Several models have been proposed that identify anatomical units which would allow intentional goal-directed behavior and reflexive motivations to influence behavior. These models are all similar and have been called the CAN (Central Autonomic Network: Benarroch, 1993, 1997), the Anterior Executive Region (Devinsky, Morrell, & Vogt, 1995) and the Emotion circuit (Damasio, 1998).

The central autonomic network. The central autonomic network (CAN) is one model proposed to support the goal-directed actions of the mind-body system (Benarroch, 1993, 1997). Functionally, this system integrates internal regulation (visceromotor, neuroendocrine and behavioral responses). Structurally, the CAN is made up of the anterior cingulate, insular, and ventromedial prefrontal cortices, the central nucleus of the amygdala, the paraventricular and related nuclei of the hypothalamus, the periaquaductal grey matter, the parabrachial nucleus, the nucleus of the solitary tract (NST), the nucleus ambiguus, the ventromedial medulla, and the medullary tegmental field (Benarroch, 1993, 1997). In addition, sensory information from the peripheral end organs, such as the heart, is fed back to the CAN, thus the CAN is not confined to the central nervous system (Porges, 2007) (see Figure 1).

The CAN is a primary example of the proposed neural-visceral model (Thayer & Lane, 2000, 2002; Thayer & Friedman, 2002, 2004). The neural-visceral model encompasses hormonal, peripheral and central nervous system actions into an arrangement which allows for system-wide response, organization, and selection (Thayer & Friedman, 2002). The neural-visceral model provides a clear neuroanatomical structure for the integration of reflexive (subcortical and non-cerebral mechanisms) and intentional (cortical centers) motivations into an interconnected reciprocal unit. The neural-visceral model is the mind-body system, necessitating the bidirectional flow of information, allowing reflexive and intentional actions to be expressed and regulated. However, while these proposed models exhibit bidirectional causality between involuntary and voluntary energies, a clear hierarchy of motivations appears to be in place.

Hierarchy of autonomic regulation. The mind-body system, as illustrated by the neural-visceral model, is an expansive network which is essential to the functions of a human organism. The mind-body system is a reciprocal system but a model of autonomic activity has been proposed which describes the mind-body system in a hierarchical fashion (Lovallo, 2005). In particular, the body-mind system regulates autonomic states through a hierarchy of control mechanisms. Individual organs and cells have the ability to regulate their own activity through local reflexivity, but local actions are limited. More global behaviors rely on an integrated hierarchy of control parameters.

An organism must constantly adjust its behaviors to a dynamic environment. The most basic actions are done to regulate local events. Organs have intrinsic regulation mechanisms which allow autonomous reflexivity to minimal environmental demands. However, local reflexes are severely limited and must rely on incoming information from the global autonomic and endocrine systems to adjust to more complex demands.

The autonomic and endocrine systems have the ability to adjust the actions of individual organs, which in turn, generate more complex system-wide behaviors. However, the ANS and endocrine systems can be controlled by specific nuclei in the brainstem (i.e nucleus ambiguus, ventral tegmental nucleus). The next chain of command in the autonomic hierarchy belongs to the hypothalamus, which exports direct and indirect instructions to the brainstem and the rest the body. The hypothalamus can in turn be controlled by cortical (prefrontal cortex, lateral dorsal motor cortex, medial dorsal motor cortex, orbitofrontal cortex, cingulated cortex, insular cortex, association areas) and limbic structures (amygdala and hippocampus).

The autonomic hierarchy is representative of systemic behavior aforementioned. Each of these levels can be viewed as reverberating circuits maintaining very basic (metabolizing energy, excreting waste), more complex (finding a mate or food), or very complex goals (deciding what to wear or solving a math problem). However, these goals or actions are organized hierarchically: complex goals appear to have greater jurisdiction over less complex goals. Yet the ability for lower hierarchical goals to direct more complex goals is still recognized as conscious and non-conscious processes represent overlapping organizational principles and not dichotomous constructs (Sarter, Givens, & Bruno, 2001).

The Jacksonian model of inhibition. Continuing along the present line, actions originate from both non-conscious reflex and conscious intention. However, the mind-body system is organized in a clear hierarchical fashion. Psychological events not only intercede on the actions of the mind-body but are in direct control of many actions. This ability relies on mechanisms that can override or augment habitual actions in order to generate voluntary actions (Miller, 2000). As a result, the mind-body system is phylogenetically arranged to favor conscious intention over non-conscious reflex. The cognitive and non-conscious functions of the mind-body system, as measured by the ANS, respond to challenges in a phylogenetically determined hierarchy (Porges, 2007). This model proposes that the older reflexive functions of the ANS can be inhibited or mitigated by the newer intentional functions. This concept is evident in Jackson's (1850, 1958) *principle of dissolution* which states that phylogenetically newer systems, like the neocortex, inhibit pylogenetically older systems, such as the limbic system. In addition, he proposed that "when the higher (newer) are suddenly rendered functionless, the lower (older) rise in activity (Jackson, 1850: 1958)."

Pushing this concept further, intentional actions, argued to be the product of cortical centers, inhibit reflexive actions because the reflexive actions are the product of older response systems (Kesner, & Olton, 1990). Utilizing Jacksonian concepts, the phylogenetically older structures of the mind-body system are under the inhibitory control of phylogenetically newer structures.

The Frontal cortex, inhibition, and parasympathetic mediation. According to the proposed hierarchical model, the upper tier of the mind-body system must lie in its conscious centers. The cortex and specifically the frontal cortex (FC) are good candidates for housing the conscious centers of the mind-body system. Neurological investigations have confirmed that the FC is involved in intentional or inhibitory action and the representation of goals (Bjork, 1989; Dempster, 1991; Diamond, 1988). The role of the frontal cortex as an organizer of conscious goals is integral to understanding top-down processing. The FC is an interconnected set of neocortical areas that have a unique but intersecting relation with almost all sensory neocortical, motor and sub-cortical structures; this bidirectional interconnectivity affords an optimal infrastructure for synthesizing the diffuse information necessary for complex behavior (Barbas & Pandya, 1991; Fuster, 1997; Goldman-Rakic, 1987; Pandya & Barnes, 1987).

One way the FC coordinates conscious goals is via inhibition. Inhibition is the process of diminishing excitation: the active suppression of goal-irrelevant information, and inappropriate or reflexive responses in the promotion of long range goals (Baddeley, 1986; Bunge, Ochsner, Desmond, Glover, & Gabrieli, 2001; Jacobsen, 1936; Knight, Hillyard, Woods, & Neville, 1981; Luria, 1966; Malmo, 1942; Thayer & Friedman, 2002; Thayer & Brosschot, 2005). A phylogenic argument posits the frontal cortex as a modulator of tonic subcortical functions (reflexive actions) to promote conscious goal-directed behavior (Skinner S., 1985). Thus, if the frontal cortex is disengaged from this duty, subcortical functions should be expressed.

The inhibitory behavior of the frontal cortex is seen in the interplay between the sympathetic and parasympathetic nervous systems. Both the cortex and NA vagal portion of the PNS are phylogenetically younger than the subcortical structures of the brain and SNS (Kesner & Olton, 1990; Porges, 2007). Increased cortical development generated increased cortical dominance over the brainstem via direct (e.g. corticobulbar) and indirect (e.g. corticoreticular) neural pathways originating in the motorcortex and terminating in the source nuclei of the myelinated motor nerves of the brainstem (Ahern et al., 2001; Porges, 2007; Ter Horst, 1999).

As a result, the myelinated vagus actively inhibits the sympathetic functions and conscious intention can activate this vagal inhibition (Porges, 2007; Ter Horst, 1999). True to the proposed Jacksonian model, if the myelinated parasympathetic functions, mediated by the frontal cortex, are disengaged from the duty of inhibiting subcortical sympathetic actions, a relative sympathetic dominance arises (Ahern et al., 2001; Benarroch, 1993, 1997; Cohen, Matar, Kaplan, & Kotler, 1999; Friedman, 2007; Friedman, Thayer & Tyrrell, 1996; & Friedman & Thayer, 1998a, 1998b; Masterman & Cummings, 1997; Spyer 1989; Thayer, Smith, Rossy, Sollers, & Friedman, 1998).

Vertical and horizontal orientation. The presented model is vertical in orientation because hierarchical control is descending. Overall, the mind-body system does operate vertically. But inter/intra cerebral inhibition exhibits another level of operation. Much of how the brain functions is a product of lateral and posterior/anterior relationships. A true model of inhibition is therefore not only vertical in nature but also arranged in a horizontal fashion (Hugdahl, 2000). Emotional responses (Baas, Aleman, & Kahn, 2004; Davis, 1992; LeDoux, 2000), immune function (Barneoud, Neveu, Vitiello, & Le Moal, 1987), neuroendocrine responses (Wittling & Pfluger, 1990), and cardiovascular function (Critchley et al., 2000; Demaree & Harrison, 1997; Oppenheimer, 2001; Sander & Klingelhofer, 1995; Zhang & Oppenheimer, 1997) are all considered to exhibit lateral inhibitory properties.

Anterior and Posterior regions also share similar characteristics. In general, the anterior region of the cerebral cortex is thought to have inhibitory control over the posterior region (Braver et al., 1997; Devinsky, Morrell, & Vogt, 1995; de Zubicaray, Andrew, Zelaya, Williams, & Dumanoir 2000a; de Zubicaray, Zelaya, Andrew, Williams, & Bullmore, 2000b; Luria, 1966; Tucker, Roth, & Bair, 1986). The extent and processes of cerebral inter/intra inhibition extends beyond the scope of this paper. As future work will lead to more information, the current study attempts investigate inhibition by applying a more simplistic model.

Testing the Relationship between Voluntary and Involuntary Actions

It has been proposed that the relationship between conscious and non-conscious actions can be observed by evoking reflexive and intentional autonomic responses simultaneously. Simultaneous elicitation forces competition and according to the presented theory, intentional actions have the power to effectively suppress reflexive actions. An effective way to measure competing autonomic functions is through coactivation. Coactivation can be generated by performing a parasympathetic eliciting task in unison with a sympathetic eliciting task. However, the crux of this experiment relies on intentional and non-intentional autonomic tasks, so each task must be primarily evoked via intentional or involuntary methods while minimizing the involvement of its dichotomous pair.

Previous Research

Coactivation experiments. Few researchers have investigated coactivation and none have utilized coactivation to investigate the presented topics. However, coactivation has been employed as a psychophysiological manipulation to investigate cardiovascular dynamics (Friedman & Santucci, 2003; Friedman & Thayer, 1998a; Friedman et al., 1993, 1996; Rossy & Thayer, 1998; Uijidehaage & Thayer, 2000). In these experiments, facial cooling served as a parasympathetic task and was paired with shock avoidance, a competitive video game, or a visual search to elicit sympathetic response.

A slight tendency towards a sympathetic dominance of autonomic response during coactivation was found across these studies. While these experiments were not designed to investigate voluntary and involuntary action, they still provide information on the subject. However, the full gamut of voluntary/involuntary coactivation tasks has not been explored. Thus, it is unclear if the same pattern of activity will always be displayed.

The Dynamics of Psychological and Physiological Manipulations. The current study explores autonomic interaction through psychological and physiological components. The effects of active (voluntary) and passive (involuntary) manipulations and how they vary is an old question in psychology. The current theory predicts that voluntary tasks would have more efficacy for altering autonomic behavior than involuntary tasks. The majority of past research supports the dominance of isolated psychological stressors over isolated physiological stressors, particularly when comparing some cognitive challenge to the cold pressor task (Brown, Szabo, & Seraganian, 1988; Goldstein & Shapiro, 1988; Light & Obrist, 1980; Manuck, Harvey, Lechleiter, & Neal, 1978; Obrist, 1978) (see Table 1 for a summary of past multiple stressor research).

However, this seems to be only half the story. Myrtek & Spital (1986) reported “synergistic effects” for stressor combinations as compared to the single stressors: Specific autonomic measures reacted differently to specific stressor tasks. For example, exercise is known to generate greater increases in cardiac output but diminished vascular responses. Others have reported autonomic reactivity to also rely on the posture of the subject as well (Hatch, Klatt, Porges, Schroeder-Jasheway, & Supik, 1986; Myrtek & Spital, 1986; Szabo, 1993). Szabo described greater reactivity to mental arithmetic in heart rate but greater cardiac sympathetic reactivity to orthostatic stress. An increase in heart rate during arithmetic is due to decreased vagal activity at the heart but orthostatic stress resulted in increased sympathetic activity at the heart.

The relationship of physical and psychological action is further evidenced by a study of mental arithmetic and aerobic exercise (Roth, Bachtler, and Fillingim, 1990). Not only did subjects performing both physical exercise and a cognitive stressor generate greater cardiovascular response than exercise alone, but an anti-anxiety effect produced by exercise was attenuated by the combination of exercise and cognitive stress. Although not all the evidence was conclusive, it appears as if active stressors evoke greater sympathetic reactivity than passive stressors and combinations of intentional and reflexive stressors elicited greater reactivity than single stressors.

Working Memory

Intentional action requires the agent to maintain specific conscious goals. The conscious representation of goals (language, planning, attention, and problem solving) that acts to temporarily maintain and manipulate task-relevant information and intentional behaviors is dependent upon a process called working memory (WM) (Baddeley, 1986; Shallice, 1988). Experiments demonstrate that WM is a function of the frontal lobes (Baddeley, 1986; Braver et al., 1997; Bunge, Ochsner, Desmond, Glover, & Gabrieli, 2001; D'Esposito, Postle, & Rypma, 2000; Jacobsen, 1936; Luria, 1966; Malmo, 1942; Sarter, Givens, & Bruno, 2001). Hence, WM is a good indicator of how efficient the FC is at maintaining goals and inhibiting irrelevant information (Curtis & D'Esposito, 2003; Engel & Singer, 2001; Hopfinger, Buonocore, & Mangun, 2000; Sarter et al., 2001). As such, WM should be a good predictor of how a subject will react when given competing intentional and reflexive tasks simultaneously. As predicted by the top-down model, if the frontal cortex does not mediate subcortical/sympathoexcititory potentiality, subcortical/sympathoexcititory activity will be expressed. Thus, subjects with weak WM should display an autonomic state dominated by the reflexive task while subjects with strong WM should display the opposite during simultaneous elicitation.

Measuring WM. One way to assess WM is through the *Wechsler Memory Scale* (WMS—III) (Wechsler, Third edition: 1945/1997). The WMS III has two subtests which are designed to gauge a subject's ability to maintain short-term goals, thus appraising an aspect of WM (Bowden, Carstairs, & Shores, 1999; Larrabee, Kane, & Schuck, 1983; Moore & Baker, 1997). The backward digit span test requires the subject to repeat a sequence of numbers back to the experimenter in the reverse order in which they were given. The backward spatial span test is similar to the digit span test except the experimenter presents the subject with a panel containing physical boxes. The experimenter then points to different boxes in a specific order. The subject is required to point to the boxes in the reverse order in which they were presented.

The working memory tests, as stated, help determine an individual's ability to maintain conscious goals. In addition, the use of both spatial and digit tasks allows the experiment to indirectly address issues of laterality. In the present study the spatial task will be considered to represent right hemisphere activity (Courtney, Petit, Maisog, Ungerleider, & Haxby, 1998; Griffiths, Rees, Witton, Cross, & Shakir, 1997; Guerrini, Berlucchi, Bricolo, & Aglioti, 2003; McCarthy et al., 1996; Posner & Petersen, 1990) and the digit span task will be used to index left hemispheric activity (Baddeley, 1998; Ehrsson, Kuhtz-Buschbeck, & Forssberg, 2002; Orsini et al., 1987; Postle & D'Esposito, 1999).

Present Study

In the proposed mind-body model, intentional processes have the ability to govern the mind-body system. One way to test this hypothesis is to match reflexive and intentional autonomic responses using ANS states as an index of the mind-body system. Four tasks were selected to elicit specific autonomic states. Each task represented two levels of categorization: source (involuntary or voluntary) and autonomic system (parasympathetic or sympathetic). Nine non-invasive physiological variables were used to measure autonomic activity.

Involuntary Tasks

Parasympathetic: facial cooling. Facial cooling, by cooling the trigeminal nerve, results in vagally mediated bradycardia (Brown, Sanya, & Hilz, 2003; Hilz et al., 1999; Uijidehaage & Thayer, 2000).

Sympathetic: hand cold pressor. The cold pressor increases alpha-adrenergic (sympathetic) activity at the vascular level, which in turn raises blood pressure (Antony, Aptecar, Lerebours, & Nitenberg, 1994; Frank & Raja, 1994; Kanayama, Tsujimura, She, Maehara, & Terao, 1997; Wirch, Wolfe, Weissgerber, & Davies, 2006).

Voluntary Tasks

Parasympathetic: guided mental relaxation. Mental relaxation has been shown to elicit parasympathetic activity (Arakawa, 1989; Benson, 1997; Jacob, Kraemer, & Agras, 1977; Kaushik, Mahajan, & Rajesh, 2006; Sebastiani, Simoni, Gemignani, Ghelarducci, & Santarcangelo, 2005; Terathongkum & Pickler 2004; Uijidehaage & Thayer, 2000; van Dixhoorn & White, 2005).

Sympathetic: mental arithmetic. Mental arithmetic requires a subject to devote significant processing resources and produces increases in sympathetic activity (Hedman & Nordlander, 1988; Sharpley et al., 2000; Pike, Smith, Hauger, & Nicassio, 1997; Willemsen, Ring, McKeever, & Carroll, 2000).

Combined Tasks

Four combination trials were created from the selected tasks: Facial Cooling x Mental Relaxation; Hand Cold Pressor x Mental Arithmetic; Hand Cold Pressor x Mental Relaxation; Facial Cooling x Mental Arithmetic

Autonomic Measurements

Heart rate variability. The cardiovascular system is innervated by both autonomic branches, which generate discrete cardiovascular behaviors. The result of this ongoing interplay of sympathetic and parasympathetic activity creates distinct temporal patterns in the heart rate referred to as heart rate variability (HRV). The oscillation of heart periods are produced by autonomic sources generated via psychological and physiological factors (Berntson et al., 1997; Saul, 1990). These patterns of cardiac activity are mediated through sympathetic (beta-adrenergic) and parasympathetic (nicotinic) neurons that innervate the heart at the sino-artrial node. It is the interplay between the two autonomic divisions which creates the complex patterns of the heart rate time series (Saul, 1990).

HRV is evident in both temporal and frequency domains. The mean inter—beat—interval (IBI) or the time between heat beats is a temporal measure and a product of both sympathetic and parasympathetic functions (Friedman et al., 2002). HRV can also be investigated by calculating the root mean square of successive IBI differences (RMSSD). RMSSD is a measure of the variability in the cardiac cycle and attributed to vagal activity (Bertson et al., 1997). Previous investigations have also employed spectral analysis to HRV. Researchers divide the periodic components of heart rate variability into three main frequency bands: High Frequency (HF); Low Frequency (LF); and Very Low Frequency (VLF). A fourth frequency band, referred to as Ultra Low Frequency (ULF) or infradian rhythms also exists. Only low and high frequency bands are considered.

High Frequency, is generally considered the respiratory component of HRV and typically spans from 0.15 Hz to 0.4 Hz but may extend below the 0.15 Hz and above 1Hz in developmental stages and various behaviors (exercise, sleep, meditation)(Peng et al., 1999, Peng et al., 2004; Saul 1990). High frequency oscillations are thought to reflect Respiratory Sinus Arrhythmia (RSA). When young healthy adults inspire, heart rate tends to increase and expiration slows the heart down. RSA is generally attributed to parasympathetic activity. Inspiration decreases vagal activity at the heart, which causes the acceleration (Bertson et al., 1997; Neff, 2003; Porges, 1995; Saul, 1990).

LF (also referred to as mid frequency) is typically labeled as frequencies occurring between 0.04 and 0.15 Hz. The most prominent oscillation is called the Mayer wave and is directed by Baroreflex HR modulation occurring approximately every 10 seconds (Cohen & Taylor, 2002; Mayer, 1877; Penáz, Honzikova, & Fiser, 1978). LF is sometimes attributed to sympathetic activity as events that increase sympathetic activity tend to increase LF (e.g. Friedman, Thayer, & Tyrrell, 1996). However, debate continues as evidence for both sympathetic and parasympathetic activity in the LF has been found and the issue remains unresolved (Dellinger, Taylor, & Porges, 1987; Eckberg, 1997; Pagani et al., 1997; Porges, 2006).

Impedance cardiogram. Impedance cardiography (ICG) is measured by passing an electrical current through the thoracic region. The electrical current travels along the aorta and is impeded by blood volume. ICG generates measures of systolic time intervals and cardiac output. ICG was used to examine the pre-ejection period (PEP) of the cardiac cycle. PEP is the amount of time (milliseconds) between the electrical signal to the ventricles initiating contraction and the ejection of blood from the left ventricle into the aorta, which is sympathetically mediated via beta-adrenergic activity.

Blood pressure. Blood pressure (BP) measures the degree of pressure (mmHg) exerted on the vascular walls by the blood. Systolic blood pressure (SBP) is defined as the peak pressure of the cardiac cycle as it measures the contraction of the ventricles. Diastolic blood pressure (DBP) is defined as the nadir of the cardiac cycle and measures the degree of pressure while the ventricles are filling with blood (Brownley, Hurwitz, & Schneiderman, 2000). Blood pressure is an autonomic index as vessel properties are under the control of sympathetic (alpha-adrenergic: vasoconstriction, beta-adrenergic: vasodilation, muscarinic: vasodilation) and reduced parasympathetic (muscarinic: vasodilation) mechanisms (Akselrod et al., 1985; Baselli et al., 1986).

Skin conductance. The skin has a natural degree of conductance (mhos) mediated by the ionic properties of sweat. As sweat ducts are excited, skin conductance is increased; this is referred to as skin conductance level. The sweat ducts are under the direct control of sympathetic cholinergic pathways. SCL is generally used as an index of arousal (Dawson, Schell & Filion, 2000).

Respiratory rate. Respiration is regulated by complex feedback loops and represents mixed autonomic influence. Both the vagus and glossopharyngeal cranial nerves play roles in respiratory regulation (Hlastala & Berger, 1996). In addition, respiratory control can be both voluntary and involuntary.

Hypotheses

Using the theorized mind-body model and assuming that a subject has an efficient inhibitory circuit (frontal cortex), predictions for combined autonomic tasks can be formulated. Each task is proposed to elicit either sympathetic or parasympathetic dominance. A parasympathetically dominated autonomic state generates decreases in blood pressure, skin conductance, and low frequency spectral power and increases in pre-ejection period, inter—beat—interval, the root mean square of successive differences, and high frequency spectral power. A sympathetically dominated autonomic state is evidenced by increases in blood pressure, skin conductance, and low frequency spectral power and decreases in pre-ejection period, inter—beat—interval, the root mean square of successive differences, and high frequency spectral power.

Facial Cooling x Mental Relaxation (FCA). Pairing a reflexive parasympathetic task with an intentional parasympathetic task is predicted to produce a strong parasympathetic state because the parasympathetic inhibitory circuit has been expressed.

Hand Cold Pressor x Mental Arithmetic (CPA). The concordant pairing of a reflexive sympathetic task with an intentional sympathetic task should disengage the parasympathetic inhibitory circuit resulting in a sympathetic dominance of the ANS.

Hand Cold Pressor x Mental Relaxation (CPR). Combining a reflexive sympathetic task with an intentional parasympathetic task is hypothesized to yield parasympathetic inhibition and evoke a parasympathetically dominated ANS.

Facial Cooling x Mental Arithmetic (FCR). Pairing a reflexive parasympathetic task with an intentional sympathetic task is predicted to attenuate parasympathetic inhibition, allowing sympathetic functions to dominate autonomic actions.

Chapter 2

Methods

Subjects

111 right-handed, non-smoking men (49%) and women (51%) were recruited via the Psychology Department online experiment management system at the Virginia Polytechnic Institute and State University. All procedures were approved by the Virginia Tech Institute Review Board.

Smokers, left-handers, and individuals with severe physical and mental problems were excluded to control for possible confounds (Barutcu et al., 2005; Demaree & Harrison, 1997; Eryonucu, Bilge, & Guler, 2000; Gallagher & Holland, 1992; Pope et al., 2001; Thayer & Friedman, 2002, 2004; Tokgözoglu et al., 1999; Wittling, 1995) as assessed by the "Mind-Body Lab Health Questionnaire" and the Depression Anxiety Stress Scale (DASS).

Apparatus and Materials

Electrocardiogram (ECG) and impedance cardiogram (ICG) were recorded using the BIOPAC MP100 system (BIOPAC Systems Inc, Goleta, CA), with two thoracic electrodes for ECG recording and a four spot impedance electrode array. Physiological signals were acquired through six disposable, pre-gelled stress-testing electrodes. The attachment sites were prepared using 70% isopropyl alcohol. Electrodes were placed according to recommendations in the BIOPAC User Manual. Subjects wore a respiration strain gage (Coulbourn Resistive Bridge Strain Gage Model V72-25) at the thoracic level to record respiratory patterns during tasks. Systolic blood pressure (SBP mmHg) and diastolic blood pressure (DBP mmHg) were recorded using a MedWave Fusion non-invasive BP monitoring system (MedWave Inc., Danvers, MA). Signals from each device were digitized at 1,000 Hz (16 bit) and analyzed by the BIOPAC AcqKnowledge software (BIOPAC Systems Inc, Goleta, CA). Subjects maintained the position of the BP monitor at the height of the 4^{th} intercostal space by resting their arm on adjustable foam padding. Skin Conductance was measured with a Coulbourn Isolated Skin Conductance Coupler Model V71-23 (Coulbourn Instruments, Allentown, PA) and measured in micro Siemens (μS). Two disposable, pre-gelled stress-testing electrodes were placed on the thenar and hypothenar areas of the palm on the left hand. Palm surface was first prepped with 70% isopropyl alcohol.

Health questionnaire. A questionnaire, designed by the Mind-Body Lab, to gauge the face value of a subject's health history, handedness and health practices was given during the screening process (Appendix A).

University of Houston Non-Exercise Test. Measures functional aerobic capacity (VO2peak) without exercise testing (Appendix B). Aerobic fitness levels have been shown to affect cardiovascular measures (Rossy & Thayer, 1998).

Depression Anxiety Stress Scale. The DASS is a set of three self-report scales designed to measure the negative emotional states of depression, anxiety and stress (Appendix C). Depression, anxiety and stress have been shown to alter cardiovascular activity (Lyonfields, Borkovec, & Thayer, 1995; Thayer, Friedman, & Borkovec, 1996; Thayer & Lane, 2000b)

Barratt Impulsivity Scale. The abbreviated (15 item version) Barratt Impulsivity Scale (Barratt, 1983; Spinella, 2007) measures impulsiveness, a foundational concept in psychology. Impulsivity is a measure of one's ability to delay gratification in the service of long-term goals (Barratt, 1983) (Appendix D).

Wechsler Working Memory Subtests. The working memory portions of the Wechsler Memory Scale (WMS III) are designed to gauge a subject's ability to maintain short-term goals (Appendix E). Experimenters administered both backward spatial span and backward digit span tests in accord with standard WMS III protocol.

Valence and Activation Scale. Measurements of valence and activation levels were assessed via a self report thirteen item questionnaire (Christie, 2005) (Appendix F).

Task Awareness and Mental Concentration Scales: Measures of subject's awareness of reflexive tasks (cold pressor or facial cooling) (Appendix G) and measures of mental concentration towards intentional tasks (relaxation or arithmetic) (Appendix H). Mental concentration and task awareness scales were developed by the experimenter based on face valid criteria.

Autonomic Variables

HRV measurements. HRV was derived from ECG measurements, both *spectral* and *temporal* methods were used (Bianchi et al. 1991; Kleiger, Stein, Bosner, & Rottman, 1995). IBI and RMSSD were averaged across each trial. Spectral analysis was derived from autoregressive (AR) techniques. AR analysis was used to generate two measures: normalized LF and HF power. Normalized units were defined as the absolute power (total power spectral density contained within specified frequency band) of either LF or HF frequency bands divided by the total absolute power of both HF and LF bands, which was then multiplied by 100 ($f/(Lf+Hf)100$). Normalized powers were averaged across each trial.

PEP. PEP was measured as the time between the Q wave onset and the B point inflection of the dZ/dt waveform (ICG) and averaged across each trial (Sherwood et al. 1990).

SBP & DBP. BP readings were taken semi-continuously (every fifteen-seconds) and averaged across the trial.

SCL. Skin conductance levels were averaged across each trial to generate the average skin conductance response.

Respiratory rate. Respiration rate (RR) was calculated as the average breaths/minute which was in turn averaged across each trial.

Procedure

The first phase of the experiment used the Virginia Tech Psychology SONA Experiment Management System to recruit prospective subjects. Subjects received one point of extra credit to complete the health history questionnaire and DASS online. Eligible subjects were invited to participate in the laboratory phase. All laboratory sessions were held at the Mind-Body Laboratory, Department of Psychology at Virginia Polytechnic Institute and State University. Subjects refrained from caffeine and alcohol at least twelve hours prior to experiment and avoided eating and rigorous exercise at least one hour before the experiment.

Upon arrival, subjects were instructed to read and sign an Informed Consent Form (Appendix I). Subjects were then connected to the physiological recording equipment. Next, subjects were required to complete the Depression, Anxiety, and Stress Scale (DASS), the University of Houston Non-Exercise Test and the Barratt Impulsivity scale. Questionnaires were administered via MediaLab software. After completing the questionnaires, subjects performed the WMS III working memory subtests administered manually by the experimenter. Upon completion, subjects underwent four ANS evoking tasks while ANS responses were monitored. All procedures occurred in the sitting position.

Design

Each subject completed 4 nine-minute recorded tasks. Each task consisted of 3 three-minute subtasks: pre-task, combination task, and post-task. Event markers were used to demarcate each task. Combination task order was randomized through MediaLab software to counteract any possible ordering effects. Following the experiment, subjects were debriefed on the purpose of the experiment, and any questions or concerns were answered. The experiment took approximately forty-five minutes to complete.

Pre-task. A pre-task preceded each combination task [Pre-task phases required subjects to view a neutral movie clip (*Powaqqatsi*, Godfrey Reggio, 1988) in an attempt to standardize autonomic levels providing accurate reactivity levels ("Vanilla Baseline;" see Jennings, Kamarck, Stewart, Eddy & Johnson, 1992c)]. An initial two-minute rest period, for acclimation, preceded the first pre-task but was not included in the analysis.

Combination tasks. Four combination tasks were employed: Facial Cooling x Mental Relaxation; Hand Cold Pressor x Mental Arithmetic; Hand Cold Pressor x Mental Relaxation; Facial Cooling x Mental Arithmetic.

Facial cooling. Subjects wore a chilled gel mask covering the forehead and cheeks (Biofreeze; Export, PA). The mask was kept at temperatures of 0°- 1° C.

Hand cold pressor. Subjects were instructed to immerse their right hand in a tub of cold water. In an effort to minimize the pain experienced while eliciting a salient sympathetic response, water temperature was kept at 10°- 15° C (LeBaron, Zeltzer, & Fanurik, 1989; Maekawa, Kuboki, Clark, Shinoda, & Yamashita, 1998; Peckerman et al., 1994; Zeltzer, Fanurik, & LeBaron, 1989).

Guided mental relaxation. Subjects were instructed to relax through a guided relaxation exercise. Subjects listened to an audio recoding which included soothing sounds and a voice conveying relaxation techniques (John Ortiz, "The Soothing Pulse" Third edition, 1998). A guided relaxation paradigm was selected to make the task more salient for the subjects and to provide them with a consistent voluntary goal.

Mental arithmetic. Subjects were instructed to verbally count backwards from 3,000 by intervals of seven without writing anything down.

Post-Task. Each task was succeeded by a post-task recovery period and immediately followed by a 2-3 minute questionnaire period. During the questionnaire period subjects completed the *Valance and Activation*, *Mental Concentration* and *Task Awareness Scales*. Scales were administered on MediaLab software. Post-task recovery data were acquired for use in future analyses.

Ethical Considerations

All scores were saved by subject number in data analysis and storage. The subjects were allowed to discontinue the experiment at any time; this fact was stated at the beginning of the experiment. Subjects were informed that the results were for research purposes only and that any concerns they had should be addressed by a medical professional. At the end of the experiment the subjects were again made aware that if she or he would like their data withdrawn from the experiment for any reason, they had that option available. Subjects could withdraw at the time of the study or by emailing the experimenter at a later date, noting that there was no penalty and that they would receive their extra credit in either case. No subjects exercised any of these rights.

Chapter 3

Results

Statistics were conducted on both raw task measurements and "reactivity" (task – baseline) measures. Measures exhibiting levels greater than three standard deviations were excluded from the statistical analyses to eliminate outliers. Nine autonomic variables [Pre-ejection period (PEP), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Respiration Rate (RR), Skin Conductance Response (SCL), Inter—beat—interval (IBI), Root Mean Square of Successive Differences (RMSSD), Autoregressive Low Frequency (LF), and Autoregressive High Frequency (HF)] were used for analyses (See Table 2 for a list of variable abbreviations). All statistical analyses used an alpha level of .05 to detect significant differences.

Multivariate tests using each autonomic variable as the dependent variable (DV) with pre-task and gender as the independent variables (IV) revealed no significant differences among the pre-task baselines. Two variables (SCL and LF) were significantly different between genders at pre-task. No significant interaction effects were detected (Tables 3 & 4). Repeated measures multiple regression analysis was originally proposed to test the relationships between working memory, task, gender and autonomic reactivity. A single linear regression was performed using working memory total as the IV and the autonomic reactivity for each task as the DV. Regression analysis demonstrated that working memory did not significantly regress onto any DV for any task except low and high frequencies during CPR (Table 5). The relationship between working memory and CPR will be investigated in a subsequent section. To simplify the analysis, multivariate tests were performed excluding working memory scores.

Variance Tests

A 2x4 multivariate test was performed with reactivity scores as the DV, gender as a between-subjects IV and task as a within-subjects IV. Multivariate tests were used because (a) there is no dependence on sphericity, (b) they have more sensitivity to treatment effects than adjusted degree of freedom univariate tests, (c) they are generally held to be appropriate for repeated measures designs in psychophysiology (Keselman, 1998; Vasey & Thayer, 1987).

Main effects. Multivariate tests displayed significant differences for task condition across each DV (Table 6). Post hoc tests were performed to detect which autonomic variables varied across task. Hochberg's (1988) step-up Bonferroni displayed that significant effects vary across task and autonomic variable (Table 7 & Table 8). SCL demonstrated the greatest variability across tasks with every task differing from each other except CPR and FCR (Figure 2). PEP and RMSSD displayed the smallest degree of variance with CPA varying only at CPR and FCR and LF showed only FCR to vary from all the other tasks (Figures 3 & 4). However, all other variables (SBP, DBP and RR) showed the same distribution of variance (Figures 5, 6 & 7). CPA differed from both CPR and FCR. CPR differed from FCA and FCA differed from FCR. A one-way ANOVA for each task between genders (Table 9 & Table 10) revealed significant main effects for gender during CPA (IBI, LF & HF), FCA (LF & HF) & FCR (PEP) (Figures 8-13).

Interaction effects. Multivariate tests displayed significant gender task interaction effects for both IBI and HF measures. A series of 2 X 2 multivariate tests (Gender X Task) were conducted on IBI and HF reaction scores to detect the specific contrast differences for interaction terms (Table 11). Only CPA and FCR varied for both IBI and HF.

Task Discriminant Function Analysis

Discriminant function analysis (DFA) was also performed across tasks using PEP, SBP, DBP, SCL, IBI, RMSSD, LF, and HF reactivity scores. DFA was used to predict group membership from a set of predictors (Cohen, J., Cohen, P., West, & Aiken, 2003) and significantly predicted group membership of task at 62.9% (women), 62.5% (men), and 60.6% (both genders) (Tables 12, 13 & 14).

Combination of tasks: Voluntary vs. Involuntary

Tasks were divided into two meta-categories: *Reflex* and *Mental*. The reflex category combined the reactivity scores from the cold pressor tasks into one group and both facial cooling tasks into another. The mental division combined the reactivity scores from the arithmetic tasks together while grouping relaxation together.

Multivariate tests were again used to extract the main and interaction effects of task and gender. A reflexive grouping did not show a significant main effect for gender or any interaction between gender and task but revealed a significant main effect for the reflexive task (Table 15). Post hoc univariate contrast tests demonstrated that the SCL and LF variables were responsible for this main effect (Table 16 & 17). Increase in SCL was greater during facial cooling than cold pressor. LF decreased during facial cooling tasks and increased during the cold pressor. Grouping the data along a mental categorization displayed a significant effect for both gender and task for but not for their interaction (Table 18). Post hoc univariate contrast tests revealed all the DVs to be significantly different across tasks (Table 19 & 20). A one-way ANOVA was performed to investigate the interaction of gender and mental task. Analysis reveals that only IBI, LF and HF varied between genders during arithmetic tasks (Table 21 & 22).

DFA was performed for mental and reflexive groupings (Tables 25-28). All groupings including divisions of gender were significant for DFA. Reflexive grouping yielded 63% (total), 66.5% (women), and 64.2% (men) prediction rates. Mental groupings yielded prediction ratings of 88.5% (across gender), 89.3% (women), and 90.3% (men). Total percentages of mental and reflexive prediction rates were found to be significantly different (Table 29).

WM and Autonomic reactivity

Working memory scores were excluded from previous analyses to simplify statistical models. Yet, working memory did have an influence on the expression of action. The data show that LF and HF spectral powers are the most informative variables to use when exploring the relationship between WM and autonomic reactivity. Scatter plots using WM total and HF or LF reactivity as coordinates were generated for each task. Linear regression analyses predicting autonomic reactivity from WM scores were generated. Scatter plots and regressive analyses were run on men and women groupings (Figures 14-21; Table 30: gender plots are excluded from figures). Women displayed significant regressive predictions for HF and LF during CPR and HF during FCR. Men showed significant predictions for LF during CPR. Linear regressive analyses predicting autonomic reactivity from spatial span WM and digit span scores were also created (Table 31). Spatial scores significantly predicted LF and HF during CPR across genders. The spatial scores of women predicted LF during CPR but men demonstrated no significant relationships.

BMI, DASS, Impulsivity, and Exercise

Regression analyses were performed predicting autonomic reactivity of both genders from, BMI, DASS, Impulsivity and Houston non-exercise scores all entered at the beginning of analysis (Table 32). Any regressions found to be significant were entered into a regression analysis in isolation. Single regression analysis reveals the following significant relationships. FCA was the most effected by the independent variables. Depression significantly regressed onto SBP (Standardized β=.243, R^2=.059), DBP (Standardized β=.237, R^2=.056), and SCL (Standardized β=.235, R^2=.055). Total impulsivity also significantly regressed onto FCA LF (Standardized β=-.215, R^2=.046). BMI during CPR regresses onto PEP reactivity (Standardized β=.193, R^2=.037). Gender differences were not considered.

Chapter 4

Discussion

The purpose of this study was to explore the relationship between voluntary and involuntary actions. Using the ANS as the vehicle of investigation, the results generally supported the predicted hypotheses of the mind-body model: Each task evoked specific autonomic states; Voluntary tasks influenced autonomic actions more than involuntary tasks; Working memory capacity mediated voluntary control.

Behavior of the ANS

Descriptive analyses & variance tests. As predicted, autonomic reactivity demonstrated a synergistic relationship between sympathetic and parasympathetic influences: CPA and FCA tasks appeared to be more sympathetically mediated; FCR and CPR tasks appeared more parasympathetically mediated. Descriptive analyses and variance tests provided a clear picture of how each autonomic variable behaved during the tasks. Blood pressure findings illustrate strong alpha-adrenergic effects for FCA and CPA and significantly decreased alpha-adrenergic effects for CPR and FCR. Beta-adrenergic reactivity as measured by PEP, demonstrates a decrease during CPA and significant increases during CPR and FCR (women showed a significantly different decrease during FCR). Vagal activity as measured by RMSSD, shows decreases during CPA and significant increases during FCR and CPR. Respiration and Galvanic responses also displayed a similar pattern of reactivity. Respiration rate showed decreases during CPR and FCR while FCA and CPA tasks increased RR. Although a portion of the increase of RR during FCA and CPA was most likely due to the verbal requirements of the arithmetic task, respiration significantly decreased during both relaxation tasks. Past studies have shown that relaxation lowers RR and contributes to decreases in sympathetic arousal and increased parasympathetic activation (van Dixhoorn, 1998). Skin conductance response, a general index of sympathetic arousal, demonstrates significant increases during both CPA and FCA and little reaction to either CPR or FCR tasks. Spectral analyses demonstrate increases of HF power during FCR and CPR but decreases during CPA and FCA. LF power only showed increases during CPA, no difference between CPR or FCA tasks and a significant decrease during FCR. Interestingly, both discordant pairings showed minimal reactions in the LF band, evidence that the LF band is sensitive to both parasympathetic and sympathetic influences during coactivated states.

Combination of tasks: Voluntary vs. Involuntary. The results of all four tasks suggest that reactivity was dominated by the voluntary tasks. This concept was further tested by generating mental and reflex groupings. Mental and reflexive groupings provided the clearest illustration of the how the mind-body is operating. The combination of variance allowed a comparison of reflexive or mental tasks across both dichotomous pairs. Exploring these groupings via descriptive analyses, DFA and multivariate tests demonstrated top-down control: The greatest control of autonomic states came from voluntary actions rather than involuntary ones. DFA revealed that both groupings demonstrated significant differences between tasks but mental groups scored a significantly higher prediction rating than did reflexive groups. Multivariate tests demonstrated that reflexive groups were significantly different only for IBI and LH measures but mental groups were significantly different across every variable. Although voluntary groupings demonstrated a greater effect on the autonomic outcomes, analyses also displayed a significant influence of reflexive actions, a clear description of the comprehensive yet hierarchical nature of actions inherent in the mind-body system.

Past research. The evidence of top-down dominance in coactivated states is in agreement with previous coactivation studies. Past studies only combined a voluntary sympathetic task with an involuntary parasympathetic task. FCA is the equivalent and demonstrates high autonomic reactivity (BP, IBI, & SCL) suggesting a relative sympathetic governance. However, FCA illustrates decreases in both LF and HF. Friedman et al. (1996) reported their combo task to more closely reflect the shock avoidance task in isolation then the facial cooling task in isolation. FCA in the current study suggests both parasympathetic and sympathetic withdrawal, which produced an intermediate affect on spectral analysis.

The synergistic responses of tasks, according to statistical analyses, are generally more sensitive to voluntary actions than involuntary. This finding supports the concept that psychological tasks have greater control over autonomic reactivity than reflexive tasks and that volition can actively inhibit or stimulate autonomic responses. The work of Joseph Wolpe (1961) is also closely linked to these results. Wolpe developed the concept of *reciprocal inhibition* to treat neurosis. Wolpe showed that one can inhibit a reflexive response (anxiety) by evoking a mutually incompatible response (relaxation) simultaneously. This is precisely what has been demonstrated in the current study.

Working Memory

The relationship between working memory scores and spectral power is one of the most intriguing findings of the study. While only CPR and FCR showed any significant relation, every regression slope behaved as predicted. Thus, one's ability to increase or decrease parasympathetic and sympathetic activity appears to have some relation to one's efficacy for maintaining conscious goals. This study is limited in investigating the effects of WM on voluntary and involuntary actions. Lateral contributions of working memory are reported but no further consideration will be given. Future studies can further clarify the relationship by using more detailed analyses of WM.

Gender Differences

Studies have demonstrated gender differences in autonomic cardiovascular regulation (Convertino, V., 1998; Evans, JM. et al., 2001; Rossy et al., 1998). Women have been found to display more vagal mediation and men to display more sympathetic domination at baseline and during a facial cooling/reaction time task. The current data showed women to have significantly less LF power and skin conductance during baseline evidence of the reported differences. Men and women also displayed significant differences for CPA, FCA, and FCR. During CPA, women showed greater decreases in IBI & HF and a greater increase in LF compared to men. The greater decreases of IBI and HF and the greater increase of LF illustrate increased sympathetic activity in women during a simultaneous cold pressor and mental arithmetic trial. During

FCA, women again displayed a sympathetic dominance in response to simultaneous facial cooling and mental arithmetic tasks as women showed a greater reduction in HF and greater increase of LF. During FCR women displayed decreases in PEP while men displayed increases. FCR PEP scores also suggest women to have greater sympathetic reactivity to the task than men. Tasks reactivity does not suggest greater vagal mediation in women than men during coactivation elicitation. The current data suggest the opposite. CPA, a stressful task, generated more sympathetic activity at the heart for women. FCA, a stressful task but with a reflexive parasympathetic influence, also produced more sympathetic cardiac responses in women. And FCR, the most relaxing task, generated greater sympathetic activity in women. By this conclusion, men appeared to have more vagal responses and less sympathetic responses to these coactivation tasks than did women.

The influence of BMI, Fitness, Psychological health

BMI, fitness, and psychological health have all been found to share a relationship with autonomic activity. In general, these factors seem to affect vagal mediation of the cardiovascular system (Rossy et al., 1998; Thayer & Friedman, 2002, 2004). Although none of the variables that showed autonomic effects (PEP, SBP, DBP, and SCL) are parasympathetic indexes, they represent autonomic states. BMI and PEP displayed a significant positive association during CPR. Therefore, during a task which consistently decreased sympathetic and increased parasympathetic responses, greater BMI scores reduced beta-adrenergic responses to the cold pressor. What is generating the relationship between BMI and PEP is unclear. The influence of depression on SBP, DBP and SCL during FCA is in accord to past studies. During a highly sympathetic task, increased depression scores further increase alpha-adrenergic and sympathetic muscarinic responses.

Limitations

The proposed hypotheses have been generally supported. However, there are some possible limitations to the study: 1) Saliency of physical stressors; 2) Lack of isolated tasks; 3) equivalency of the autonomic response to the tasks.

The voluntary dominance of the autonomic reactions questions the relative efficacy of the involuntary tasks. All the tasks used are well established psychophysiological manipulations and produced the expected affect. While the cold pressor task used water temperature well above what is normally used (10-15°C as opposed to 0-5°C). Past and the present results confirmed that the elevated temperature still produced the desired pressor response.

Lack of isolated task reactions question the ability to look at the perceived effects of the tasks in tandem. First, the inclusion of isolated tasks would have greatly extended the length of the experiment. Second, each task is well established in the area of psychophysiological research and included in the normal battery of psychophysiological tools. Finally, the exclusion of isolated tasks results from the inability to control mental states during reflexive tasks. Future studies could address some of the issues by using between-subject groupings.

The ANS is complex, and the effect of each task on the autonomic activity is clearly not equivalent. Facial cooling is not autonomically equivalent to the cold pressor, nor is arithmetic equivalent to relaxation. However, the current study provides valuable information on autonomic activity via DFA. DFA provides a way to look at the complex synergistic effects of the tasks across multiple autonomic variables by generating a linear probability model. DFA employs multiple regression models to predict the probability of group membership based on these linear relations. DFA and other multiple variable tests (such as MANOVA) provide the necessary tools for exploring complex multifaceted systems like the ANS.

Future directions

The current study lends support to the proposed mind-body system and how the ANS integrates voluntary and involuntary actions. According to this research, humans are phylogenetically organized to favor voluntary action over involuntary action. The ability for humans to favor intention over reflex is further supported to be a product of cortical inhibition and is readily present in autonomic states. In consideration of future research: 1) The replication of the current study must first be achieved to strengthen the proposed mind-body system model; 2) Numerous autonomic tasks, such as orthostatic stress, should be investigated in their relation to varying autonomic behaviors; 3) A between-subjects design should be employed to verify the synergistic character of multiple tasks in comparison to isolated tasks; 4) A more detailed investigation (such as the use of clinical populations with impaired frontal function) of the relationship between working memory and autonomic inhibition would further the current conception of the neuroanatomical organization of the mind-body system; 5) If the proposed model is correct, one important question emerges. To what extent can cortical inhibition limit reflexive actions? One approach to answering this question involves stepping outside normative circumstances. An increase in the strength of the involuntary tasks and the utilization of subjects with exemplary concentration and inhibitory skills (experienced meditators could be considered experts in inhibition) would greatly benefit future understanding of the mind-body system.

Chapter 5

Conclusion

Both intentional and reflexive mechanisms evoke mind-body states. However, complex organisms are proposed to have evolved to favor voluntary over involuntary action. This process is organized and facilitated by the autonomic nervous system, the neurological basis of the proposed mind-body system. Using the ANS as an index of the mind-body system, the current study demonstrates that voluntary tasks, during coactivation trials, dominate autonomic responses. This finding is in support of and extends research investigating neuro-viseral integration models, inhibitory processes, multiple stressors and coactivation.

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APPENDIX A

Health Status Questionnaire

It is necessary for us to obtain a very brief medical history in order to determine if you are eligible for participation in the second part of the study. It is very important that you be completely honest. This screening information will be kept strictly confidential.

1. What is your age, height, weight, and gender?
Age: _____ years
Height: _____ feet, _____ inches
Weight: _____ pounds
Gender: ___M ___F

2. Since birth, have you ever been hospitalized or had any major medical problems?
___ Yes ___ No
If Yes, briefly explain:

3. Have you ever experienced a concussion or lost consciousness due to a blow to the head?
___ Yes ___ No
If Yes, briefly explain:

4. Have you ever had problems that required your seeing a counselor, psychologist, or psychiatrist?
___ Yes ___ No
If Yes, briefly explain:

5. Do you use tobacco products of any kind?
___ Yes ___ No
If Yes, describe what kind how often/much:

6. Do you drink alcohol? If yes how often?
___a few times a month ___once a week ___2-3 times a week
___more than 4 times a week

How much do you drink when you drink?
___1-2 drinks ___3-6 drinks ___6-9 drinks ___ 10 or more drinks

7. Do you currently have or have you ever had any of the following?
___ Yes ___ No …..Strong reaction to cold weather
___ Yes ___ No …..Circulatory problems
___ Yes ___ No …..Tissue disease
___ Yes ___ No …..Skin disorders (other than facial acne)
___ Yes ___ No …..Arthritis
___ Yes ___ No …..Asthma
___ Yes ___ No …..Lung problems
___ Yes ___ No …..Cardiovascular disorder/disease
___ Yes ___ No …..Diabetes
___ Yes ___ No …..Hypoglycemia
___ Yes ___ No …..Hypertension (high blood pressure)
___ Yes ___ No …..Hypotension (low blood pressure)
___ Yes ___ No …..Hepatitis
___ Yes ___ No …..Neurological problems
___ Yes ___ No …..Epilepsy or seizures
___ Yes ___ No …..Brain disorder
___ Yes ___ No …..Stroke
If you responded Yes to any of the above conditions, briefly explain:

8. Have you ever been diagnosed as having:
___ Yes ___ No …..Learning deficiency or disorder
___ Yes ___ No …..Reading deficiency or disorder
___ Yes ___ No …..Attention deficit disorder
___ Yes ___ No …..Attention deficit hyperactivity disorder;

9. Do you have:
___ Yes ___ No Claustrophobia (extreme fear of small closed spaces)
___ Yes ___ No Blood phobia (extreme fear of needles or blood)

10. List any over-the-counter or prescription medications you are currently taking:

11. List any other medical conditions that you have or have had in the past:

12. How healthy do you consider your diet to be?
___very healthy ___moderately healthy ___poor

13. Have you ever meditated in the past? Yes___ No___
If so, how often do you meditate?
___daily ___weekly ___monthly ___a few times a year

How long have you practiced meditation?
___one year or less   ___two or three years   ___four or five years
___more than five years (please write how many)

APPENDIX B

University of Houston Non-Exercise Test

Circle the number below that corresponds with the best description of your GENERAL LEVEL of physical activity during the PREVIOUS MONTH. Circle only ONE NUMBER out of the eight possible choices.

0 Avoid walking or exertion (e.g. always use elevator, drive whenever possible instead of walking).

1 Walk for pleasure, routinely use stairs, occasionally exercise sufficiently to cause heavy breathing or perspiration.

Participate regularly in recreation or work requiring modest physical activity such as golf, horseback riding, calisthenics, table tennis, weight lifting, yard work, etc.

2 10 to 60 minutes per week

3 Over one hour week

Participate regularly in heavy physical exercise such as running, swimming, cycling, tennis, or similar aerobic activity.

4 Run or equivalent activity < 30 minutes per week.

5 Run or equivalent activity 30-60 minutes per week.

6 Run or equivalent activity 1-3 hours per week.

7 Run or equivalent activity > 3 hours per week.

APPENDIX C

Depression Anxiety Stress Scale

DASS21

Please read each statement and circle a number 0, 1, 2 or 3 that indicates how much the statement applied to you *over the past week*. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree, or a good part of time
3 Applied to me very much, or most of the time

1	I found it hard to wind down	0	1	2	3
2	I was aware of dryness of my mouth	0	1	2	3
3	I couldn't seem to experience any positive feeling at all	0	1	2	3
4	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5	I found it difficult to work up the initiative to do things	0	1	2	3
6	I tended to over-react to situations	0	1	2	3
7	I experienced trembling (eg, in the hands)	0	1	2	3
8	I felt that I was using a lot of nervous energy	0	1	2	3
9	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
10	I felt that I had nothing to look forward to	0	1	2	3
11	I found myself getting agitated	0	1	2	3
12	I found it difficult to relax	0	1	2	3
13	I felt down-hearted and blue	0	1	2	3
14	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
15	I felt I was close to panic	0	1	2	3
16	I was unable to become enthusiastic about anything	0	1	2	3

17	I felt I wasn't worth much as a person	0	1	2	3
18	I felt that I was rather touchy	0	1	2	3
19	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)	0	1	2	3
20	I felt scared without any good reason	0	1	2	3
21	I felt that life was meaningless	0	1	2	3

APPENDIX D

Barratt Impulsivity Scale (15 item version)

Please read each statement and choose the number 0, 1, 2 or 3 that indicates how much the statement applied to you. There are no right or wrong answers.

The rating scale is as follows:

0 Rarely/Never
1 Ocasionally
2 Often
3 Always/Almost Always

Questions:

1. I act on impulse
2. I act on the spur of the moment
3. I do things without thinking
4. I say things without thinking
5. I buy things on impulse
6. I plan for job security
7. I plan for the future
8. I save regularly
9. I plan tasks carefully
10. I am a careful thinker
11. I am restless at lectures or talks
12. I squirm at plays or lectures
13. I concentrate easily
14. I don't pay attention
15. Easily bored solving thought problems

APPENDIX E

Wechsler Memory Scale III (Working Memory subtests)

Digit Span Test

Item	Trial	Response/(Correct Response)	Score 0 or 1
1.	Trial 1	**2-4** (4-2)	
	Trial 2	**5-7** (7-5)	
2.	Trial 1	**6-2-9** (9-2-6)	
	Trial 2	**4-1-5** (5-1-4)	
3.	Trial 1	**3-2-7-9** (9-7-2-3)	
	Trial 2	**4-9-6-8** (8-6-9-4)	
4.	Trial 1	**1-5-2-8-6** (6-8-2-5-1)	
	Trial 2	**6-1-8-4-3** (3-4-8-1-6)	
5.	Trial 1	**5-3-9-4-1-8** (8-1-4-9-3-5)	
	Trial 2	**7-2-4-8-5-6** (6-5-8-4-2-7)	
6.	Trial 1	**8-1-2-9-3-6-5** (5-6-3-9-2-1-8)	
	Trial 2	**4-7-3-9-1-2-8** (8-2-1-9-3-7-4)	
7.	Trial 1	**9-4-3-7-6-2-5-8** (8-5-2-6-7-3-4-9)	
	Trial 2	**7-2-8-1-9-6-5-3** (3-5-6-9-1-8-2-7)	

Spatial Span Test

Item	Trial	Response/(Correct Response)	Score 0 to 1
1.	Trial 1	**7-4** (4 – 7)	
	Trial 2	**3-10** (10 – 3)	
2.	Trial 1	**8-2-7** (7-2-8)	
	Trial 2	**1-9-3** (3-9-1)	
3.	Trial 1	**10-6-2-7** (7-2-6-10)	
	Trail 2	**4-9-1-6** (6-1-9-4)	
4.	Trial 1	**5-7-9-8-2** (2-8-9-7-5)	
	Trail 2	**6-5-1-4-8** (8-4-1-5-6)	
5.	Trail 1	**9-2-6-7-3-5** (5-3-7-6-2-9)	
	Trail 2	**4-1-9-3-8-10** (10-8-3-9-1-4)	
6.	Trail 1	**2-6-3-8-2-10-1** (1-10-2-8-3-6-2)	
	Trail 2	**10-1-6-4-8-5-7** (7-5-8-4-6-1-10)	
7.	Trail 1	**6-9-3-2-1-7-10-5** (5-10-7-1-2-3-9-6)	
	Trail 2	**7-3-10-5-7-8-4-9** (9-4-8-7-5-10-3-7)	
8.	Trail 1	**8-2-6-1-10-3-7-4-9** (9-4-7-3-10-1-6-2-8)	
	Trail 2	**5-8-4-10-7-3-1-9-6** (6-9-1-3-7-10-4-8-5)	

APPENDIX F

Valance and Activation Self-Report Scale

Circle the number on the scale that best describes how you felt during the task. If the word does not at all describe how you felt during the task, circle 1. If the word very accurately describes how you felt, circle 7, or an intermediate amount, circle 3, etc.

Good 1 2 3 4 5 6 7
Calm 1 2 3 4 5 6 7
Active 1 2 3 4 5 6 7
Unpleasant 1 2 3 4 5 6 7
Neutral 1 2 3 4 5 6 7
Excited 1 2 3 4 5 6 7
Negative 1 2 3 4 5 6 7
Relaxed 1 2 3 4 5 6 7
Passive 1 2 3 4 5 6 7
Positive 1 2 3 4 5 6 7
Agitated 1 2 3 4 5 6 7
Bad 1 2 3 4 5 6 7
Pleasant 1 2 3 4 5 6 7

Rate the intensity of what you felt? 1 2 3 4 5 6 7

APPENDIX G

Task Awareness Scale

On average, how aware or focused were you of the physical task (coldpressor or facial cooling) during the experiment?

0 no awareness
1 very little awareness
2
3 more non-awareness than awareness
4 more awareness than non-awareness
5
6 almost total awareness
7 total awareness

APPENDIX H

Mental Concentration Scale

On average, how well were you able to maintain mental concentration (arithmetic or relaxation) during the task?

0 no concentration
1 very minimal concentration
2
3 more non-concentration than concentration
4 more concentration than non-concentration
5
6 almost absolute concentration with little deviation
7 total unwavering concentration

APPENDIX I

INFORMED CONSENT (Laboratory Session)

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Subjects in Research Projects Involving Human Subjects
Title of Project: Measuring Reflexive and Intentional Autonomic Responses
Investigator: Thomas J. Pardikes, Dr. Bruce H. Friedman
I. Purpose of this Research: The purpose of this research is to examine autonomic nervous system (ANS) activity while engaged in reflexive and intentional responses.
Approximately 150 male and female subjects will be recruited for participation in the study.
II. Procedures: The study exists in two phases. Individuals participating in the first stage may or may not be invited to participate in the second stage. The first phase of the study is an online screening process that consists of a physical health history screening, exercise habits, and mental health screening; this phase should take less than one-half hour to complete. Only nonsmoking, right-handed individuals, without major medical problems, will be included in the study. Subjects in the second phase of the study will begin with the placement of electrodes. Six chest and back electrodes and two palm electrodes will be placed on the subject by a gender-matched research assistant to measure autonomic cardiovascular activity and skin conductance. Subjects will then fill out the health and exercise questionnaires. Next, they will perform a working memory task administered by the experimenter. Physiological measures will begin during the baseline period and continue throughout the experiment. The second stage of the study will take approximately one hour to complete and will be carried out in a behavioral research lab on campus. Experimental procedure will require subjects to perform physically evoked autonomic tasks with psychologically evoked tasks simultaneously.
III. Risks: The risks of this study are minimal. At times the removal of the disposable electrodes results in irritation or redness of the skin. Submersion of hand in cold water can be painful but subjects will be instructed that they can remove their hand at any time.
IV. Benefits of this Project: Taking part in this study will contribute to the general scientific knowledge regarding the relationship between frontal cortical activity and autonomic states. Subjects may request further information regarding the study's findings by giving the experimenter an email address or other contact information.
V. Extent of Anonymity and Confidentiality: Any information acquired by questionnaire or physiological recording will be kept strictly confidential and will be accessed only by trained research personnel. Subjects will be identified only by means of an assigned number during subsequent analysis and written reports. A participant's indication of intent to harm others or themselves obligates the researcher to break confidentiality and notify the appropriate agency.
VI. Compensation: Subjects will receive one point of extra credit for their participation in the online screening. Those who participate in the second stage of the study will receive an additional two points of extra credit. Availability of extra credit for a given course is dependent upon their instructor's permission.
VII. Freedom to Withdraw: Subjects may withdraw from the study at any time without penalty. If a participant chooses to withdraw, he/she will be compensated for the portion of time spent taking part in the study.
VIII. Approval of Research: This research project is pending by the Department of Psychology's Human Subjects Committee and by the Institutional Review Board for Research Involving Human Subjects at Virginia Tech.
IX. Participant's Responsibilities: I voluntarily agree to participate in this study and agree to take part in the procedures described above.
X. Subjects Permission: I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

________________________ ________________________ __________
Name (please PRINT clearly) Signature Date

Should I have any questions about this research or its conduct, I may contact:
Thomas J. Pardikes, Main Investigator, Department of Psychology 231-3630
pardikes@vt.edu
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Table 1

Previous Multiple Stressor Studies

Study	Manipulation Tasks	Posture	Autonomic Measures	Results
Szabo, 1993	Mental Arithmetic Orthostatic Stress	Sitting Standing	Heart Rate Pulse Time Transit T-wave Amplitude	Cognitive Challenge elicited greater reactivity in Heart Rate Orthostatic Stress produced greater reactivty in cardiac-sympathetic reactivity
Roth et al., 1990	Working Memory Task Exercise		Heart Rate Pulse Time Transit	Exercise in isolation elicited great reactivity Exercise in combination with cognitive task generated the greatest reactivity
Brown et al., 1988	Mental Arithmetic Speech Mimicking Task	Sitting	Heart Rate	Cognitive Challenge elicited greater reactivity
Goldstein & Shapiro, 1988	Orthostatic Stress Mental Arithmetic Hand Grip Task	Sitting Standing Sit/Stand Stand/Sit	Heart Rate Systolic BP Diastolic BP Skin Conductance	Cognitive Challenge elicited greater reactivity
Klatt et al., 1986	Mental Arithmetic Cold Pressor	Horizontal 70° tilt Sitting	HF Spectral Power LF spectral Heart Period Systolic BP Diastolic BP Respiration	Cognitive Challenge elicited greater reactivity Reactivity dependent upon posture
Myrtek & Spital, 1986	Cold Pressor Exercise Mental Arithmetic	Sitting	Heart Rate Diastolic BP Respiration	Combination of Stressors produced a Synergistic effect: Arithmetic generated high RR, relatively high DBP and relatively low HR; Cold pressor demonstrated the greatest increases in DBP; Exercise produced the greatest HR increase
Light & Obrist, 1980	Shock Avoidance	Sitting	Heart Rate Systolic BP Diastolic BP Carotid dP/dt Pulse Time Transit	Cognitive Challenge elicited greater reactivity
Manuck et al., 1978	Aversive Shock	Sitting	Systolic BP Diastolic BP	Cognitive Challenge elicited greater reactivity
Obrist et al., 1978	Shock Avoidance Cold Pressor Pornographic Film	Sitting	Heart Rate Systolic BP Carotid dP/dt	Cognitive Challenge elicited greater reactivity

Table 2

Variable and Task Abbreviations
Abbreviations Table

Autonomic Variables

DBP	Diastolic Blood Pressure
HF	High Frequency
IBI	Inter-Beat-Interval
LF	Low Frequency
PEP	Pre-ejection Period
RR	Respiration Rate
RMSSD	Root Mean Square of Successive Differences
SCL	Skin Conductance Response
SBP	Systolic Blood Pressure
Combination Tasks	
CPA	Cold Pressor/Arithmetic
CPR	Cold Pressor/Relaxation
FCA	Facial Cooling/Arithmetic
FCR	Facial Cooling/Relaxation

Table 3

Pre-Task Multivariate Tests

Pre-Task Raw Scores											
			PEP	**SBP**	**DBP**	**RR**	**SCL**	**IBI**	**RMSSD**	**LF**	**HF**
Multivariate Test	**TASK**	df	3	3	3	3	3	3	3	3	3
Wilk's λ		F value	0.446	2.099	0.935	0.394	2.635	1.603	0.356	1.988	2.210
		p value	0.721	0.106	0.427	0.758	0.054	0.193	0.785	0.120	0.091
	TASK*GENDER	df	3	3	3	3	3	3	3	3	3
		F value	1.075	0.700	0.974	1.881	1.442	1.440	0.188	1.823	1.011
		p value	0.363	0.555	0.409	0.138	0.235	0.235	0.904	0.147	0.391
	GENDER	df	1	1	1	1	1	1	1	1	1
Between-Subjects Effects		F value	3.050	0.021	3.372	0.908	9.189	0.111	2.043	6.191	1.725
		p value	0.084	0.886	0.069	0.343	0.003	0.740	1.560	0.014	0.192

Table 4

Pre-Task Raw Means

Pre-Task Raw Scores		N	Mean	STD
	Female	56	56.96	21.19
	Male	55	67.48	23.35
LF	Total	111	62.17	22.80
	Female	54	16.40	7.44
	Male	53	22.65	13.17
SCL	Total	107	19.50	11.07

Table 5

WM Reactivity Regression Analysis

Regression Working Memory x Reactivity		PEP	SBP	DBP	RR	SCL	IBI	RMSSD	LF	HF
CPA	Standardized β Coefficient	0.04	-0.107	0.015	-0.154	-0.125	0.073	0.115	0.113	-0.045
	p value	0.684	0.292	0.885	0.117	0.205	0.458	0.240	0.246	0.643
CPR	Standardized β Coefficient	-0.107	0.164	0.161	0.015	-0.027	0.133	0.096	-0.331	0.294
	p value	0.273	0.103	0.109	0.881	0.784	0.171	0.325	0.001	0.002
FCA	Standardized β Coefficient	-0.018	-0.164	-0.162	-0.086	-0.133	-0.102	-0.099	0.142	-0.168
	p value	0.852	0.103	0.108	0.381	0.178	0.297	0.315	0.149	0.086
FCR	Standardized β Coefficient	0.091	-0.093	-0.038	0.106	0.077	0.039	0.036	-0.118	0.123
	p value	0.352	0.362	0.712	0.283	0.441	0.696	0.720	0.233	0.211

Table 6

Task Multivariate Tests

Multivariate Test			PEP	SBP	DBP	RR	SCL	IBI	RMSSD	LF	HF
Wilk's λ	**TASK**	df	3	3	3	3	3	3	3	3	3
		F	7.079	54.350	69.890	26.680	66.060	80.790	8.456	11.100	19.227
		p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TASK*GENDER	df	3	3	3	3	3	3	3	3	3
		F	0.701	2.43	2.65	1.171	2.627	2.696	0.843	0.773	1.535
		p	0.554	0.070	0.054	0.325	0.054	0.05	0.474	0.512	0.021
	GENDER	df	1	1	1	1	1	1	1	1	1
Between-Subjects Effects		F	2.076	0.099	0.094	0.443	0.111	7.008	1.158	3.29	10.383
		p	0.153	0.754	0.760	0.507	0.739	0.009	0.284	0.53	0.002

Table 7

Task Main Effect Post Hoc Tests

Task Main Effects
Post Hoc Tests
Hochberg P values

			CPA	CPR	FCA
	PEP		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.000		
		FCA	0.199	0.286	
		FCR	0.002	1.000	0.498
	SBP		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.000		
		FCA	0.990	0.000	
		FCR	0.000	0.900	0.000
	DBP		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.000		
		FCA	1.000	0.000	
		FCR	0.000	0.622	0.000
	RR		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.000		
		FCA	1.000	0.000	
		FCR	0.000	0.912	0.000
	SCL		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.000		
		FCA	0.021	0.000	
		FCR	0.000	0.357	0.000
	IBI		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.000		
		FCA	0.910	0.000	
		FCR	0.000	0.928	0.000
	RMSSD		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.013		
		FCA	0.904	0.200	
		FCR	0.003	0.994	0.059
	LF		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.326		
		FCA	0.978	0.833	
		FCR	0.000	0.014	0.000
	HF		**CPA**	**CPR**	**FCA**
		CPA			
		CPR	0.011		
		FCA	0.999	0.038	
		FCR	0.000	0.191	0.000

Table 8

Task Mean Reactivity

	CPA			CPR			FCA			FCR		
	N	Mean	STD	N	Mean	STD	N	Mean	STD	N	Mean	STD
PEP	107	-3.891	10.14	107	1.377	6.95	107	-1.366	10.66	107	1.043	6.854
SBP	99	13.116	18.51	100	2.287	13.01	100	14.725	16.25	99	-0.315	21.6
DBP	99	10.507	11.96	100	1.744	8.178	100	10.645	10.57	99	0.392	16.78
RR	105	0.886	2.636	106	-0.6	1.524	106	1.033	2.124	105	-0.756	1.696
SCL	104	3.642	8.563	106	-0.88	3.088	105	5.060	4.375	102	0.319	2.172
IBI	107	-0.068	0.069	107	0.024	0.055	107	-0.066	0.065	105	0.032	0.03
RMSSD	107	-1.64	17.62	107	4.955	14.12	106	0.536	17.04	104	6.219	8.702
LF	107	4.891	19.97	107	-0.52	22.74	105	1.714	25.05	105	-12.12	25.39
HF	107	-6.174	18.46	107	2.109	18.74	105	-5.725	19.87	105	8.969	20.76

Table 9

1-way ANOVA DV x Gender

DV x Gender

	CPA	**CPR**	**FCA**	**FCR**
PEP				
F	0.026	0.177	0.814	4.026
p	0.871	0.675	0.369	0.047
SBP				
F	0.798	1.562	0.881	0.007
p	0.374	0.214	0.350	0.931
DBP				
F	0.059	2.048	0.613	0.222
p	0.809	0.156	0.436	0.639
RR				
F	0.354	1.420	1.405	0.218
p	0.553	0.236	0.239	0.642
SCL				
F	1.988	1.915	1.141	0.499
p	0.162	0.169	0.288	0.482
IBI				
F	7.672	2.948	2.245	0.106
p	0.007	0.089	0.137	0.746
RMSSD				
F	2.411	0.805	0.267	0.009
p	0.124	0.372	0.607	0.923
LF				
F	4.150	0.047	4.540	0.397
p	0.044	0.828	0.035	0.530
HF				
F	7.000	0.473	5.515	0.074
p	0.009	0.493	0.021	0.787

Table 10

Task and Gender Mean Reactivity

	CPA			CPR			FCA			FCR		
	N	Mean	STD	N	Mean	STD	N	Mean	STD	N	Mean	STD
PEP												
Women	54	-4.050	12.460	54	1.096	7.205	54	-2.288	12.988	54	-0.256	7.271
Men	53	-3.729	7.165	53	1.663	6.738	53	-0.427	7.613	53	2.366	6.192
SBP												
Women	51	11.502	9.416	51	3.876	7.497	51	13.229	11.153	51	-0.132	20.742
Men	48	14.831	24.789	49	0.632	16.883	49	16.281	20.245	48	-0.509	22.703
DBP												
Women	51	10.791	12.352	51	2.885	4.762	51	9.832	8.122	51	-0.381	12.939
Men	48	10.206	11.662	49	0.556	10.559	49	11.490	12.655	48	1.213	20.191
RR												
Women	54	0.737	3.191	54	-0.425	1.354	54	1.273	1.896	54	-0.831	1.446
Men	51	1.044	1.900	52	-0.777	1.676	52	0.784	2.330	51	-0.676	1.937
SCL												
Women	54	2.508	2.984	54	-0.470	3.521	53	4.609	3.311	53	0.465	1.819
Men	50	4.866	11.898	52	-1.297	2.528	52	5.520	5.236	49	0.160	2.509
IBI												
Women	54	-0.086	0.072	54	0.016	0.038	54	-0.075	0.072	53	0.031	0.028
Men	53	-0.050	0.062	53	0.034	0.067	53	-0.057	0.055	52	0.033	0.033
RMSSD												
Women	54	-4.242	21.333	54	3.741	13.161	53	1.393	18.735	52	6.136	8.104
Men	53	1.012	12.435	53	6.192	15.051	53	-0.322	15.292	52	6.303	9.341
LF												
Women	54	8.730	19.540	54	-0.042	22.536	52	6.885	29.191	54	-10.596	24.423
Men	53	0.979	19.817	53	-1.003	23.148	53	-3.359	19.132	51	-13.728	26.522
HF												
Women	54	-10.725	19.415	54	0.871	19.654	52	-10.22	21.721	54	9.506	19.539
Men	53	-1.537	16.342	53	3.370	17.870	53	-1.309	16.935	51	8.401	22.168

Table 11

Gender Task Interaction Post Hoc Tests

Gender*Task Multivariate			**CPR**		**FCA**		**FCR**	
Wilk's λ	**CPA**	**IBI**	df	1	df	1	df	1
			F	1.28	F	2.488	F	6.804
			p value	0.26	p value	0.12	p value	0.01
		HF	df	1	df	1	df	1
			F	1.929	F	0	F	4.006
			p value	0.168	p value	0.993	p value	0.048
	CPR	**IBI**			df	1	df	1
					F	0.002	F	1.597
					p value	0.969	p value	0.209
		HF			df	1	df	1
					F	1.716	F	0.614
					p value	0.193	p value	0.435
	FCA	**IBI**					df	1
							F	1.364
							p value	0.246
		HF					df	1
							F	3.179
							p value	0.078

Table 12

DFA Task Total

Significance test for classification across Tasks					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
CPA	94	55	23.5	7.503	0.0001
CPR	98	63	24.5	8.981	0.0001
FCA	94	50	23.5	6.312	0.0001
FCR	87	58	21.75	8.975	0.0001
Overall	**373**	**226**	**93.25**	**15.874**	**0.0001**
TASK	**TOTAL**	60.60%			

Table 13

DFA Task Women

Significance test for classification across Tasks					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
CPA	51	28	12.75	4.932	0.0001
CPR	51	33	12.75	6.548	0.0001
FCA	47	32	11.75	6.821	0.0001
FCR	48	31	12	6.333	0.0001
Overall	**197**	**124**	**49.25**	**12.299**	**0.0001**
TASK	**WOMEN**	62.90%			

Table 14

DFA Task Men

Significance test for classification across Tasks					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
CPA	43	28	10.75	6.075	0.0001
CPR	47	28	11.75	5.474	0.0001
FCA	47	25	11.75	4.463	0.0001
FCR	39	29	9.75	7.119	0.0001
Overall	**176**	**110**	**44**	**11.489**	**0.0001**
TASK	**MEN**	62.50%			

Table 15

Reflex Multivariate Tests

REFLEX			
Multivariate			
	GENDER	df	9
Wilk's λ		F statistic	1.572
		p value	0.122
	REFLEX	df	9
		F statistic	2.745
		p value	0.004
GENDER*REFLEX		df	9
		F statistic	1.127
		p value	0.342

Table 16

Reflex Post Hoc Tests

REFLEX		PEP	SBP	DBP	RR	SCL	IBI	RMSSD	LF	HF
Contrast Univariate										
	F statistic	1.528	0	0.346	0.15	10.744	0.332	0.742	6.244	2.196
	P value	0.217	0.983	0.557	0.699	0.001	0.571	0.39	0.013	0.139

Table 17

Reflex Mean Reactivity

		N	Mean	STD
SCL	Cold Press	210	1.362	6.786
	Face Cool	207	2.724	4.198
	Total	417	2.038	5.686
LF	Cold Press	214	2.186	21.519
	Face Cool	210	-5.202	26.096
	Total	424	-1.473	24.152
HF	Cold Press	214	-2.033	19.018
	Face Cool	210	1.622	21.569
	Total	424	-0.222	20.380

Table 18

Mental Multivariate Tests

MENTAL			
Multivariate			
	GENDER	df	9
Wilk's λ		F statistic	2.026
		p value	0.036
	MENTAL	df	9
		F statistic	45.957
		p value	0.000
GENDER*MENTAL		df	9
		F statistic	1.378
		p value	0.196

Table 19

Mental Post Hoc Tests

MENTAL		**PEP**	**SBP**	**DBP**	**RR**	**SCL**	**IBI**	**RMSSD**	**LF**	**HF**
Contrast Univariate										
	F statistic	16.248	49.553	70.659	55.542	90.201	258.72	16.007	16.266	29.239
	P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 20

Mental Mean Reactivity

		N	Mean	STD
PEP	Arithmetic	214	-2.629	10.456
	Relaxation	214	1.210	6.888
	Total	428	-0.710	9.050
SBP	Arithmetic	199	13.924	17.385
	Relaxation	199	0.992	17.814
	Total	398	7.458	18.733
DBP	Arithmetic	199	10.576	11.255
	Relaxation	199	1.071	13.163
	Total	398	5.824	13.124
RR	Arithmetic	211	0.960	2.388
	Relaxation	211	-0.676	1.610
	Total	422	0.142	2.193
SCL	Arithmetic	209	4.354	6.811
	Relaxation	208	-0.290	2.738
	Total	417	2.038	5.686
AVEIBI	Arithmetic	214	-0.067	0.067
	Relaxation	212	0.028	0.045
	Total	426	-0.020	0.074
RMSSD	Arithmetic	213	-0.557	17.326
	Relaxation	211	5.578	11.752
	Total	424	2.496	15.115
LF	Arithmetic	212	3.317	22.629
	Relaxation	212	-6.263	24.724
	Total	424	-1.473	24.152
HF	Arithmetic	212	-5.952	19.127
	Relaxation	212	5.507	20.021
	Total	424	-0.222	20.380

Table 21

Mental x Gender 1-way ANOVA

Mental x Gender		Arithmetic	Relaxation
PEP	df	1	1
	F	0.581	2.892
	p	0.447	0.09
SBP	df	1	1
	F	1.688	0.509
	p	0.195	0.476
DBP	df	1	1
	F	0.115	0.039
	p	0.735	0.843
RR	df	1	1
	F	0.077	0.199
	p	0.781	0.656
SCL	df	1	1
	F	3.100	2.371
	p	0.080	0.125
IBI	df	1	1
	F	9.257	2.738
	p	0.003	0.099
RMSSD	df	1	1
	F	0.571	0.675
	p	0.451	0.412
LF	df	1	1
	F	8.719	0.32
	p	0.004	0.572
HF	df	1	1
	F	12.532	0.055
	p	0.000	0.814

Table 22

Arithmetic Mean Reactivity x Gender

Arithmetic	Mean Reactivity **Women**			**Men**		
	N	Mean	STD	N	Mean	STD
IBI	108	-0.081	0.072	106	-0.053	0.058
LF	106	7.825	24.647	106	-1.190	19.507
HF	106	-10.480	20.481	106	-1.423	16.562

Table 23

DFA Reflex Total

Significance test for classification across Reflex task					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
Cold Press	192	123	96	3.897	0.0001
Face Cool	181	112	90.5	3.196	0.0014
Overall	**373**	**235**	**186.5**	**5.022**	**0.0001**
REFLEX	TOTAL	63.00%			

Table 24

DFA Reflex Women

Significance test for classification across Reflex task					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
Cold Press	102	67	51	3.168	0.0014
Face Cool	95	64	47.5	3.386	0.0001
Overall	**197**	**131**	**98.5**	**4.631**	**0.0001**
REFLEX	WOMEN	66.50%			

Table 25

DFA Reflex Men

Significance test for classification across Reflex task					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
Cold Press	90	57	45	2.530	0.0114
Face Cool	86	56	43	2.804	0.0051
Overall	**176**	**113**	**88**	**3.769**	**0.0001**
REFLEX	MEN	64.20%			

Table 26

DFA Mental Total

Significance test for classification across Mental task					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
Arithmetic	188	155	94	8.898	0.0001
Relaxation	185	175	92.5	12.131	0.0001
Overall	**373**	**330**	**186.5**	**14.860**	**0.0001**
MENTAL	TOTAL	88.50%			

Table 27

DFA Mental Women

Significance test for classification across Mental task					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
Arithmetic	98	80	49	6.263	0.0001
Relaxation	99	96	49.5	9.347	0.0001
Overall	**197**	**176**	**98.5**	**11.043**	**0.0001**
MENTAL	WOMEN	89.30%			

Table 28

DFA Mental Men

Significance test for classification across Mental task					
Task	**N**	**Observed**	**Expected**	**Z**	**P**
Arithmetic	90	78	45	6.957	0.0001
Relaxation	86	81	43	8.195	0.0001
Overall	**176**	**159**	**88**	**10.704**	**0.0001**
MENTAL	MEN	90.30%			

Table 29

Significance of Proportion Test

Significance of Proportion Test	
Total reflex %	63
Total mental %	88.5
Difference of %	25.5
Standard Error	2.996
Z=change %/SE	8.5105
P value	0.000

Table 30

WM Regression Scores

Total		LF	HF
CPA	R^2	0.013	0.002
	β	0.113	-0.045
CPR	R^2	0.109	0.086
	β	-0.33	0.294
FCA	R^2	0.02	0.028
	β	0.142	-0.168
FCR	R^2	0.014	0.015
	β	-0.12	0.123

Female		LF	HF
CPA	R^2	0.000	0.006
	β	0.012	-0.077
CPR	R^2	0.151	0.134
	β	-0.388	0.366
FCA	R^2	0.053	0.053
	β	0.299	-0.231
FCR	R^2	0.054	0.072
	β	-0.23	0.269

Male		LF	HF
CPA	R^2	0.055	0.005
	β	0.234	-0.067
CPR	R^2	0.082	0.052
	β	-0.286	0.228
FCA	R^2	0.011	0.030
	β	0.106	-0.173
FCR	R^2	0.000	0.000
	β	-0.019	0.019

Table 31

Spatial and Digit Working Memory Regression Scores

Total CPR		**LF**	**HF**
Spatial	**p**	0.008	0.046
	β	-0.26	0.198
Digit	**p**	0.116	0.088
	β	-0.153	0.169

Female		**LF**	**HF**
CPR			
Spatial	**p**	0.028	0.064
	β	-0.295	0.25
Digit	**p**	0.109	0.087
	β	-0.213	0.23
FCR			
Spatial	**p**		0.218
	β		0.17
Digit	**p**		0.184
	β		0.184

Male CPR		**LF**	**HF**
Spatial	**p**		0.289
	β		0.162
Digit	**p**		0.471
	β		0.11

Table 32

BMI, Houston, DASS, Impulsivity and Reactivity Regression

Regression			PEP	SBP	DBP	RR	SCL	IBI	RMSSD	LF	HF
BMI Houston DASS Impulsivity x Reactivity											
CPA	Depression	Standardized β	-0.017	0.035	-0.048	0.063	0.224	-0.115	-0.026	-0.034	0.111
		p value	0.886	0.772	0.691	0.591	0.058	0.328	0.825	0.772	0.343
	Anxiety	Standardized β	-0.075	0.029	-0.077	0.073	0.048	0.002	0.084	0.025	0.043
		p value	0.602	0.843	0.601	0.617	0.735	0.987	0.560	0.860	0.763
	Stress	Standardized β	0.085	-0.033	0.051	0.053	-0.281	0.157	-0.013	-0.004	-0.185
		p value	0.570	0.829	0.741	0.727	0.058	0.295	0.933	0.978	0.214
	Impulsivity	Standardized β	-0.146	-0.009	-0.037	-0.084	-0.043	-0.001	0.123	-0.090	0.039
		p value	0.192	0.939	0.752	0.456	0.695	0.990	0.270	0.422	0.723
	Houston	Standardized β	-0.066	-0.046	0.036	-0.128	-0.100	-0.035	-0.063	-0.151	0.104
		p value	0.526	0.679	0.744	0.222	0.331	0.734	0.540	0.148	0.313
	BMI	Standardized β	0.122	0.124	0.101	0.064	0.097	0.021	-0.103	0.098	-0.094
		p value	0.238	0.258	0.353	0.540	0.345	0.837	0.318	0.347	0.360
CPR	Depression	Standardized β	-0.071	-0.074	-0.047	0.065	0.002	0.126	-0.023	0.030	-0.001
		p value	0.536	0.541	0.695	0.580	0.988	0.285	0.847	0.796	0.993
	Anxiety	Standardized β	-0.198	-0.078	-0.093	-0.084	-0.036	0.055	-0.042	0.068	0.064
		p value	0.162	0.594	0.527	0.567	0.800	0.705	0.771	0.634	0.649
	Stress	Standardized β	0.042	0.015	0.017	0.068	-0.023	0.008	0.145	-0.182	0.149
		p value	0.773	0.920	0.909	0.656	0.875	0.955	0.337	0.223	0.310
	Impulsivity	Standardized β	0.071	-0.033	-0.074	0.134	-0.166	-0.018	-0.066	-0.094	0.045
		p value	0.519	0.779	0.526	0.230	0.141	0.875	0.561	0.400	0.684
	Houston	Standardized β	0.057	-0.044	-0.015	0.056	-0.106	-0.025	0.041	-0.159	1.573
		p value	0.577	0.686	0.890	0.589	0.310	0.814	0.694	0.125	0.119
	BMI	Standardized β	0.213	0.090	0.075	-0.123	0.021	-0.067	-0.003	0.019	0.048
		p value	0.037	0.400	0.484	0.238	0.839	0.521	0.749	0.852	0.635
FCA	Depression	Standardized β	-0.093	0.283	0.252	0.097	0.262	-0.100	0.096	0.036	0.024
		p value	0.426	0.017	0.034	0.403	0.024	0.387	0.417	0.752	0.837
	Anxiety	Standardized β	-0.038	0.138	0.059	-0.034	0.187	-0.113	0.041	-0.116	0.179
		p value	0.792	0.328	0.676	0.814	0.187	0.427	0.779	0.411	0.216
	Stress	Standardized β	0.134	-0.116	-0.045	-0.023	-0.204	0.238	-0.091	0.156	-0.146
		p value	0.370	0.429	0.763	0.877	0.167	0.110	0.547	0.288	0.328
	Impulsivity	Standardized β	0.070	-0.071	-0.007	-0.181	0.024	0.114	-0.023	-0.262	0.097
		p value	0.532	0.526	0.952	0.103	0.824	0.303	0.838	0.019	0.386
	Houston	Standardized β	-0.005	-0.062	-0.044	-0.194	-0.073	0.023	0.038	-0.142	0.176
		p value	0.959	0.557	0.680	0.062	0.469	0.820	0.717	0.167	0.090
	BMI	Standardized β	0.130	-0.101	-0.108	0.002	-0.111	0.109	-0.105	0.007	-0.012
		p value	0.208	0.332	0.303	0.981	0.273	0.287	0.317	0.948	0.909

Regression			PEP	SBP	DBP	RR	SCL	IBI	RMSSD	LF	HF
BMI Houston DASS Impulsivity x Reactivity											
FCR	Depression	Standardized β	0.196	0.049	-0.004	0.169	-0.099	-0.188	-0.160	-0.100	-0.008
		p value	0.088	0.680	0.971	0.145	0.411	0.110	0.177	0.398	0.942
	Anxiety	Standardized β	0.188	-0.100	-0.075	-0.227	-0.056	0.111	0.213	0.197	-0.143
		p value	0.181	0.486	0.608	0.113	0.701	0.438	0.139	0.175	0.321
	Stress	Standardized β	-0.216	0.079	-0.015	0.220	0.012	-0.114	-0.168	0.021	-0.004
		p value	0.139	0.599	0.923	0.141	0.940	0.444	0.261	0.890	0.980
	Impulsivity	Standardized β	0.018	0.164	0.117	-0.137	-0.039	-0.010	0.054	0.017	-0.138
		p value	0.868	0.157	0.313	0.215	0.735	0.929	0.630	0.877	0.216
	Houston	Standardized β	0.187	-0.101	-0.117	-0.061	-0.121	-0.071	0.039	0.027	-0.066
		p value	0.066	0.351	0.285	0.554	0.254	0.493	0.709	0.798	0.527
	BMI	Standardized β	-0.076	-0.043	-0.030	0.038	-0.084	-0.036	0.003	-0.038	0.007
		p value	0.452	0.687	0.779	0.712	0.429	0.727	0.976	0.713	0.946

Figure Captions

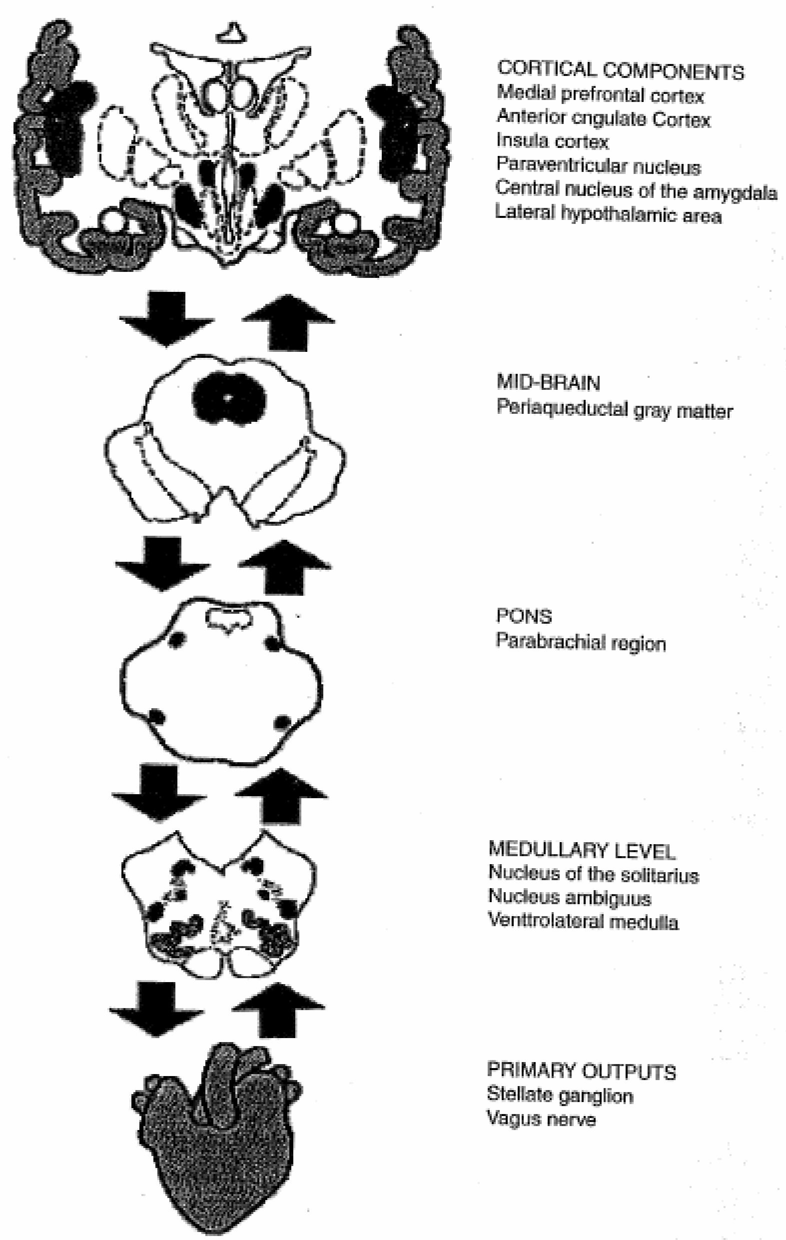

Figure 1.

Neuroanatomical Structures of the Neuro-Visceral Model reprinted from Thayer & Friedman, 2004 with permission of authors.

Figure 2.

Mean SCL Reactivity

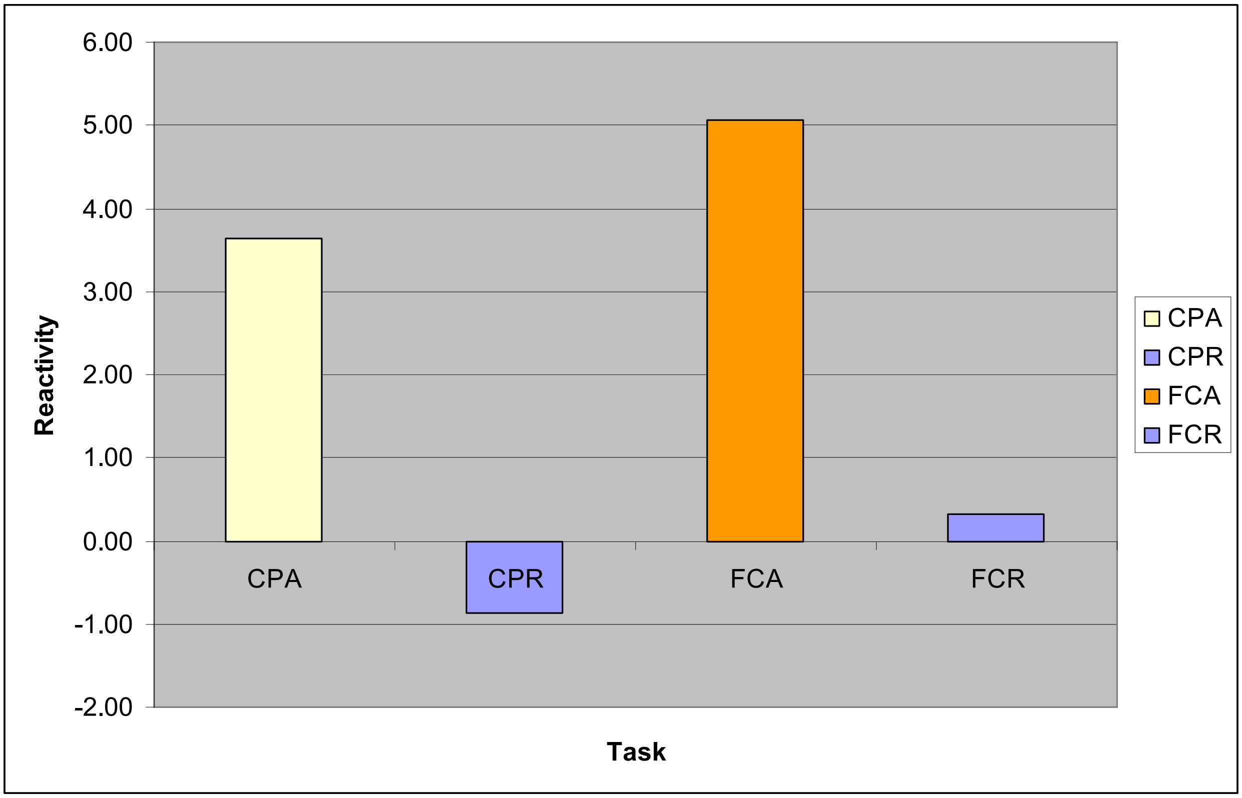

Figure 3.

Mean PEP Reactivity

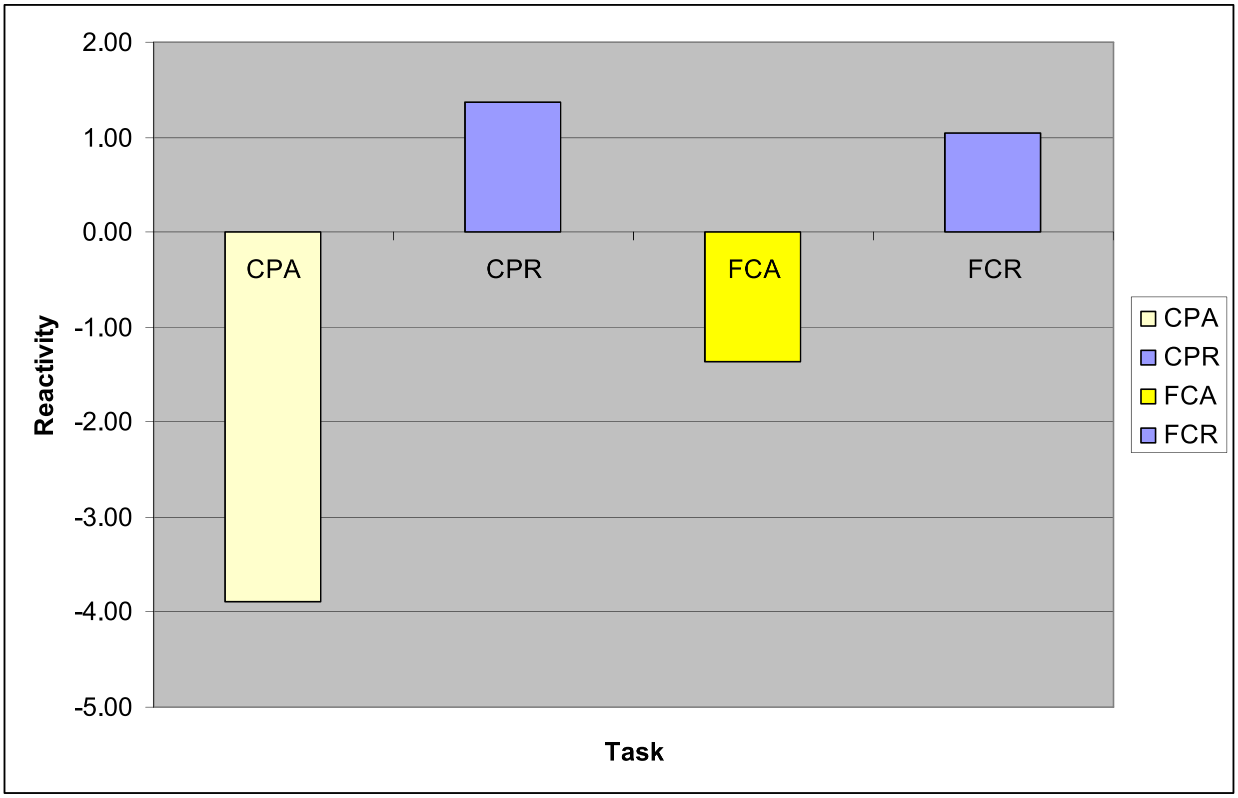

Figure 4.

Mean RMSSD Reactivity

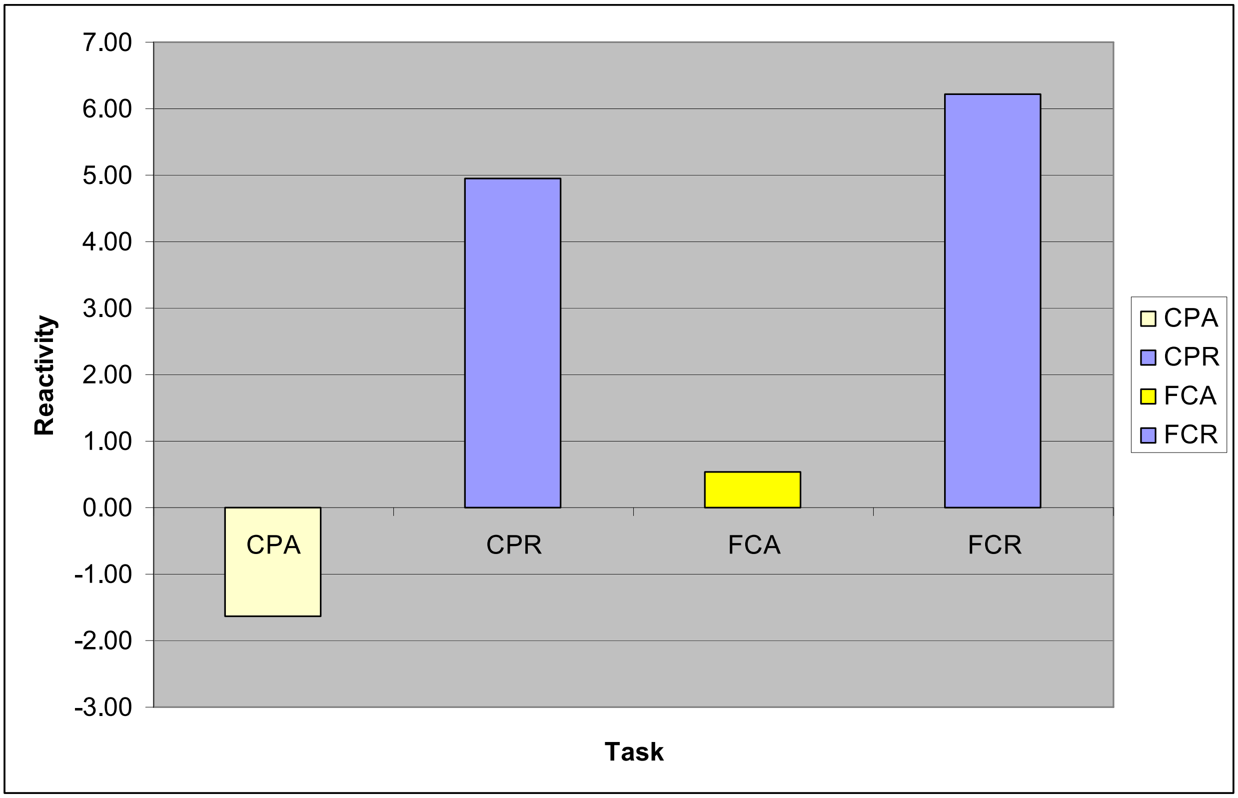

Figure 5.

Mean SBP Reactivity

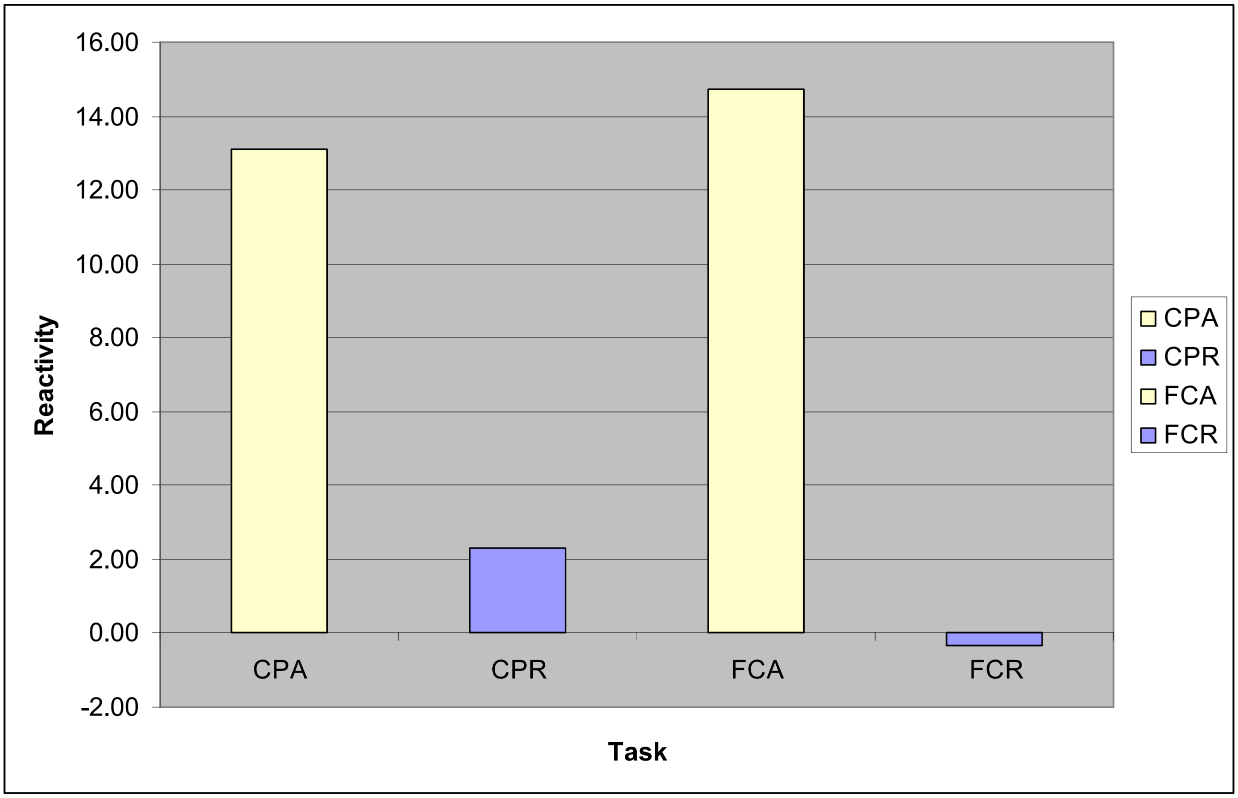

Figure 6.

Mean DBP Reactivity

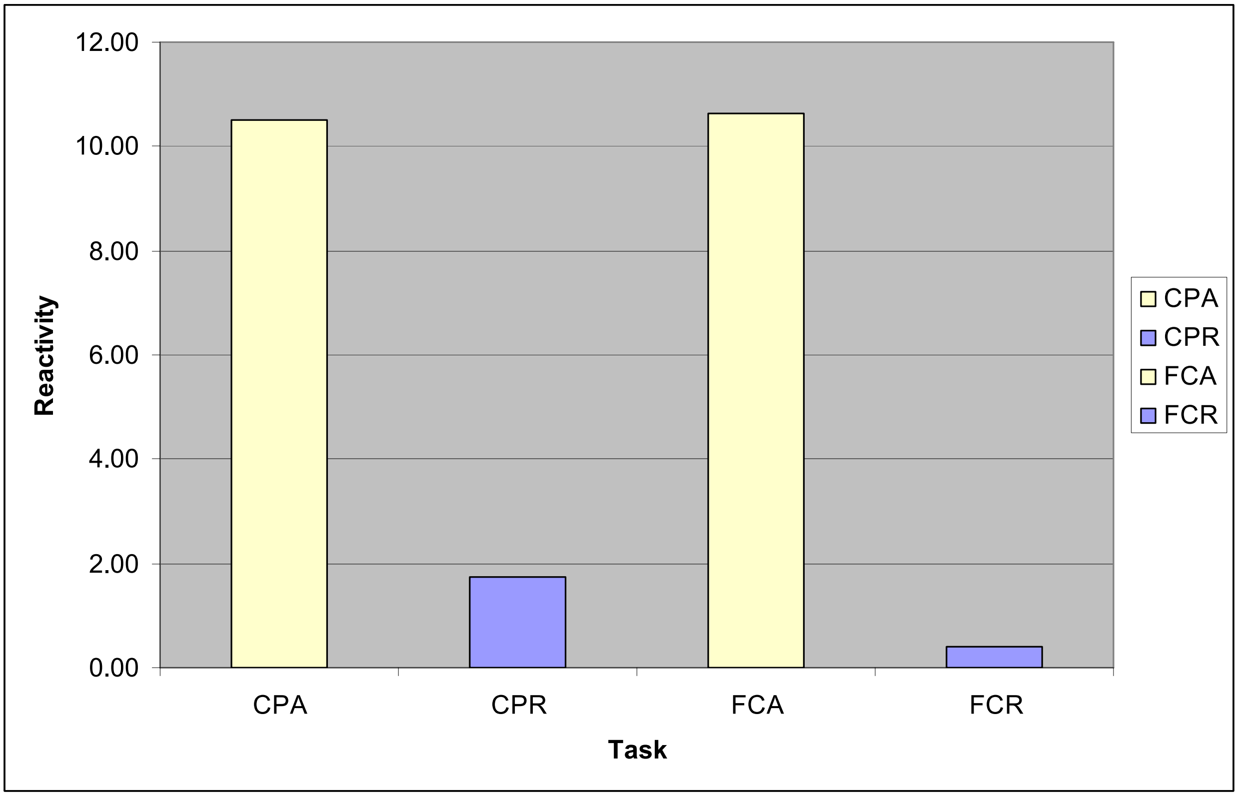

Figure 7.

Mean RR Reactivity

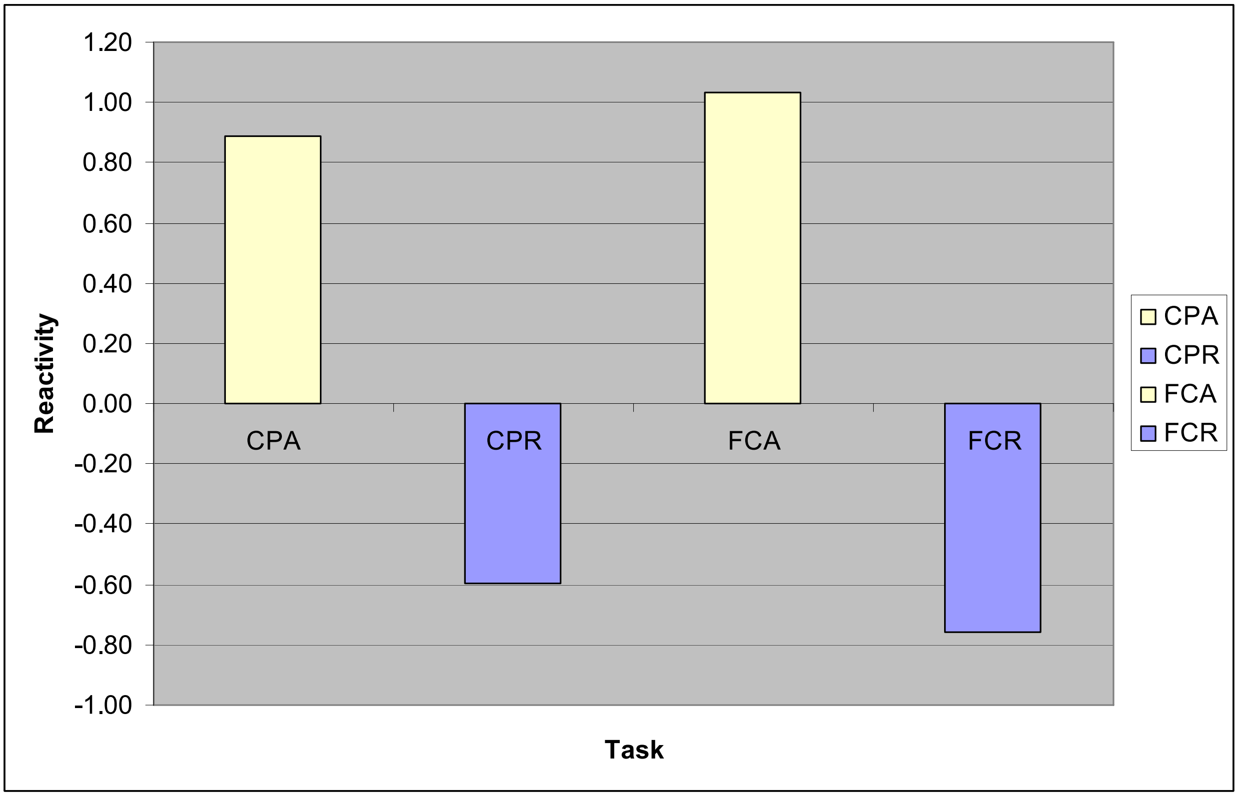

Figure 8.

CPA Mean IBI Reactivity x Gender

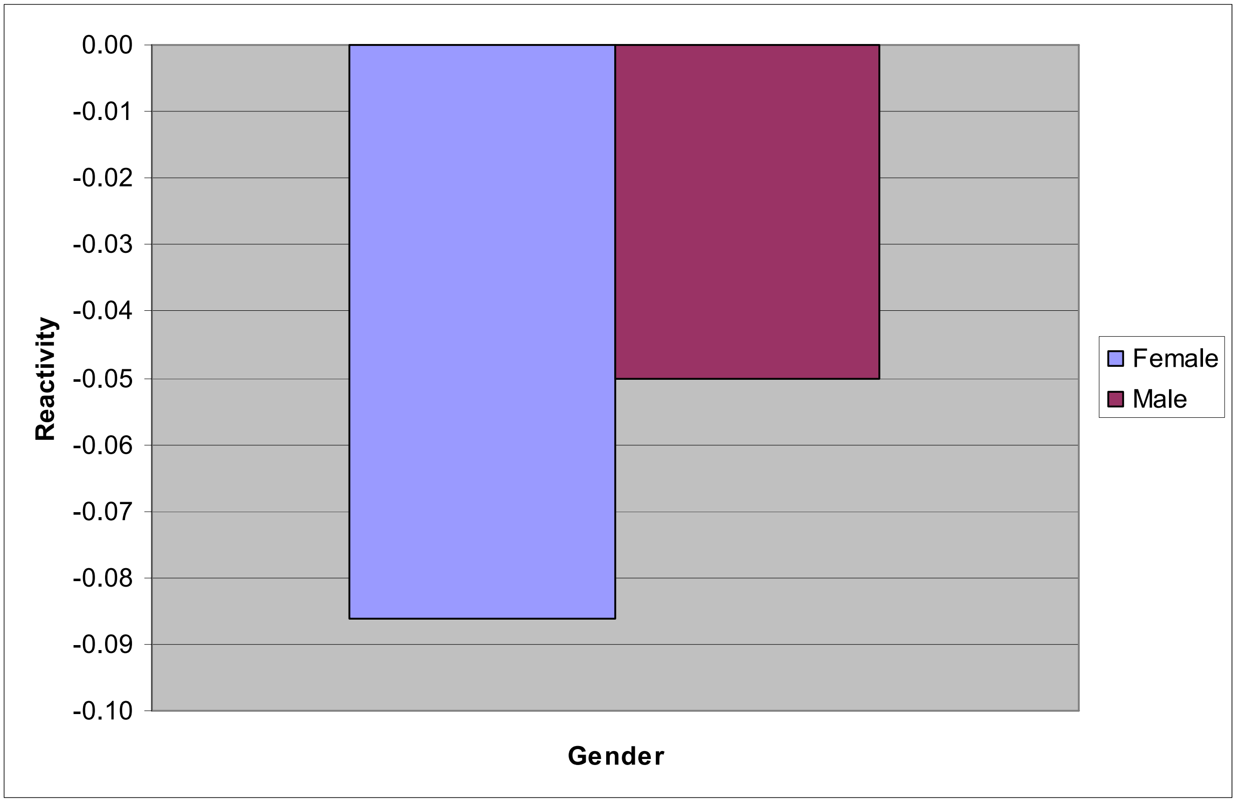

Figure 9.

CPA Mean LF Reactivity x Gender

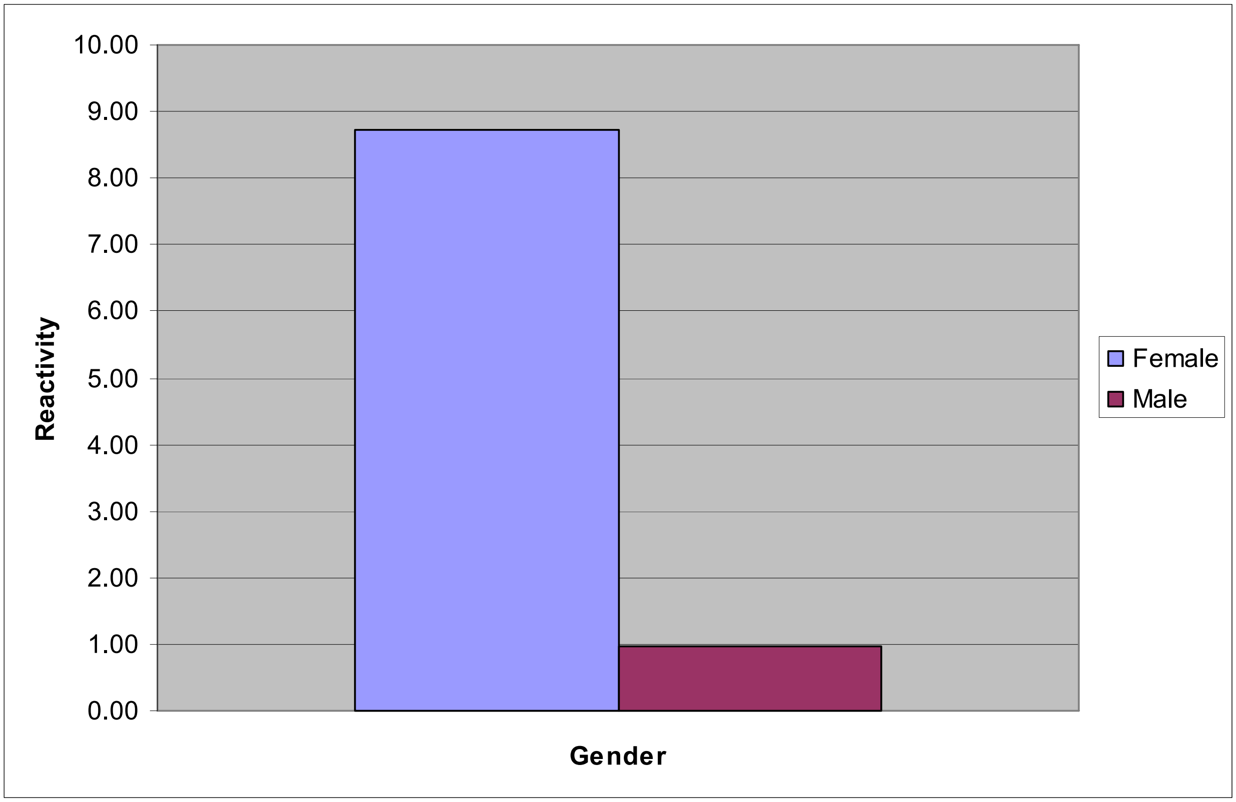

Figure 10.

CPA Mean HF Reactivity x Gender

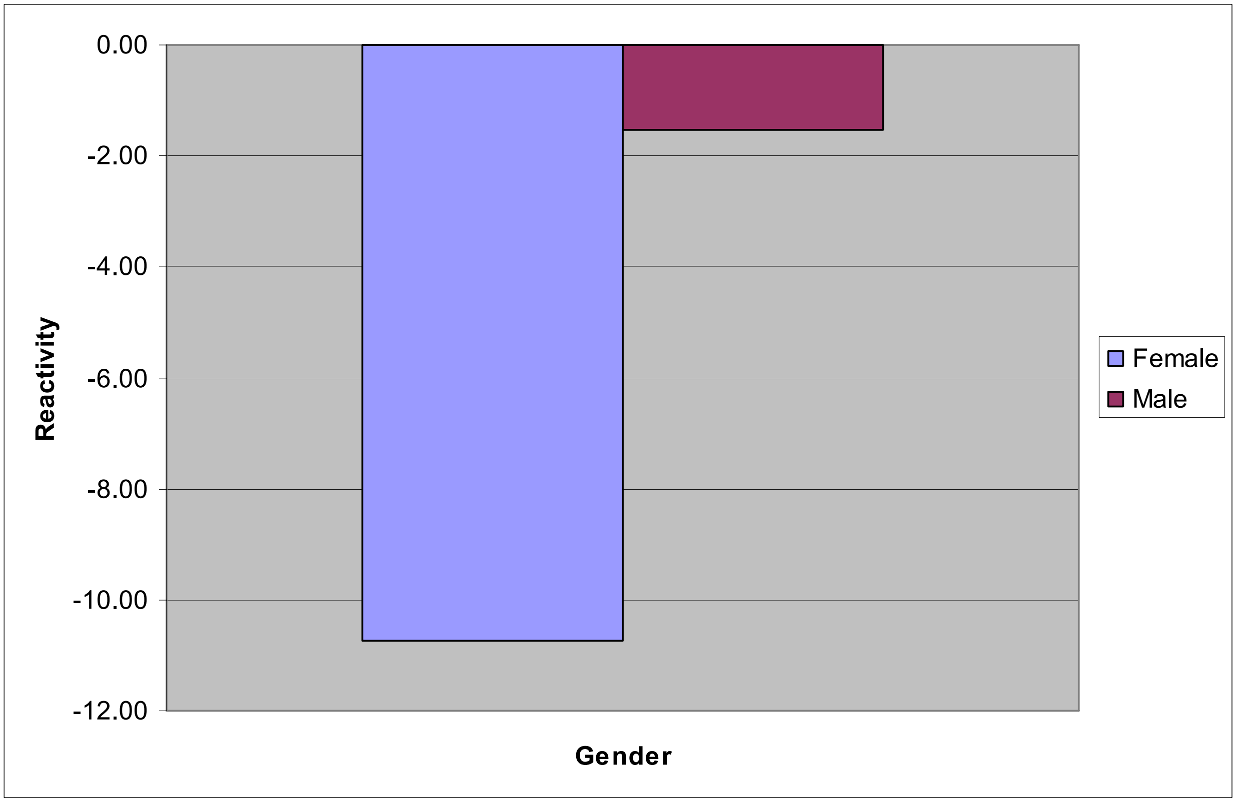

Figure 11.

FCA Mean LF Reactivity x Gender

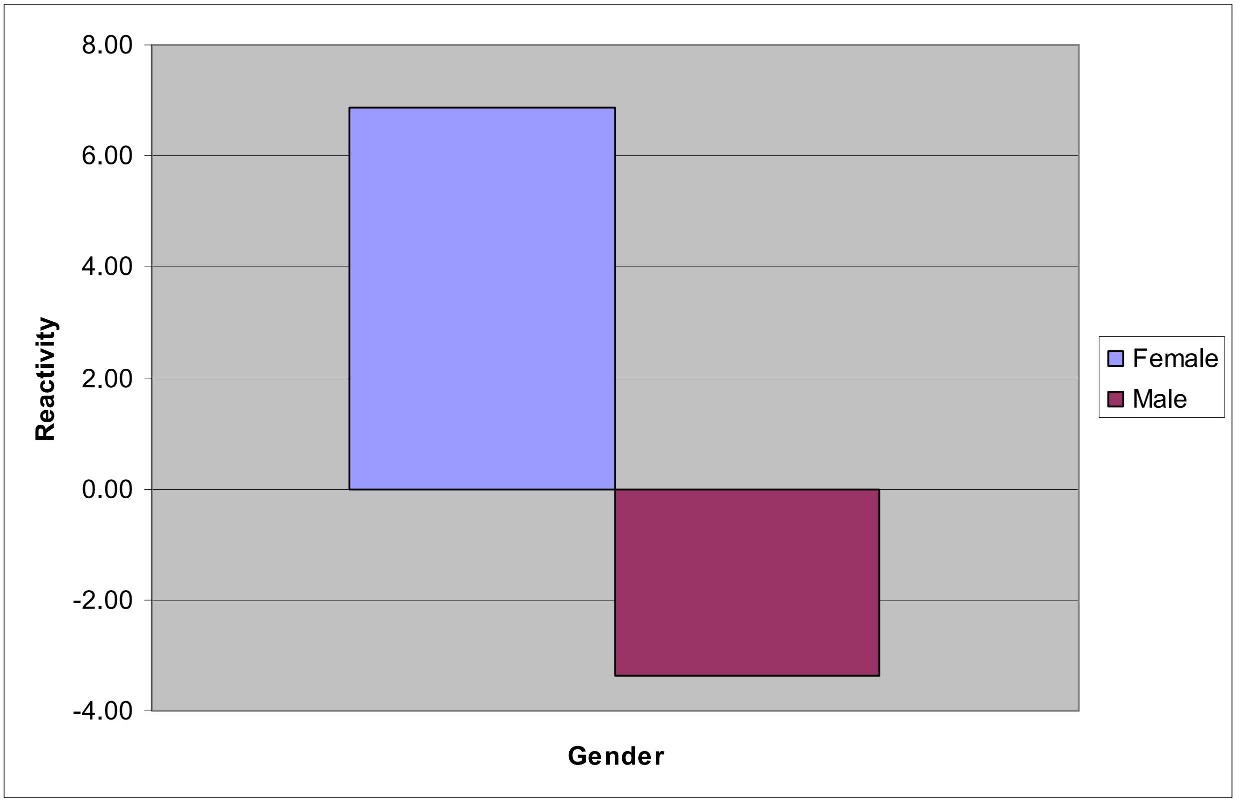

Figure 12.

FCA Mean HF Reactivity x Gender

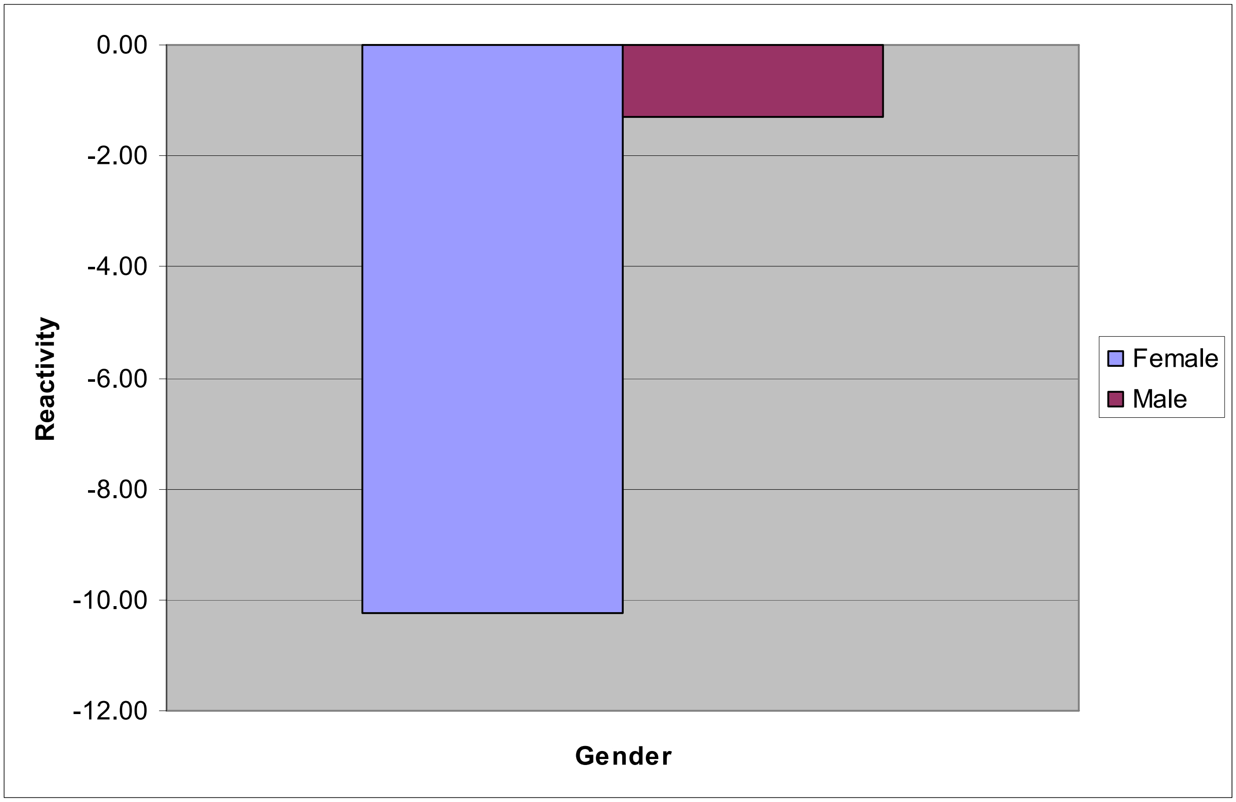

Figure 13.

FCR Mean PEP Reactivity x Gender

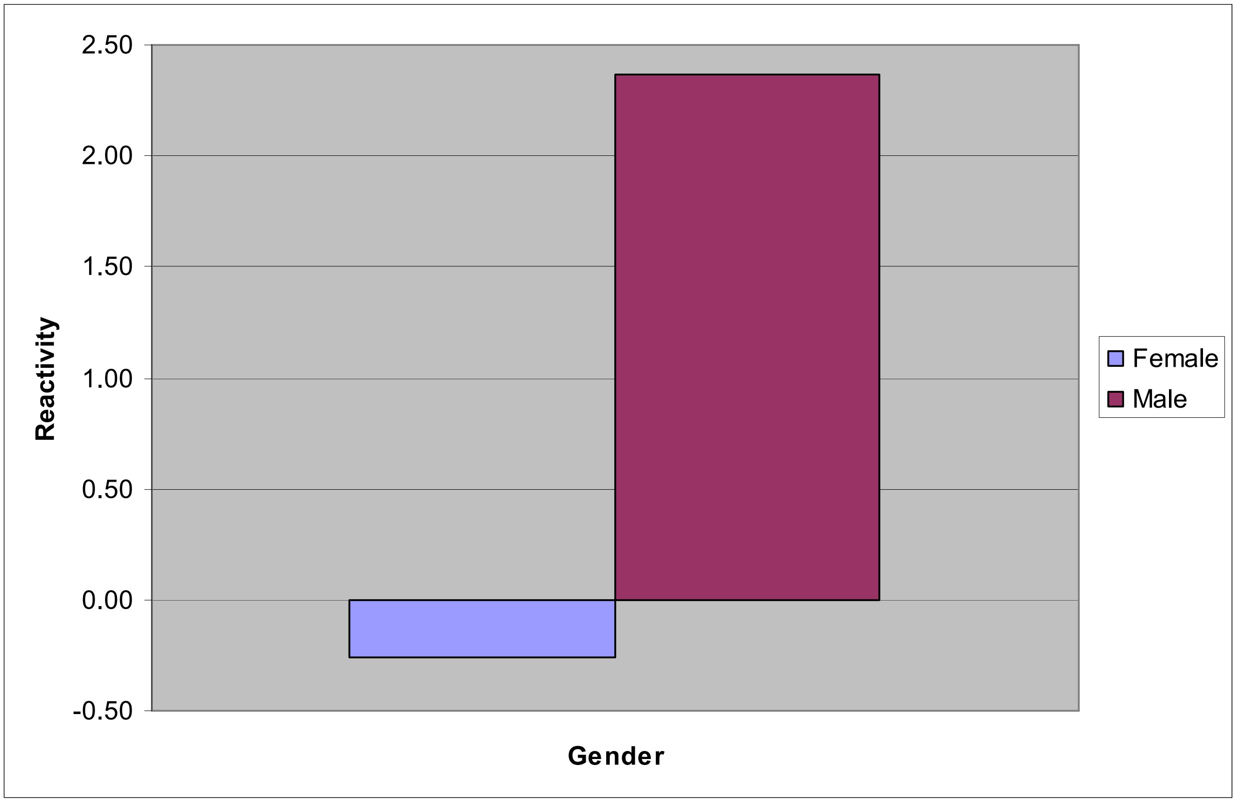

Figure 14.

CPA LF WM Regression

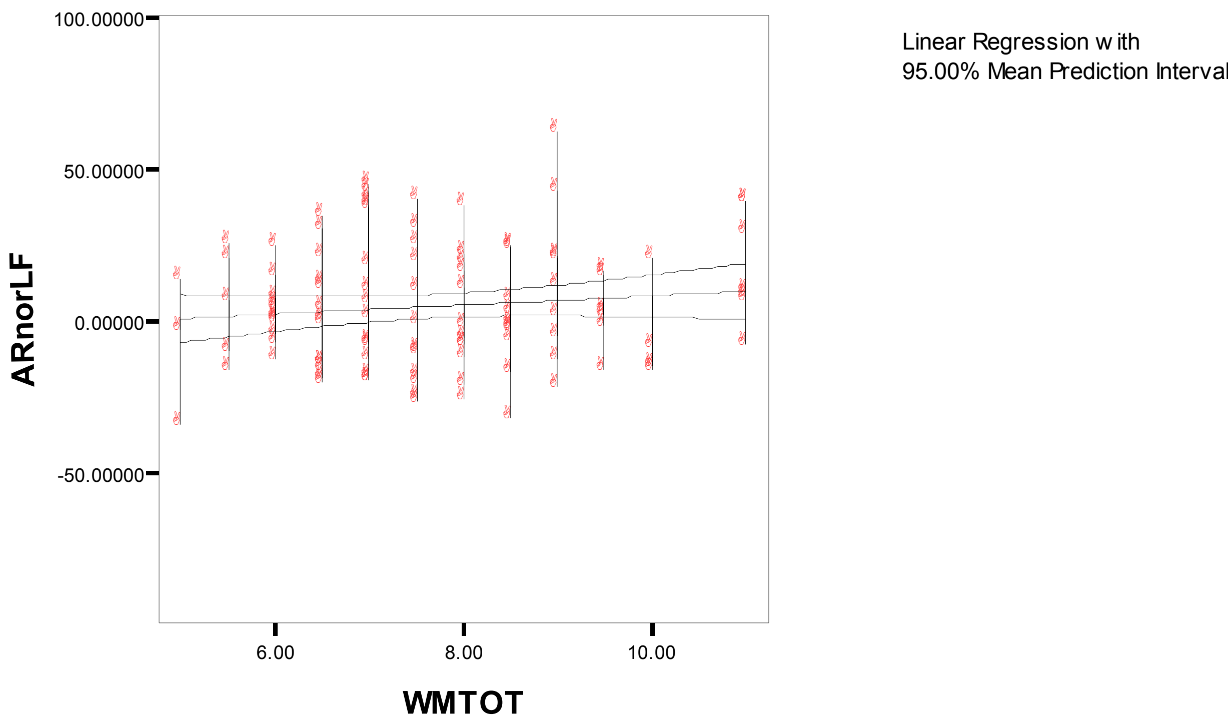

Figure 15.

CPA HF WM Regression

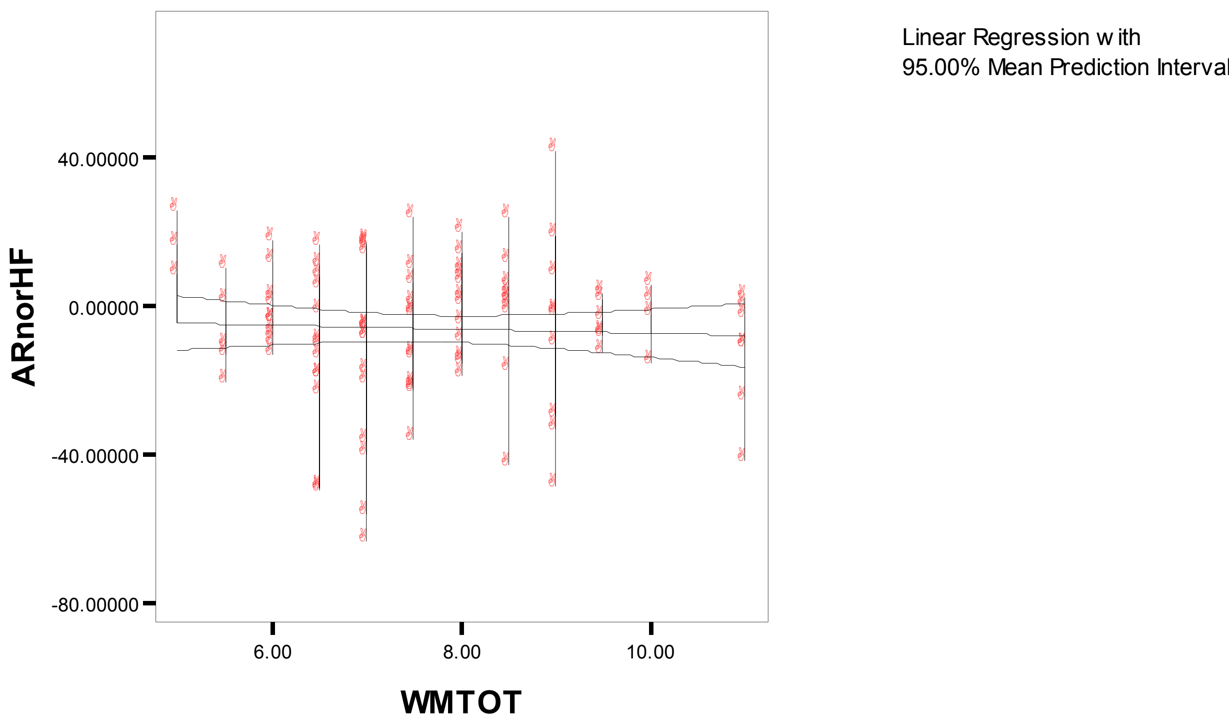

Figure 16.

CPR LF WM Regression

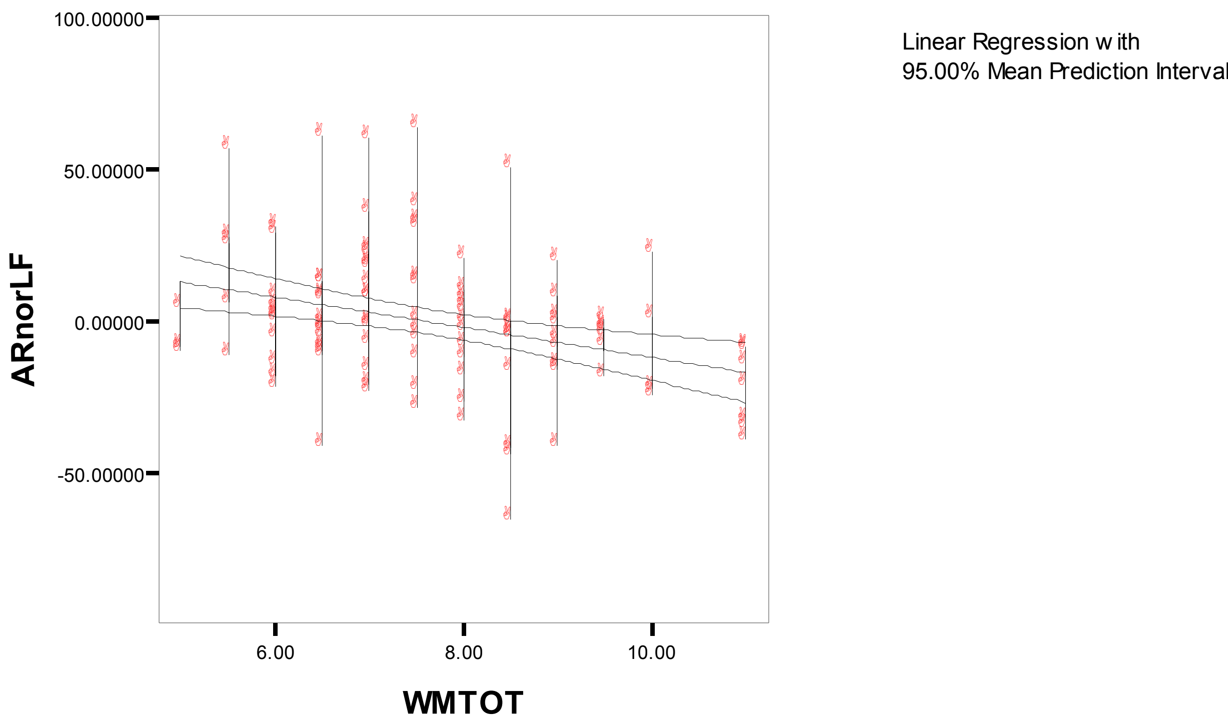

Figure 17.

CPR HF WM Regression

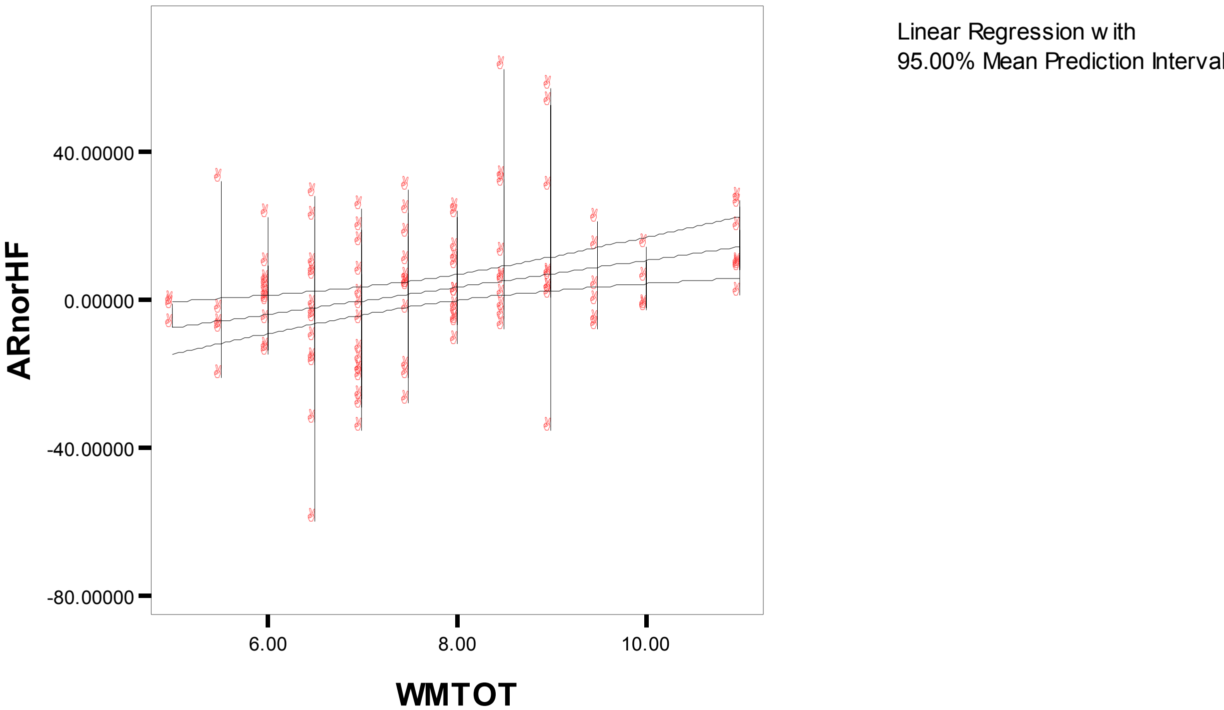

Figure 18.

FCA LF WM Regression

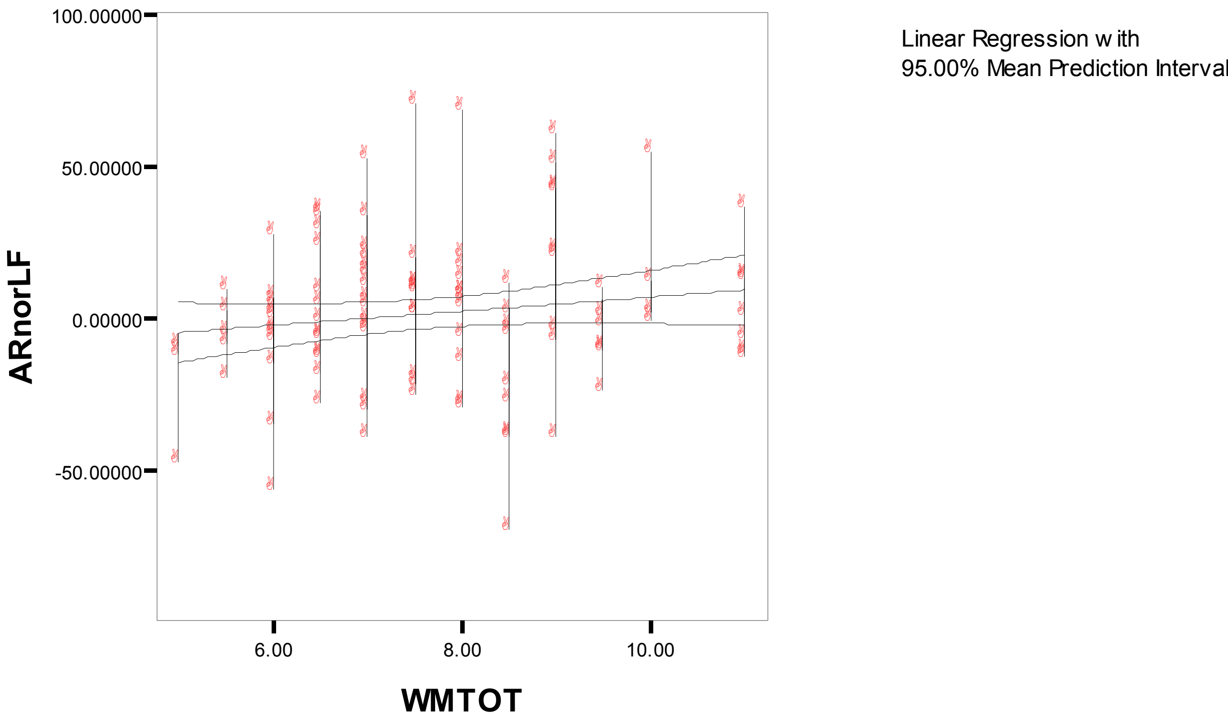

Figure 19.

FCA HF WM Regression

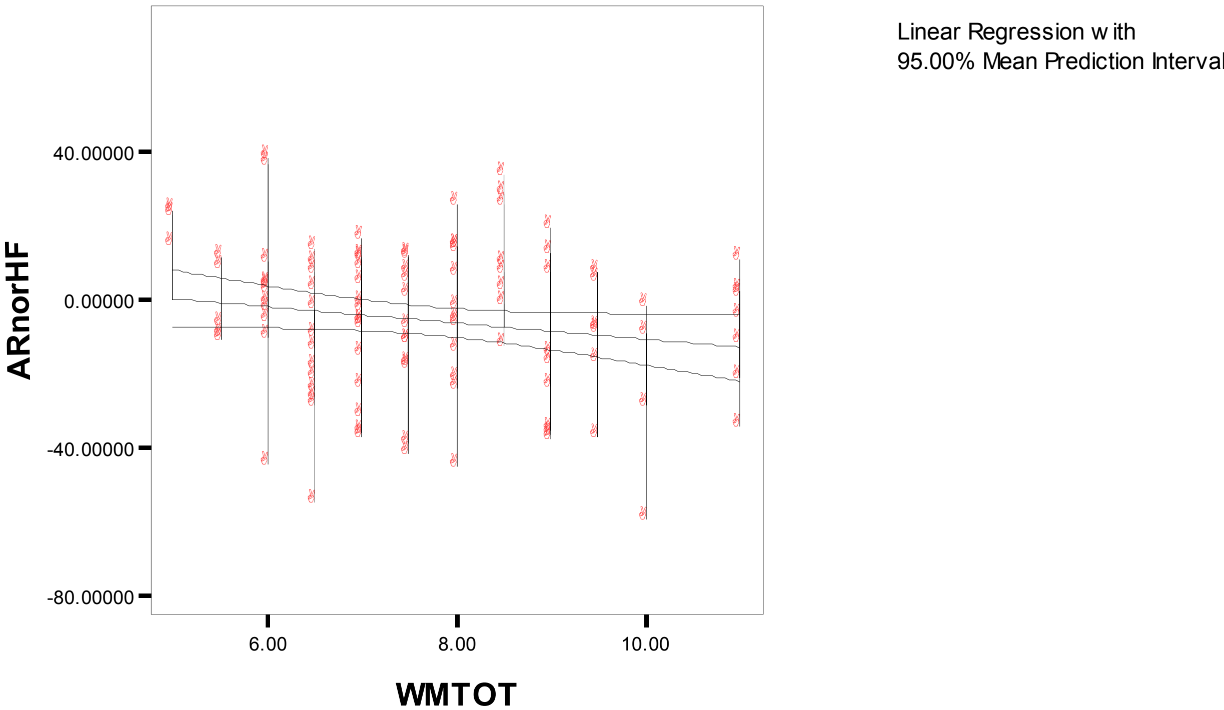

Figure 20.

FCR LF WM Regression

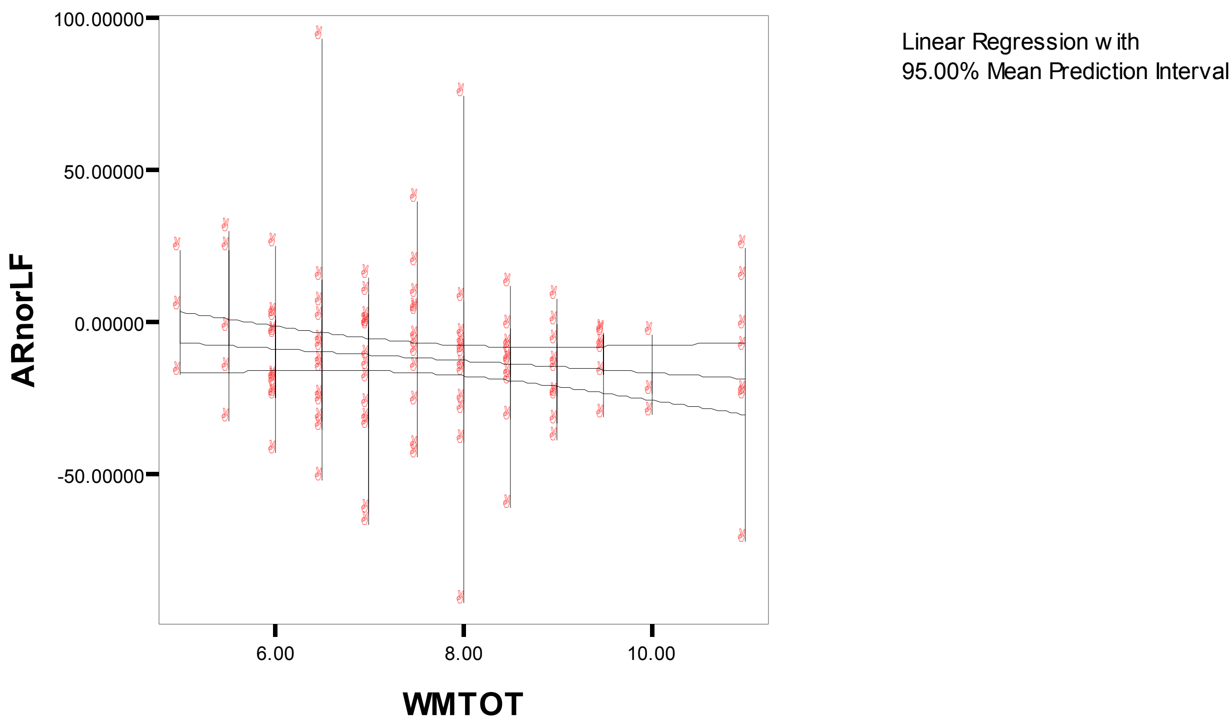

Figure 21.

FCR HF WM Regression