Neuropsychological and Psychophysiological Correlates of

Anger Expression Styles

David E. Cox

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David W. Harrison, Ph.D.
(Committee Chair)
Martha Ann Bell, Ph.D.
(Committee Member)
Lee D. Cooper, Ph.D.
(Committee Member)
Jungmeen Kim, Ph.D.
(Committee Member)

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ABSTRACT

The proposed research will investigate the effects of self-reported anger expression style on cerebrally lateralized physiological responses to a neuropsychological stressor and a painful stimulus. Specifically, this research will examine changes in systole and grip strength in response to a verbal fluency task, a figural fluency task and exposure to a cold pressor. Significant group by trial interaction effects were found for mean number of perseverative errors on neuropsychological measures ($F(1,54) = 10.89$, $p < 0.05$), systolic blood pressure following administration of a verbal fluency measure($F(1,54) = 5.86$, $p < 0.05$), and non-verbal fluency measure ($F(1,54) = 13.68$, $p<.001$), heart rate following administration of verbal ($F(1,54) = 5.86$, $p < 0.05$), and non verbal fluency measures ($F(1,54) = 13.68$, $p<.001$), and grip strength following exposure to the cold pressor ($F(1,54) = 13.69$, $p < 0.001$). Results are discussed in terms of functional cerebral systems and potential implications for physiological models of anger.

DEDICATION

This dissertation is dedicated to my wife Susan, my daughters Dorian and Adrian who make all efforts worthwhile, and the entire Virginia Tech community which has shown a tremendous sense of cohesiveness and resiliency in the face of overwhelming tragedy. I hope that someday I will be able to give back to this community what it has given me over the past 4 years.

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CONTENTS

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Elements of the multifaceted emotional construct of anger, such as hostility have been shown to be associated with increased risk for negative health outcomes such as cardiovascular disease (Barefoot, Dodge, Peterson, Dahlstrom, & Williams, 1989; Guijarro, Hallet, Miller, Smith, & Turner, 1996; Helmer, Ragland, & Syme, 1991), cerebrovascular accident (Everson, Kaplan, Goldberg, Lakka, Sivenius, & Salonen, 1997) and the metabolic syndrome (Walters, 2006). Not surprisingly, anger represents one of the most frequently investigated emotional constructs over the past decade (Eckhardt & Deffenbacher, 1995). Despite the frequency of investigation and the health implications ascribed to anger, the mechanisms by which this emotional construct impacts physiological function are not fully understood. One mechanism that has been discussed in terms of health impact is how an individual deals with the experience of anger. When an individual experiences anger, one may internalize the feeling or she/he may externalize the feeling. Although there has been substantial debate regarding which of these strategies may lead to negative health outcomes (for review see Walker & Singleton, 1999), there have been surprisingly few empirical investigations into the mechanisms underlying expression styles. The present research will examine changes in functional cerebral systems associated with relevant physiological processes among individuals reporting different anger expression styles.

Defining Anger

Before any investigation can be conducted in the area of anger, the construct must be clearly defined. Many different definitions have been offered and the construct has been divided into multiple constructs and factors. A brief review of the history of the construct and its various definitions is offered here to establish the basis of the operational definition that will be used in the current experiment. Overall, the construct of anger is considered to be multidimensional with distinct affective, behavioral, and cognitive dimensions and distinct physiological elements that contribute to both the experience and expression of the emotion (Spielberger, Johnson, Russell, Crane, Jacobs & Worden, 1983). Additionally, the expression of anger may be directed inwardly or outwardly (Spielberger, Reheiser, & Sydeman, 1995)

The affective dimension of anger

The operational definition most frequently ascribed to the affective dimension of anger is that of a subjective, negatively felt state associated with cognitive deficits and distortions as well as physiological correlates that occur in response to a stimulus that is perceived as negative and may result in maladaptive patterns of behavior (Kassinove & Suckhodolsky, 1995). While this definition provides some clarification of how the affective dimension of anger is associated with the emotional construct, further elaboration is necessary in order to capture how this emotion occurs as an emotive state. In order to evaluate anger in this manner the stability, frequency and intensity with which this emotion is experienced as well as how the experience and expression of this emotion differ must be addressed (Deffenbacher, Oetting, Huff, Cornell, & Dallagher, 1996). This affective dimension of anger can best be described as an emotional state, which occurs in response to an immediate stressor and may vary in both intensity and duration. This definition is consistent with the idea the affective experience of emotions are best defined in terms of states (Spielberger et al, 1995).

The behavioral dimension of anger

It has been suggested that all observable behaviors are influenced by the integration of emotions and cognitions (Lemerise & Arsenio, 2000). Therefore, the behavioral dimension of anger, most frequently referred to as aggression, can be seen as arising from the cognitive and affective dimensions (Weiner, 1995). Although there has been considerable debate regarding fear induced aggression or aggression as a "defensive" act (Graham, & Hoehn, 1995), and these behaviors may be shown to meet the behavioral dimension of aggression (e.g., causing harm), they lack the cognitive intent and the full affective experience of anger (Lemerise & Arsenio, 2000). Thus, it is inappropriate to conceptualize the behavioral dimension independent of the cognitive, affective and behavioral dimensions as they are highly interrelated and interdependent (Loeber, & Coie, 2001).

The cognitive dimension of anger

The cognitive dimension of anger, often referred to as hostility in the literature, has most frequently been defined as a cognitive phenomenon of an attitudinal nature that subserves the emotional process, but is not an emotion *per se* (Smith, 1994). Buss (1961), who is most frequently credited with the definition of hostility, suggested that hostility is defined by negative cognitive appraisals of circumstances and individuals. These definitions point to the idea that cognitive anger or hostility is a stable set of schema through which one interprets incoming stimuli. Inasmuch as the affective domain may be viewed as an emotional state, this cognitive dimension may best be represented as an emotional trait. Trait anger refers to the overarching construct of anger and is defined as anger-proneness or a relatively stable predisposition to react to stimuli perceived as negative in an angry manner (Spielberger et al, 1995).

A theoretical argument has been made that suggests that hostility represents an independent construct rather than a dimension of anger. Such theories are drawn from the fact that certain measures of the constructs have demonstrated significant psychometric evidence of distinction (Smith, Glazer, Ruiz, & Gallo, 2004). However, the empirical support has not been overwhelming, and a factor analysis of 24 different self-report measures of anger and related constructs revealed that although three distinct domains may be discerned, there is substantial overlap among hostility and anger that can not be accounted for by measurement similarities alone (Martin, Watson, & Wan, 2000). Thus, the terms anger, hostility and aggression may merely serve as convenient, heuristic labels to differentiate between the affective, behavioral and cognitive components of a single construct (LeDoux, 1994). For the purposes of the proposed research, anger is viewed as a primary construct with distinctions between the cognitive, affective, behavioral dimensions and associated anger expression styles.

Anger Expression Styles

In addition to the multiple dimensions that compose the experience of anger, there is the additional level of expression. Anger expression styles refer to the manner in which an individual expressed her/his emotional experience of anger. Spielberger et al (1995) suggested that the tendency to express one's anger in an outwardly negative manner represented an outward directed style known as anger out. Anger out may involve the use of aggressive actions (e.g., assaultive behavior, destruction of property, or making offensive gestures) and/or aggressive verbal behavior (e.g., insults, offensive/inappropriate language, or shouting). Individuals displaying the anger out style may choose targets for hostile or aggressive behavior if they are seen as even remotely related to the cause of their anger or merely by proximity when the outburst occurs (Spielberger, 1988). Conversely, the concept of anger in refers to the extent to which individuals suppress anger when they are experiencing this negative emotion (Spielberger, Ritterband, Sydeman, Reheiser, & Unger, 1995[a]). High levels of anger suppression have been found to lead to the angry feelings being suppressed and replaced with guilt, anxiety and depression as the person blames herself for the problems surrounding the anger-provoking situation (Spielberger, Ritterband, Sydeman, Reheiser, & Unger, 1995[b]).

Interaction among the dimensions of anger and anger expression style are of particular interest in the current research. According to Spielberger and colleagues (1995), individuals with a high degree of trait-like cognitive anger are more likely to have more frequent state-like experiences of affective anger. Once an individual experiences affective anger, the emotion may be expressed outwardly or repressed. Although any individual that experiences anger may employ an anger expression style, individuals with chronic, state-like anger are more likely to perceive events in a negative manner and experience anger more frequently. Therefore, these individuals will demonstrate persistent and consistent patterns of anger repression or expression and thus be vulnerable to any effects caused by the expression style. For this reason, the current research is particularly interested in the effects of the differing expression styles among those individuals with high levels of trait-like cognitive anger.

Physiological Sequelae of Anger

There have been numerous investigations into the effects of anger on physiological function (for review see Miller, Smith, Turner, Guijarro, & Hallet, 1996). The bulk of the literature in this area conceptualizes anger as an emotion induced physiological stressor, with the same physiological outcomes associated with environmental stressors (Smith, 1994). The physiological response to anger is consistent with Selye's (1976) stress model, which maintains that the body increases autonomic arousal in response to a stressor. This increase in autonomic arousal may result in increased cardiovascular activity, glucose metabolism (Carlson, 2001), and changes in patterns of cortical arousal (Andreassi, 1989; Morruzzi & Magoun, 1949). The bulk of this research has been conducted utilizing either cognitive anger (hostility) or affective (experience) anger as the variable of interest. Therefore, it is reasonable to suggest that chronic feelings of anger or the subjective experience of anger are associated with increased autonomic arousal.

There is a wealth of evidence to suggest that there are specific, predictable changes in cardiovascular functions that occur in response to anger (Demaree, Robinson, Schmeichel, & Everhart, 2003; Demaree & Everhart, 2004; Foster & Harrison, 2004; Spielberger et al., 1995). The overwhelming majority of this research indicates that anger inducement or the subjective report of anger is associated with increased systolic blood pressure and heart rate (for review, see Cox & Harrison, 2008). However, certain patterns of cardiovascular function have been found to be associated with cognitive anger (hostility). For example, Foster & Harrison (2002) found that high hostile men demonstrate increased systolic blood pressure and heart rate in response to a design fluency task and reduced heart rate and systolic blood pressure in response to a verbal fluency task. It has been proposed that the mechanism underlying such findings may be the role that the frontal lobes play in autonomic nervous system function (Lane & Jennings, 1995). For example, it has been shown that the frontal cerebral regions contribute differentially to cardiovascular reactivity, myocardial instability, and cardiac arrhythmias (Lane & Schwartz, 1987; Lane & Jennings, 1995). Furthermore, specific patterns of cardiac activation may also result from asymmetric stimulation of the structures of the right and left frontal region (Lane & Schwartz, 1987). Additionally, recent research has shown that in addition to the association between increased activation of the right anterior region and increased sympathetic tone, the differences in magnitude of cerebral asymmetries may play a large role in determining the overall changes in cardiovascular responses (Foster & Harrison, 2004).

In terms of anger expression, there have been fewer investigations into the physiological responses to anger suppression and/or anger expression. However, there has been some evidence that anger suppression, as measured by the Anger – In scale of the State – Trait Anger Expression Inventory (STAXI; Spielberger, et al, 1983) is associated with increased incidence of coronary artery disease (Yousfi, Matthews, Amelang, & Schmidt-Rathjens, 2004), increased blood pressure in response to anger provocation (DelVecchio & O'Leary, 2004), and poorer response to therapeutic interventions (Erwin, Heimberg, Schneier, & Liebowitz, 2003). Findings such as these suggest that there may be different patterns of physiological responses to anger, based on expression style.

Electroencephalograph studies examining patterns of cortical activation are frequently employed as a method of investigating the neuroanatomy underlying cognitive and behavioral constructs. The vast majority of these studies have suggested that the neuroanatomy underlying emotions is lateralized based on emotional valence (e.g. Schwartz, Davidson, & Maer, 1975) or motivational direction (e.g., Davidson, 1995; Gray, 1982). While the majority of these models have focused on the anterior brain regions, some researchers have posited anterior/posterior patterns associated with the expression and reception of emotion (Heilman & Bowers, 1990; Heller & Levy, 1981). The primary models include the right hemisphere model (Borod, Koff, & White, 1983; Heilman & Bowers, 1990), the valence model (Ehrlichman & Barret, 1983), the approach/avoidance (appetitive/aversive) model (Davidson, 1998) and the behavioral inhibition-behavioral activation (BIS/BAS) model (Gray, 1982). While all of these models contribute to the understanding of the mechanisms underlying anger, the current research is most closely associated with the BIS/BAS model. A brief review of this model is provided below to provide background for the current research.

The BIS/BAS model

The behavioral inhibition/behavioral activation model is a motivational model of emotion. Under the motivation framework, the determination of emotional experience is based on whether the emotion tends to provoke approach behaviors or withdrawal behaviors (Gray, 1982). This model proposes that emotions that tend to provoke withdrawal behaviors are associated with relative activation of the right hemisphere while emotions associated with approach behaviors are associated with relative left hemisphere activation (Davidson, 1995; Harmon Jones, Sigelman, Bohlig, & Harmon-Jones, 2003).

The BIS/BAS model proposes that although behavioral inhibition is a primary function of BIS, active avoidance of negative emotion requires some behavioral activation and may lead to initiation of the BAS system (Gray, 1982). Under this framework active inhibition (i.e., anger control) would represent behavioral activation, whereas passive avoidance would represent behavioral inhibition (Hewig, Hagemann, Seifert, Neumann, & Bartussek, 2004).

Empirical support for the BIS/BAS model has been provided by electroencephalography studies that have demonstrated that bilateral anterior cortical patterns of activation correlate with measures of BIS/BAS as predicted by the model (Harmon-Jones, 2001; Hewig, et al., 2004; Wacker, Heldmann, & Stemmler, 2003). Research in support of the BIS/BAS predictions that anger is lateralized primarily to the left hemisphere has grown with an increased number of studies indicating relative activation of the left hemisphere in response to anger provocation (Lane, Fink, & Chau, 1997). For example, Wacker et al (2003) demonstrated that relative activation patterns of the left anterior region in response to imagining a past event that elicited anger were strongly correlated with scores on measures of BAS. Building from the evidence produced by Harmon-Jones and Allen (1998) regarding the utility of resting anterior cortical activation to predict trait anger, researchers have shown that resting relative activation of the left anterior region is associated with measures of BAS and trait anger (Hewig et al., 2004). However, it has been proposed that there is a relationship between BAS and positive affect, causing some researchers to question whether the observed patterns of anterior cortical activation are due to the BAS system or positive affect (Carver & White, 1994).

Using a paradigm that either allowed participants to express their anger or force them to inhibit such expression, Harmon-Jones (2003), found that when participants are allowed to express their anger relative activation of the left anterior region results, whereas, participants forced to inhibit expression of anger demonstrate relative activation of the right anterior region. Consistent with the postulations of the BIS/BAS model, it would appear logical that the expression of anger would be considered as an approach behavior and lead to relative activation of the left anterior region, while inhibition of such behaviors would be considered withdrawal behaviors and would lead to relative activation of the right anterior region. When combined with the previously discussed findings regarding lateralized cerebral control of physiological functions, this paradigm provides a theoretical justification for investigating the physiological correlates of anger expression in terms of behavioral inhibition and/or activation.

Functional Systems

The key to the neuropsychological investigation of emotional expression lies in Luria's functional cerebral systems model (Molett, 2006), and Kinsbourne's (1978) cerebral space. The functional cerebral systems model proposes that there are specific coordinated regions of the brain that are utilized to complete certain tasks. While the original model as proposed by Luria (1973) is far too complex to thoroughly explain in this brief review, the most important feature of this model is that it moves away from the notion of strict localization and toward a more systemic view of cerebral systems. The functional systems model proposes that multiple regions in different parts of the brain may be involved in similar tasks, so while there may be evidence of diffuse activation in a given process (e.g., expressive speech), the activation patterns will be consistent for that particular activity across individuals (Luria, 1973). The idea of functional cerebral space maintains that tasks (cognitive, motor, or emotional) require utilization of cerebral resources within a given functional system. When one is performing multiple tasks, the proximity of the tasks to one another may predict decrements in performance on one of the competing tasks (Kinsbourne, 1978). The following sections provide discussion of previous findings regarding the effects of anger, as a competing task, on functional cerebral systems across the visual, auditory, and motor modalities.

Visual modality

Research has demonstrated that anger can be shown to impact visual system functioning in both the affective and cognitive domains. For example, research has shown that affective anger can negatively impact latency and accuracy on measures of facial affect recognition (Harrison & Gorelczenko, 1990; McKeever & Dixon, 1981; Reuter-Lorenz, Givins, & Moscovitch, 1983; Suberi & McKeever, 1977). Extending this line of research, Herridge, Harrison, Mollet, & Shenal (2004) found that these latency and accuracy effects can be shown to be greater for individuals scoring higher on a measure of cognitive anger (Cook-Medley Hostility Inventory; Cook & Medley, 1954) than those scoring in the lower range. Utilizing a go/no go paradigm, Maxwell, Shackman, & Davidson (2005) examined the effects of emotionally valenced faces on inhibitory processes. The results of this experiment indicated that presentation of angry faces as distractors led to increased inhibitory errors compared to happy or neutral face presentation.

Studies of clinical populations indicate that patients with brain damage of the right temporal region demonstrate significantly greater difficulty perceiving emotional valence of visual and auditory material compared to intact individuals (Adolphs, Damasio, Tranel, & Damasio, 1996). Likewise, functional studies of neurologically intact individuals have demonstrated greater recognition and discrimination of affective material presented to the right hemisphere compared to the left hemisphere in the visual, auditory, speech and motor modalities (for review see Demaree,Everhart, Youngstrom, & Harrison, 2005). Neuropsychological studies have also indicated that individuals with affective dysfunction (e.g., depression, anxiety) show impaired performance on neuropsychological measures assessing right hemisphere processes (e.g., Everhart, Harrison, Shenal, Williamson, & Wuensch, 2002; Levy, Heller, Banich, & Burton, 1983). Tachistoscopic experiments have shown that neutral faces are more likely to be judged as positive when presented to the right visual field (left hemisphere) than when presented to the left visual field (Natale, Gur, & Gur, 1983). Similarly, individuals demonstrate increased latency and accuracy when identifying "happy" faces presented in the right visual field relative to the left visual field (Reuter-Lorenz et al, 1983).

In regard to anger, the aforementioned results clearly demonstrate that negative emotions have significant impact on functions of the right hemisphere. Beyond the fact that such emotions show clear preferential patterns of cerebral activation, these results suggest that under a dual-concurrent task paradigm, functional systems of the right hemisphere are disrupted by processes related to negative emotionality.

Auditory modality

While there is less research of the effects of anger in the auditory modality, there have been some experiments that provide strong support for asymmetrical processing of affectively valenced auditory material (Demaree et al, 2005). For example, although it has been shown that individuals experiencing negative affectivity (depressive symptoms) demonstrate a significant right ear (left hemisphere) advantage for detection of tones (Tucker et al, 1981), Borod, Bloom, and Haywood (1998) found greater impairment in detecting affective prosody among individuals with right hemisphere damage than among those with left hemisphere damage. This finding suggests that, although the left hemisphere may be dominant for receptive and expressive language, emotional prosody may be a property of the right hemisphere.

Although there is limited investigation of the effect of anger on auditory processes, there have been some experimental investigations which are supportive of the lateralization hypotheses. For example, it has been shown that individuals reporting high levels of cognitive anger demonstrate a left ear (right hemisphere) advantage on a dichotic listening task while individuals reporting lower levels of cognitive anger demonstrate a relative right ear (left hemisphere) advantage on dichotic listening tasks (Demaree & Harrison, 1997). Although numerous studies utilizing the Affective Auditory Verbal Learning test (AAVL; Snyder & Harrison, 1997) have demonstrated interesting effects in terms of cortical activation and cardiovascular effects, these studies have failed to demonstrate any consistent patterns related to the affective verbal learning component in the auditory modality (Everhart, Demaree, & Harrison, 2005).

Although much more research is needed to clarify the effects of anger in the auditory modality, there is ample research to support the idea that the right hemisphere is critical for determining the prosodic elements of sound. The relationship between the affective domain of anger and auditory processes may provide a stable basis for further investigation of this sensory modality.

Motor modality

Experiments looking at the effects of emotion on gross motor function have shown significant effects. For example, it has been shown that depressed patients demonstrate significantly greater grip strength at the left hand (right hemisphere; Crews & Harrison, 1994). Although the mechanism by which the right frontal region becomes dysregulated in depression is different than in anger, the disruption of other functions of that region remains consistent.

Similar experiments have been conducted to examine the effects of anger on grip strength, with similar results. Demaree et al (2002) found decreased grip strength at the left hand (right hemisphere) and increased grip strength at the right hand (left hemisphere) among individuals reporting higher levels of cognitive anger. Other experiments have demonstrated that a higher reported level of cognitive anger is associated with reduced performance on reaction time tasks (Bolmont, Thuller, & Abraini, 2000), increased muscle tonus at the shoulder (Rugieri & Giustini, 1991), and increased activity of the corrugator muscle (Vigne, Dale, & Klions, 1988). These results provide consistent support for the effect of anger on functional systems of the right frontal region.

Summary

Although functional neuropsychological systems have become much more complicated than early localizationalists indicated, research in this area has yielded some very important findings regarding the manner in which the brain directs certain types of behavior. For example, the lateralization of verbal and visuospatial processes, although not without its detractors, has received substantial support in the literature and is frequently used to index hemispheric function (Kandel, Schwartz, & Jessell, 2000). Likewise, the importance of the posterior regions to perceptual processes (Maitlin, 1996) and the anterior regions in planning and sequencing (Stuss, 1992), are well supported and widely utilized within the field of neuropsychology.

In regard to the investigation of anger; although there are well supported findings that may provide a foundation for general hypotheses, the evidence is far from equivocal and further investigations are needed. The basic finding reviewed above, in conjunction with the aforementioned cerebral activation model, may be integrated in order to provide further evidence of the involvement of specific cerebral systems in the emotional construct of anger. In addition to supporting these previous findings, this paradigm may be utilized to advance this area of study by investigating the mechanisms underlying the concepts of “anger in” and “anger out.”

The current research investigated the effects of self-reported anger expression style on cerebrally lateralized physiological responses to a neuropsychological stressor and a painful stimulus. Specifically, this research examined changes in systole and grip strength in response to a verbal fluency task, a figural fluency task and exposure to a cold pressor. Previous research has demonstrated that the verbal fluency and figural fluency tasks are appropriate for eliciting performance-related lateralized activation (e.g., Foster et al, 2005), as verbal fluency has been shown to be a stressor for the left anterior region and design fluency has the same effect on the right anterior region (Williamson & Harrison, 2003). The application of a painful stimulus, in this case a cold pressor, has been shown to produce neuropsychological and physiological responses that are highly similar to those produced by anger, including increased autonomic nervous system arousal (Mollet & Harrison, 2006). Based on the preceding review, the following hypotheses were made regarding the outcomes from the current experiment.

Hypotheses

1) Participants' performance on the fluency tasks was predicted to differ based on anger expression style.
    a. It was predicted that participants reporting a repressive "anger-in" style would perform more poorly on a design fluency task compared to participants reporting an expressive "anger out" style.

    b. It was predicted that participants reporting an expressive "anger-out" style would perform more poorly on a verbal fluency task compared to participants reporting a repressive "anger in" style.

    c. It was predicted that participants reporting a repressive "anger in" style would commit more perseverative errors on a non-verbal fluency task compared to participants reporting an expressive "anger out" style.

    d. It was predicted that participants reporting an expressive "anger out" style would commit more perseverative errors on measures of verbal fluency compared to participants reporting a repressive "anger in" style.

2) Systolic blood pressure and heart rate were predicted to differ in response to a neuropsychological stressor based on anger expression style.

    a. It was predicted that, although participants in both groups would demonstrate increased systolic blood pressure and heart rate in response to a non-verbal fluency task, participants reporting a repressive "anger-in" style would demonstrate significantly greater increases in these cardiovascular measures compared to participants reporting an expressive "anger out" style.

    b. It was predicted that participants reporting an expressive "anger-out" style would show increases in systolic blood pressure and heart rate in response to a verbal fluency task.

c. It was predicted that participants reporting a repressive “anger in” style would show decreased heart rate and blood pressure in response to a verbal fluency measure

3) Grip strength was predicted to differ based on subjective report of anger expression style.

a. It was predicted that although participants in both groups would demonstrate increased grip strength at the left hand in response to the cold pressor, participants reporting a repressive “anger-in” style would demonstrate a significantly greater increase in left hand grip strength, compared to participants reporting an expressive “anger-out” style.

Methods

Participants

Participants were recruited from the undergraduate psychology population of a large public University located in the mid-Atlantic region of the United States. Participants completed an online pre-screening that included an Informed Consent Form, a Medical History Questionnaire, the Coren, Porac, and Duncan Laterality Questionnaire (Coren, Porac, & Duncan, 1979), the Cook Medley Hostility Scale (Cook & Medley, 1954), and the State-Trait Anger Expression Inventory (Spielberger et al, 1989). Participants reporting left hand dominance, a history of brain-related insult (e.g., stroke seizure, traumatic brain injury, etc.), use of psychotropic medications or significant physical, or mental health difficulties that would prohibit or limit their participation in this research were excluded. Additionally, to continue to the experimental phase, participants had to score 29 or above on the Cook Medley Hostility Scale, and demonstrate a significant elevation (>70th percentile) on one or both of the anger expression scales on the STAXI. Individuals participating in this initial screening were awarded one course credit point for their participation.

Of the 377 students that completed the online screening, 62 met criteria for inclusion in the experimental phase and were scheduled for follow-up testing. Among those not included in the experimental phase, most were excluded for not meeting scoring criteria on the Cook Medley Hostility Scale (n=256), or the State Trait Anger Expression Inventory (n=97) others were excluded for medical or psychiatric conditions (n=5), on the basis of handedness (n=3) or sex (n=2). Data were excluded from participants whose scores differed significantly between the screening assessment and the second administration. Specifically, individuals that scored in the upper one-third of scores on the CMHI during the online screening but scored significantly lower at the follow-up assessment were not included in the experimental phase (n=9). Data were also excluded for a subset of participants that demonstrated significant elevations on both anger expression scales (n=5). The final analysis included 56 high hostile men between the ages of 18-24 (M=19.50, SD=1.50). Participants received an additional course credit point for their participation in the experimental phase.

Materials

Questionnaires

To ensure that medical and psychiatric conditions that may impede the participants' ability to complete this experiment or interfere with the interpretation of results of this experiment; general health was assessed using a brief inventory designed for use in neuropsychological research (Crews, 1998; Appendix B). As previous research has suggested emotional processing laterality may differ based on sex and handedness (Heller & Levy, 1981), only right-handed men were selected. The Coren-Porac-Duncan Laterality Test (CPDLT; Coren, Porac, & Duncan, 1979), which was utilized to determine laterality, has demonstrated particular utility in neuropsychological research and is consistent with previous research conducted in this area (Foster, Williamson, & Harrison, 2005).

As previous research from this laboratory has demonstrated self reported level of cognitive anger is positively associated with physiological responses to stress, the current experiment selected only participants reporting higher levels of cognitive anger. Cognitive anger was assessed using the Cook-Medley Hostility Inventory (CMHI; Cook & Medley, 1954). The CMHI is a self-report questionnaire purported to tap cynicism, anger, suspiciousness, and resentment in the hostility construct (Smith & Frohm, 1985). The scale consists of 50 true false items and has been the most widely used measure of hostility in physiological research (Dembroski & Costa, 1987). Numerous studies have demonstrated very good internal consistency estimates (□=.84) and stability coefficients (1-year = .85; 4-year= .84; Smith & Frohm, 1985). The CMHI demonstrates adequate discriminant validity (depression = .38; anxiety = .26) and good convergent validity (cynicism = .75; anger = .61; Hardy & Smith, 1988). Its validity as a predictor of medical and psychological outcomes has made it one of the more commonly used measurements of hostility (Contrada & Jussim, 1992). The success of this instrument in measuring hostility in previous research (Demaree & Harrison, 1997; Herridge, Harrison, & Demaree, 1997; Harrison & Gorelczenko, 1990; Davis, Matthews, & McGrath, 2000, Larkin, Martin, & McClain, 2002; Shapiro et al., 2000) demonstrates that it is a valid measure.

Consistent with previous research from this laboratory, the highest one-third of scores on the CMHI were considered to be indicative of high levels of cognitive anger (Harrison & Gorelczenko, 1990; Demaree & Harrison, 1997; Demaree et al., 2002; Williams & Harrison, 2003). Among participants who completed the online screening and met other criteria, scores over 29 were the found to be in the upper one-third. Therefore, as the current experiment was focused on individuals with higher levels of cognitive anger, participants with CMHI scores of 29 or higher were retained for the remainder of the experiment.

The State-Trait Anger Expression Inventory (STAXI; Spielberger et al., 1983), used to assess anger expression style, is the only available measure that allows investigation of transient (state) anger expression (anger out) and anger inhibition (anger in) congruent with the aims of the proposed research. This measure has been used extensively in neuropsychological studies of anger and demonstrates excellent internal consistency (α=.90; Eckardt et al, 2004). The anger in and anger out scales used in the current experiment have yielded good internal validity estimates (α=.86).

In order to compare anger expression styles, participants were placed in groups based on STAXI scores on the anger in scale (AIS) and anger out scale (AOS). Cutoff scores for group inclusion were determined using clinical norms on the expression scales (AIS > 70^{th} percentile = anger in; AOS > 70^{th} percentile = anger out). As individuals did not cleanly fit into an expression category due to both scales being elevated above the 70^{th} percentile, individuals were grouped according to their highest elevation. For example, a participant scoring at the 73^{rd} percentile on the anger in scale and the 95^{th} percentile on the anger-out scale would be placed in the anger out group. Assessment of anger expression style at the follow up assessment revealed unequal distribution of participants scoring higher on the anger in (n=33) and anger out (n=28). A total of 17 participants demonstrated clinically significant elevations on both expression scales and were distributed between the anger in (n=12) and anger out (n=5) groups. To maximize between group comparability, data were excluded from a subset of these participants showing elevations on both expression scales (n=5). Final grouping resulted in an equal distribution of participants in both anger in (n=28) and anger out groups (n=28) with roughly equivalent distribution of individuals demonstrating significant elevations on both scales with primary elevations on the anger in scale (n=7) or the anger out scale (n=5).

Neuropsychological Measures

The Controlled Oral Word Association Test (COWAT; Spreen & Benton, 1977) was administered to assess verbal fluency. This test is purported to be one of the most sensitive measures of left anterior cerebral function (Miceli, Caltagirone, Gainotti, Masullo, & Silveri, 1981). The COWAT represents the most common measure of verbal fluency used in neuropsychological assessment and one of the most frequently used neuropsychological measures used in research. This measure requires generation of words based on initial letter. The COWAT has demonstrated excellent interrater reliability (.95), good retest reliability (1-year= .70) and excellent alternate forms validity (.91 for the FAS-CFL versions; Spreen & Strauss, 1999). The COWAT has shown adequate convergent validity with other measures of executive function (with Wechsler Adult Intelligence Scales; mathematics = .34; digits backward = .49 and the Trail Making Test, form B = .52; Long, Matchnick, & Ross, 1991).

Consistent with previous research (Everhart & Harrison, 2002; Williamson & Harrison, 2003; Williamson, Harrison, & Walters, 2006), the proposed experiment utilized a modified version of the COWAT. The letters F, S, and T were used based on normative data that indicates intact individuals tend to produce an equal number of responses for each letter (approximately 11-12 words per minute; Walters, Mollet, & Harrison, 2006).

The Ruff Figural Fluency Test (RFFT; Ruff, Light, & Evans, 1987), which has been shown to be a valid measure of right anterior cerebral functions (e.g., Foster & Harrison, 2004) and has been used in a number of neuropsychological research paradigms investigating laterality (Williamson & Harrison, 2003; Williamson, et al, 2006) was used as the measure of nonverbal fluency. Statistical analyses have revealed high inter-rater reliability for both the RFFT in terms of both novel output (.99) and perseverative errors (.99). Convergent validity of the RFFT has been indicated through associations with other measures of non-verbal executive function such as the Stroop Color-Word Test (.86) and the Design Fluency Test (.91; Sands, 1998). The RFFT demonstrated divergent validity with measures assessing posterior cerebral function (e.g., Judgment of Line Orientation = .17 and Facial Recognition = .09; Spreen & Strauss, 1998). In order to improve comparability with the verbal fluency measure, only the first three sheets of the RFFT were utilized. This modification is consistent with previous research from this laboratory (Williamson, et al, 2006).

Apparati

The Norelco Healthcare Electronic Digital Blood Pressure/Pulse Meter (Model HC3030; Norelco Health Group Inc.: New York) was used to provide an oscillometric measure of systolic blood pressure and heart rate. This instrument has been shown to demonstrate adequate accuracy and reliability in empirical comparison trials (Harrison & Kelly, 1987).

A Lafayette hand dynamometer (Model 79011; Lafayette Instrument Company: Lafayette, Indiana) was utilized to assess grip strength. The dynamometer assesses grip strength ranging from 0-100 kg and has been used extensively in clinical and research applications. The normative data for this instrument suggests that it represents a reliable and valid method of assessing grip strength among individuals over the age of 5 years (Layfayette Instrument Company, 1992). The dynamometer was set to a fixed adjustment of 2.54 cm for the average adult male.

Cold Pressor: Ice water for the cold pressor was maintained at 0-3 degrees Celsius using a 12-gallon Igloo ice cooler. Water temperature was measured using a mercury thermometer. The cooler was located in proximity to the participant's left arm, adjusted at a height that allowed the participant to submerge his arm up to the elbow without changing posture so as to impact heart rate or blood pressure.

Procedure

Participants meeting full criteria on the online screen were contacted to participate in the experimental phase and an appointment was made at that time. Upon arrival, all participants completed an Informed Consent Form and were given the opportunity to ask investigators questions regarding the procedures prior to completing the initial screening form. Participants were informed that the purpose of the experiment was to investigate physiological responses to a neuropsychological task and a cold pressor task. Individuals then completed all of the measures that comprised the online screening again to ensure accuracy (Medical History Questionnaire, CPDLT, CMHI, and STAXI).

Baseline systolic blood pressure and heart rate data were then collected from participants in accordance with previous procedures used in this laboratory (Demaree &

Harrison, 1997; Harrison & Kelly, 1987; Williamson, et al, 2006). Participants were instructed to sit with eyes closed, arms and legs partially extended with the arms supported and positioned at the fourth intercostal space with their palms facing up. Brachial artery location was determined by palpation and the cuff was placed on the upper left arm over the brachial artery and 2.5 cm above the antecubital space. Participants then received the following instructions: "Please open your eyes and take one minute to become accustomed to your surroundings." At the end of one minute the measurement procedures began. If consecutive measures failed to meet reliability criteria (less than 20 mmHg for SBP and a difference of 10 or less beats per minute for HR), additional measurements were taken until criteria was achieved.

Following the baseline physiological measurements, participants completed measures of either verbal or figural fluency (Controlled Oral Word Association Test COWAT; Benton, Hamsher & Sivan, 1983; Ruff Figural Fluency Test, RFFT; Ruff, 1996). Immediately following completion of the fluency measure participants' blood pressure and heart rate were taken as measures of physiological reactivity to the task. Following the first neuropsychological measure, participants completed the converse measure. Following completion of the second fluency test, blood pressure and heart rate data were obtained utilizing the method described above. Neuropsychological test administration was counterbalanced to control for any possible order effects.

Participants were given a 3-minute rest period before beginning the second part of the experiment. Following this rest period, baseline grip strength measures were obtained from each participant. Baseline grip strength was the mean of measures gathered across 5 consecutive trials. Participants received the following instructions:

"I would like to see how hard you can squeeze this handle. When I say go, please squeeze as hard as you can until I say stop. Place your forearm on the table and when you squeeze, please use only the muscles that you would normally use to squeeze something. Do not change your body posture or attempt to use your shoulder or chest muscles"

Prior to the trial, the investigator demonstrated the method for the participant. For all trials, the dynamometer needle was reset to zero and grip strength recorded in kilograms. The measurement scale was directed away from the participants' view to prevent performance feedback.

Following collection of the baseline data, the participants were exposed to the cold pressor. The cold pressor was introduced by the experimenter instructing the participant to place his left hand in a container of ice water up to the elbow and to leave it there for 30 seconds. Once the participant had removed his hand from the ice water, the experimenter towel dried the extremity. Grip strength was reassessed using the mean of five consecutive trials as described above.

Treatment of the Data

Questionnaire Data

Separate t-tests were conducted to compare group scores on the Coren, Porac, and Duncan Laterality Questionnaire (Coren, Porac, & Duncan, 1979), to insure there were no significant preexisting differences in regard to laterality scores. These same procedures were utilized to determine within group comparability on the Cook Medley Hostility Scale (Cook & Medley, 1954), baseline measures of systolic and diastolic blood pressure, and baseline heart rate.

Neuropsychological Data

The effects of group membership (anger-in or anger-out) on fluency performance were assessed using a two-factor mixed design ANOVA with the fixed factor of Anger Expression Group (Anger-in; Anger-out; Anger-neutral) and fluency measure (Design Fluency; Verbal Fluency). Specific elements of performance on these measures (perseverations) were examined in a separate two-factor mixed design ANOVA with the fixed factor of anger expression style and fluency measure.

Cardiovascular Data

Separate mixed design ANOVAs were conducted to investigate the effects of anger expression style on systolic blood pressure and heart rate as a function of each cognitive stressor (COWAT, RFFT). The following factors were included in separate ANOVAs of systolic blood pressure and heart rate: fixed effects of group (Anger-in; Anger-out) and the repeated measure of Condition (pre and post cognitive stressor).

Grip Strength Data

To examine the main effects of group membership on grip strength, a mixed design analysis of variance was performed. The analysis consisted of the fixed effect of Group (Anger-in; Anger-out) by the repeated measure of Condition (Pre-stressor; Post-stressor).

Interaction Effects

As the statistical package used to analyze these data does not provide a method for conducting multiple comparison tests on significant interaction effects, post hoc analyses were conducted using paired-sample t-tests of all possible pairs. To control for the increased risk of Type I errors associated conducting with multiple t-tests, and to reduce the elevated risk of Type II errors created by the use of a standard Bonferroni correction, Holm's sequential Bonferroni correction was utilized. This adjustment sets the significance level for first order comparisons at .0125, and second order comparisons at .016.

Results

Comparability of Groups

Anger expression groups did not differ in terms of laterality preferences (CPDLT; t = .153, 53, p = .879), reported smoking (Fagerstrom; t = .-537, 54, p = .593), CMHI scores (.769, 53, p = .445), baseline systolic blood pressure (t = .177, 54, p = .860), diastolic blood pressure (t = 1.122, 54, p= .267), heart rate (t = .634, 53, p=.529), or grip strength (t = .671, 53, p =.505). Mean values for baseline measures are presented in Table 1.

Neuropsychological Findings

Contrary to the prediction made in hypothesis 1, baseline measures of fluency did not vary significantly between anger expression style groups. The mean fluency scores are shown in Table 2. A significant main effect for the within subjects variable of measure was found (F (1, 54) = 125.86, p = .000). See Table 3. No main effect for anger expression style (F (1, 54) = 2.59, p = .113) was found. See Table 4. There were no significant interactions of fluency measure and anger expression style (F (1,54) = 2.69, p =.106).

Specific elements of performance, as measured by number of perseverations on the fluency measures, were found to differ between anger expression groups. Mean perseveration on the neuropsychological measures are presented in Table 5. A main effect for the within group variable of perseveration was found (F (1, 54) = 8.57, p =.05). No main effect was found for the between group variable of group (F (1, 54) = .29, p = .59). A significant group by measure perseveration interaction effect was found (F (1, 54) = 11.00, p = .002). Multiple comparisons conducted on this data showed that participants in the anger in group made significantly more perseverative errors on the RFFT, compared to the COWAT (t (27) = -4.56, p = .000). Conversely, participants in the anger out group did not demonstrate significant differences in terms of the number of perseverations on these fluency measures (t (27) = .268, p = .791). The ANOVA values are presented in Tables 5 and 6.

Cardiovascular Findings

Systole

Consistent with the prediction made in hypothesis 2, systolic blood pressure varied significantly as a function of anger expression style. Mean systolic blood pressure values are presented in table 7. ANOVA 1 examined the effects of verbal fluency on systolic blood pressure. No significant main effect of trial (F (1, 54) = .94, p = .34) or anger expression style (F (1, 54) = .937, p = .34) was found. However, there was a significant interaction of trial and anger expression style (F (1, 54) = 10.89, p = .02). Multiple comparisons of the interaction effects showed that participants in the anger out expression style group demonstrated significantly higher systolic blood pressure following the completion of a verbal fluency measure (t (27) = -2.718, p = .011). Conversely, individuals in the anger out group demonstrated a non-significant decrease in systolic blood pressure following completion of the COWAT (t (27) = 1.88, p = .07). ANOVA results are presented in Tables 8 and 9.

The second ANOVA examined the effects of a non-verbal fluency measure on systolic blood pressure. Main effects were found for trial (F (1, 54) = 16.67, p = .000) and group (F (1, 54) = 4.30, p = .04). Additionally, a significant trial by group interaction effect was found (F (1, 54) = 54.47, p = .000). Multiple comparisons of the interaction effect showed that participants in the anger in group demonstrated significant increases in systolic blood pressure (t (27) = 6.92, p = .000) and individuals in the anger out group demonstrated significant decreases in systolic blood pressure (t (27) = 4.10, p = .000). ANOVA values are shown in Tables 10 and 11.

Heart Rate

As predicted in the hypotheses, these data demonstrated significant changes in heart rate in response to completion of fluency measure based on anger expression style. Mean heart rate values are shown in table 12. The first ANOVA examined the effects of the verbal fluency measure on heart rate. No significant main effect was found for trial (F (1, 54) = 1.74, p = .193) or anger expression style (F (1, 54) = .048, p = .83). However, there was a significant trial by group interaction effect (F (1, 54) = 5.89, p = .02). Multiple comparisons of this interaction indicated that participants in the anger in expression style group demonstrated non-significant reductions in heart rate (t (27) = 1.09, p = .28). Conversely, participants in the anger out group demonstrated a non-significant increase in heart rate following the completion of a verbal fluency measure (t (27) = 2.71, p = .03). ANOVA results are presented in Tables 13 and 14.

The second ANOVA examined the effects of a non-verbal fluency measure on heart rate. Main effects were found for trial (F (1, 54) = 13.29, p = .001) and group (F (1, 54) = 7.34, p = .009). Additionally, a significant trial by group interaction effect was found (F (1, 54) = 57.12, p = .000). Multiple comparisons of the interaction effect showed that participants in the anger in group demonstrated significant increases in heart rate (t (27) = -7.33, p = .000). Conversely, individuals in the anger out group demonstrated significant decreases in systolic blood pressure (t (27) = 3.03, p = .005). ANOVA values are presented in Tables 15 and 16.

Grip Strength

Consistent with the prediction made in hypothesis 2, grip strength varied significantly as a function of anger expression style. Mean grip strength values are presented in Table 17. A significant main effect was found for trial (F (1, 54) = 35.31, p = .000) and group (F (1, 54) = 4.04, p = .05). Additionally, there was a significant trial by group interaction effect (F (1, 54) = 13.68, p = .001). Multiple comparisons of the interaction effects showed that participants in the anger in expression style group demonstrated significantly increased grip strength at the left hand following exposure to the cold pressor (t (27) = 5.82, p =.000). Conversely, individuals in the anger out group demonstrated a non-significant increase in grip strength following exposure to the cold pressor (t (27) = 2.04, p = .05). ANOVA values are shown in Table 18.

DISCUSSION

The results of the current experiment provide mixed support of the a priori hypotheses. In regard to performance differences on neuropsychological measures based on anger expression style, the current experiment did not find any significant differences between anger expression style groups in overall scores on the measures of fluency as predicted in the hypotheses. However, consistent with predictions made in the hypotheses, perseverative errors on the fluency measures differed significantly between groups. In terms of cardiovascular functions, this experiment provided support for the hypothesis that participants' systolic blood pressure and heart rate responses to neuropsychological stressors would differ based on reported anger expression style. These data were also supportive of the hypothesis that left hand grip strength would increase in response to the cold pressor.

Patterns of performance on the neuropsychological measures, in terms of perseverative errors (a measure of cognitive efficiency), in this experiment were supportive of the prediction that perseverative errors on the fluency measures would vary as a result of anger expression style. Specifically, this experiment demonstrated that participants in the anger in group committed more perseverative errors on measures of non-verbal fluency, while those in the anger out group committed more perseverative errors on measures of verbal fluency. These results may be best explained under the capacity framework described in the quadrant model in conjunction with the proposed model of anger expression. Under this framework the repressive "anger in" style, as an avoidant emotional state, calls upon resources of the right frontal region and the figural fluency task represents a cognitive stressor to this same region. This competition would account for the decreased performance on the figural fluency task among anger repressive participants. Conversely, the expressive "anger out" style, as an approach emotional state, calls upon resources of the left frontal region and the verbal fluency task represents a cognitive stressor to this same region, resulting in decreased performance on this task due to competition for cerebral resources.

Hypotheses regarding cardiovascular responses to neuropsychological stressors were supported by the current experiment. Significant interactions between anger expression styles and cardiovascular responses were found for both verbal and non-verbal measures. For example, participants reporting an expressive "anger out" style demonstrated a significant increase in systolic blood pressure and a non-significant increase in heart rate following administration of the verbal fluency task, while participants reporting a repressive "anger in" style demonstrated non-significant decrease in these cardiovascular responses. Conversely, participants reporting a repressive "anger in" expression style demonstrated significant increases in systolic blood pressure and heart rate following a measure of non-verbal fluency, while participants reporting an outward anger expression style demonstrated significant decreases in systolic blood pressure and heart rate to the same neurocognitive stressor.

These data are also consistent with the quadrant model and the anger expression model employed in this experiment. Among individuals reporting an expressive "anger out" style, the model predicts greater utilization of left frontal resources (consistent with behavioral activation). The additional stressor of a verbal fluency measure would provide further competition for these frontal resources, causing significant activation of the left frontal area. The concept of balance in the quadrant model predicts that significant activation of the left frontal region may lead to compensating deactivation of the right frontal region. As cardiac control has been linked to the right frontal region (Wittling, 1995) deactivation of this region would logically be expected to result in dysregulation of cardiovascular responses. Conversely, among individuals reporting a repressive "anger in" style, the left frontal activation produced by verbal fluency tasks is not competing for resources with the individuals' anger expression style. Therefore, the frontal regions are balanced and the available right frontal resources to allow for greater capacity to attend to cardiovascular regulation, resulting in a decrease in systolic blood pressure and heart rate.

Similarly, the cardiovascular responses to the non-verbal fluency measure among individuals reporting a repressive "anger in" expression style demonstrate similar support of the balance and competition elements of the quadrant model. The anger expression model predicts greater utilization of right frontal resources (consistent with behavioral inhibition) for the repressive "anger in" anger expression style. The additional stressor of a non-verbal fluency measure would provide competition for these frontal resources, resulting in increased right frontal activation. This right frontal activation is in direct competition for the right frontal resources utilized for cardiovascular regulation. Therefore, significant increases in systolic blood pressure and heart rate in this condition are congruent with the predictions of the model.

In terms of grip strength, this experiment provided support for the hypothesis that participants reporting the "anger in" expression style would demonstrate significantly greater increases in grip strength at the left hand following exposure to the cold pressor, compared to those participants endorsing an "anger out" style. However, these data do not show the same pattern of interaction seen in the cardiovascular data. Although grip strength at the left hand showed a significantly greater increase among subjects in the anger in group following exposure to the cold pressor, it increased for participants in both the anger in and anger out groups.

Consistent with the other findings of this experiment, these data demonstrate the effects of balance and competition as described in the quadrant model. Once again, calling on the balance element of the quadrant model, grip strength increases in response to the cold pressor can be explained. Increased activation of the left frontal region, in result to the painful stimulus, may result in decreased activation at the right frontal region, creating a lack of inhibitory function as evidenced by increased grip strength at the left hand. As described previously, the proposed anger expression model would predict significantly greater increases in grip strength among individuals expressing a repressive “anger in” style as the tasks are directly competing for the same right frontal resources.

Not all of the predictions made in the a priori hypotheses were supported by the results of this experiment. In particular, predictions regarding overall score differences on the neuropsychological measures and the prediction that both anger expression groups would demonstrate systolic blood pressure and heart rate increases in response to a neuropsychological stressor were not supported

Although there was a significant difference in overall scores between the measures themselves, group membership did not have a significant effect on overall scores. Interestingly, individuals with a repressive “anger in” style tended to score somewhat lower on measures of figural fluency than on verbal fluency measures while individuals with an expressive “anger out” style tended to score marginally lower on measures of verbal fluency than on measures of figural fluency. Furthermore, individuals in the “anger in” group scored somewhat lower on measures of figural fluency compared to individuals in the “anger out” group. Conversely, participants in the “anger out” group score marginally higher on measures of verbal fluency compared to participants in the “anger out” group. Although these results were not significant, they are consistent with the significant findings related to perseverative errors on these measures. Together these findings may be viewed as supportive of the anger expression model with performance decrements lateralized in accordance with anger expression style.

The data regarding cardiovascular responses to the non-verbal fluency measure among participants reporting an expressive "anger out" style are not readily interpreted under the framework of the quadrant model. One possible explanation for these results that would be congruent with the quadrant model involves the element of balance. It may be that individuals with an expressive "anger out" style have a greater capacity for design fluency tasks and therefore, do not process this task as a cognitive stressor. Although there may be competition for right frontal resources by the design fluency task and cardiovascular control, the left frontal region is not activated (as the task is not stressful to this group, there is no activation of this region) and can balance the heightened activity of the right frontal region, allowing for greater control of cardiovascular functions.

Overall, the current experiment was supportive of the proposed anger expression theory within the larger context of the quadrant model. The elements of competition and balance, as described in the literature review, can be viewed as accounting for the bulk of the findings reported here. Direct competition for right frontal resources such as non-verbal fluency, muscular control of the left extremities, and regulation of systolic blood pressure demonstrated significant dysregulation among participants reporting a repressive "anger in" expression style. Direct competition may also be shown to cause individuals reporting an expressive "anger out" style reduced efficiency in verbal fluency, as measured by perseverative errors. These results further suggest that hemispheric balance may provide the clearest explanation of the dysregulation of cardiovascular control and left hand grip strength among individuals reporting an expressive "anger out" style in this experiment.

The results of the current experiment may have important implications for the assessment and treatment of anger and anger-related disorders. For example, the finding that neurocognitive tasks may increase physiological responses (arousal) suggests that, among certain populations, these instruments may represent cognitive stressors that increase the likelihood of experiencing anger, rather than unbiased measures of cognitive functioning. In terms of treatment, these results may be amenable to use in treatment planning. For example, if individuals with a repressive anger expression style demonstrate decreased physiological responses to verbal fluency tasks, it is possible that treatment for this subset of individuals may benefit from some mechanism that allows them to verbalize their anger. Conversely, as verbal fluency seems to increase physiological arousal among individuals reporting an expressive anger expression style, therapy might be better served by decreasing verbal content and increasing mental imagery. Certainly, there needs to be more research in this area before these results can be realistically interpreted in terms of practical applications however, given the limited efficacy in the treatment of anger and anger-related disorders, the importance of this line of research should be considered.

The current experiment was not without limitations. The inclusion of individuals that demonstrated significant elevations on both anger expression scales may have reduced the clarity of the results of this experiment. Although the bulk of the a priori hypotheses were supported in this experiment, future research should more clearly define anger expression groups to limit potential contamination of the results. Additionally, future research in this area should be conducted utilizing a more diverse and representative sample. Although previous research does indicate that sex and handedness can impact lateralized functions, there is little research into the effects of education, age, and ethnicity on such tasks. In regard to sample heterogeneity, the findings here apply only to those individuals reporting higher levels of cognitive anger. In order to fully investigate the role that anger expression style may play in the findings of cerebral lateralization studies (e.g., Davidson, 1998; Harmon-Jones et al, 2003), future experiments should be designed to examine these differences across levels of cognitive anger.

One of the more controversial limitations of the current experiment, and the bulk of empirical investigations of anger, is how to determine to what degree investigators can be certain that the stressor is eliciting an anger response. The current experiment utilized neuropsychological stressors that have been previously shown to elicit angry responses from high hostile individuals. However, debates over the certainty that the emotional responses are anger rather than frustration, anxiety, or even depression are cause for some caution. Similarly, the use of the cold pressor cannot be shown to elicit anger rather than pain. Although there is strong evidence that pain and anger utilize similar functional systems, there remains much debate over the appropriateness of this technique.

The implication of this paradigmatic limitation to the current experiment is that the results reported as supportive of the quadrant model may be interpreted in a completely different manner. It is possible that the experimental paradigm resulted in conditions that created homogeneity of the anger expression style. Although participants completed a valid measure of his anger expression style, individuals with an expressive "anger out" style were not explicitly given the opportunity to employ that style during the experimental phase. An alternative explanation for the results of this experiment may be that across all participants, a repressive anger style was employed, resulting in the described right frontal dysregulation. This potential confound could easily be corrected in future research by querying participants as to their reactions to the stressors throughout the experiment. This addition to the protocol would give participants the opportunity to activate primary anger expression styles in response to the immediate stressor.

Finally, future investigations of anger need to provide greater focus into the role of the posterior cerebral systems. Although the results of this experiment demonstrate a clear relationship between frontal regions and anger expression styles, the potential contributions of posterior cerebral systems are not addressed. In particular the potential role and neuroanatomical underpinnings of the right posterior region in relation to perception of anger and the left posterior region in relation to cognitive appraisals, and how these systems may be related to anger expression warrants further investigation.

Given the clear association between anger and negative physical health outcomes (e.g., cardiovascular disease, increased risk for cerebrovascular accident, metabolic syndrome, and hypertension), there is a clear need to better understand the physiological components of this emotion. The results of this experiment indicate that a repressive "anger in" expression style is associated with dysregulation of the right frontal region. This same region has been shown to be intimately involved in cardiovascular recovery, glucose metabolism, and blood pressure regulation.

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Table1. Means and Standard Deviations for CPDLT, Fagerstrom, CMHS, Systole, Diastole, Heart Rate, Grip Strength

Measure	Anger Expression Style	N	Mean	Standard Deviation	Standard Error
CPDLT	In	28	9.39	1.59	3.01
	Out	28	9.32	1.88	3.57
Fagerstrom					
	In	28	.25	.52	.10
	Out	28	.32	.48	.09
CMHS					
	In	28	34.46	2.80	.53
	Out	28	33.93	2.40	.45
Systole					
	In	28	128.36	6.69	1.26
	Out	28	128.04	6.87	1.30
Diastole					
	In	28	70.00	3.78	.72
	Out	28	68.79	4.30	.81
Heart Rate					
	In	28	73.57	2.73	.52
	Out	28	73.11	2.75	.52
Grip Strength					
	In	28	19.21	4.39	.83
	Out	28	18.39	4.76	.90

Table 2: Means and Standard Deviations for RFFT and COWAT

Measure	Anger Expression Style	N	Mean	Standard Deviation	Standard Error
RFFT					
	In	28	39.00	15.12	2.63
	Out	28	48.93	13.58	2.48
PFFT Perseverations					
	In		.54	.74	.14
	Out		1.21	.88	.17
COWAT					
	In	28	46.36	4.86	.92
	Out	28	45.86	5.20	.98
COWAT Perseverations					
	In	28	1.68	.94	.18
	Out	28	1.14	.80	.15

Table 3: ANOVA Table for Neuropsychological Measures Within Groups Test

Effect	df	Means Square	F	P	Observed Power
Measure	1	5700.09	125.83	.000	1.00
Measure by Group	1	122.22	2.69	.106	.365
Error	54	45.30			

Table 4: ANOVA Table for Neuropsychological Measures Between Groups Test

Effect	df	Means Square	F	P	Observed Power
Measure	1	317476.51	11668.21	.000	.995
Measure by Group	1	70.72	2.60	.113	.354
Error	54	27.21			

Table 5: ANOVA Table for Perseverations on Neuropsychological Measures Within Groups Test

Effect	df	Means Square	F	P	Observed Power
Measure	1	8.04	8.57	.05	.820
Measure by Group	1	10.32	11.06	.002	.903
Error	54	45.30			

Table 6: ANOVA Table for Perseverations on Neuropsychological Measures Between Groups Test

Effect	df	Means Square	F	P	Observed Power
Intercept	1	146.28	297.29	.000	1.00
STAXI Rate	1	.14	.29	.59	.08
Error	54	.49			

Table 7: Means and Standard Deviation for Post Fluency Systole, Diastole, and Heart Rate

Measure	Anger Expression Style	N	Mean	Standard Deviation	Standard Error
COWAT Systole	In	28	126.89	7.55	1.43
	Out	28	130.71	7.48	1.41
COWAT Diastole					
	In	28	70.11	3.66	.69
	Out	28	68.93	4.04	.76
COWAT Heart Rate					
	In	28	72.61	4.19	.64
	Out	28	73.39	3.20	.51
RFFT Systole					
	In	28	133.57	7.05	1.33
	Out	28	126.54	6.79	1.28
RFFT Diastole					
	In	28	70.18	3.57	.68
	Out	28	69.25	4.17	.79
RFFT Heart Rate					
	In	28	73.29	4.19	.79
	Out	28	72.79	3.20	.61

Table 8: ANOVA Table for COWAT Systole Within Groups Test

Effect	df	Means Square	F	P	Observed Power
Time	1	10.32	.94	.34	.158
Time by Group	1	120.43	10.89	.02	.900
Error	54	11.02			

Table 9: ANOVA Table for COWAT Systole Between Groups Test

Effect	df	Means Square	F	P	Observed Power
Intercept	1	924686.00	20214.74	.000	1.00
STAXI Rate	1	42.88	.937	.34	.158
Error	54	45.74			

Table 10: ANOVA Table for RFFT Systole Within Groups Test

Effect	df	Means Square	F	P	Observed Power
Time	1	96.57	16.67	.000	.980
Time by Group	1	315.57	54.47	.000	1.00
Error	54	5.79			

Table 11: ANOVA Table for RFFT Systole Between Groups Test

Effect	df	Means Square	F	P	Observed Power
Intercept	1	933702.88	21210.00	.000	1.00
STAXI Rate	1	189.45	4.30	.043	.531
Error	54	.492			

Table 12: ANOVA Table for COWAT Heart Rate Within Groups Test

Effect	df	Means Square	F	P	Observed Power
Time	1	3.22	1.74	.193	.253
Time by Group	1	10.94	5.89	.019	.664
Error	54	1.86			

Table 13: ANOVA Table for COWAT Heart Rate Between Groups Test

Effect	df	Means Square	F	P	Observed Power
Intercept	1	299812.61	39849.39	.000	1.00
STAXI Rate	1	.362	.048	.827	.055
Error	54	.492			

Table 14: ANOVA Table for RFFT Heart Rate Within Groups Test

Effect	df	Means Square	F	P	Observed Power
Time	1	15.01	13.29	.001	.947
Time by Group	1	64.51	57.12	.000	1.00
Error	54	1.13			

Table 15: ANOVA Table for RFFT Heart Rate Between Groups Test

Effect	df	Means Square	F	P	Observed Power
Intercept	1	304218.86	41132.89	.000	1.00
STAXI Rate	1	55.00	7.34	.009	.764
Error	54	7.40			

Table 16: Means and Standard Deviations for Post Cold-Pressor Grip Strength

Measure	Anger Expression Style	N	Mean	Standard Deviation	Standard Error
Grip Strength					
	In	28	23.36	4.92	.74
	Out	28	19.39	4.97	.79

Table 17: ANOVA Table for Grip Strength Within Groups Test

Effect	df	Means Square	F	P	Observed Power
Time	1	182.58	35.31	.000	1.00
Time by Group	1	70.72	13.68	.001	.953
Error	54	5.17			

Table 18: ANOVA Table for Grip Strength Between Groups Test

Effect	df	Means Square	F	P	Observed Power
Intercept	1	22580.36	1122.24	.000	1.00
STAXI Rate	1	81.36	4.04	.049	.506
Error	54	20.12			

Figure 1: Perseverative Errors, Group by Measure Interaction

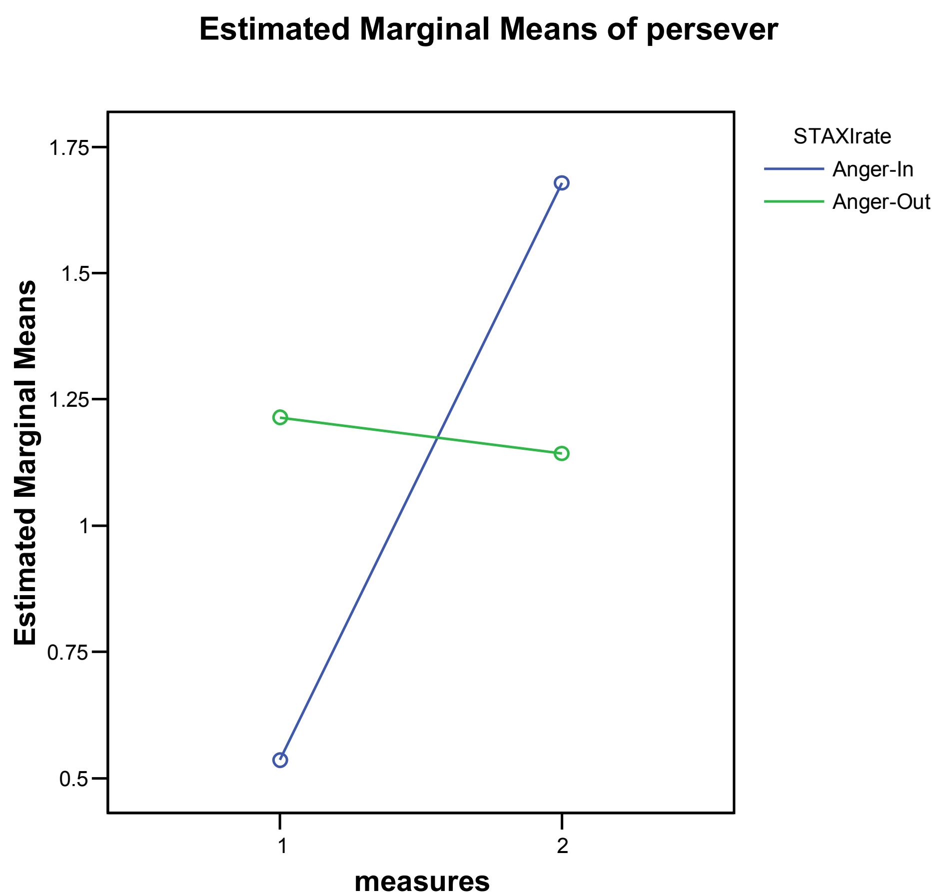


Figure 2: COWAT Systolic Blood Pressure, Group by Time Interaction

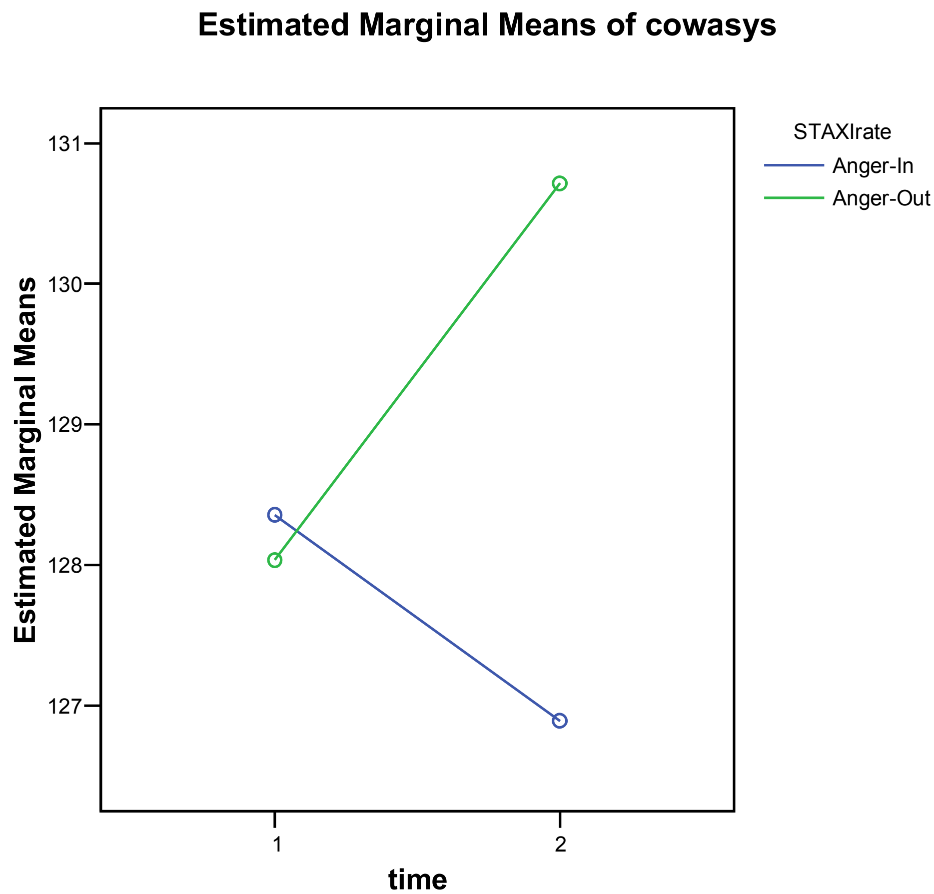


Figure 3: COWAT Heart Rate, Group by Time Interaction

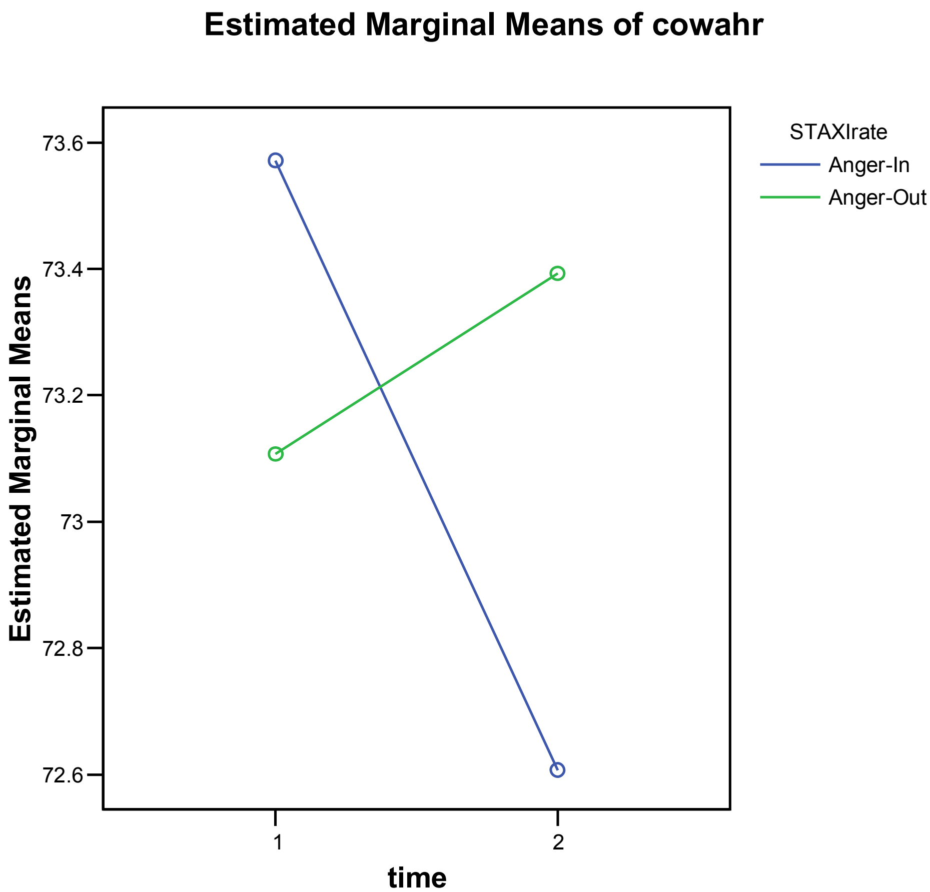


Figure 4: RFFT Systolic Blood Pressure, Group by Time Interaction

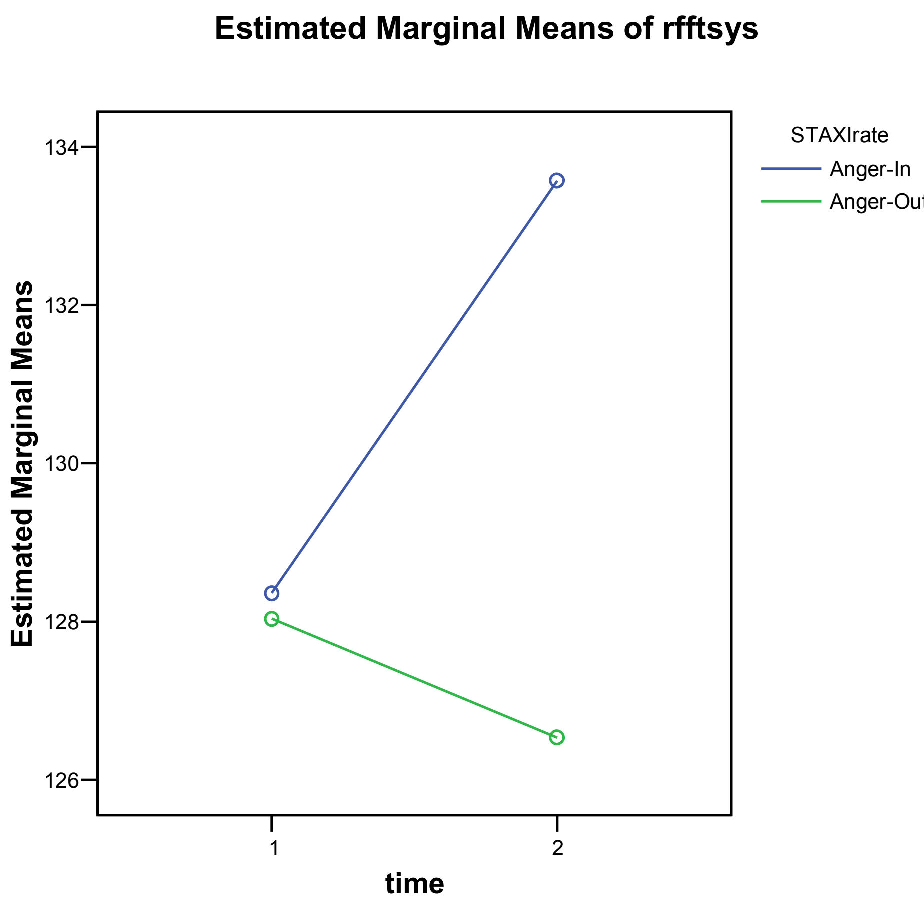


Figure 5: RFFT Heart Rate, Group by Time Interaction

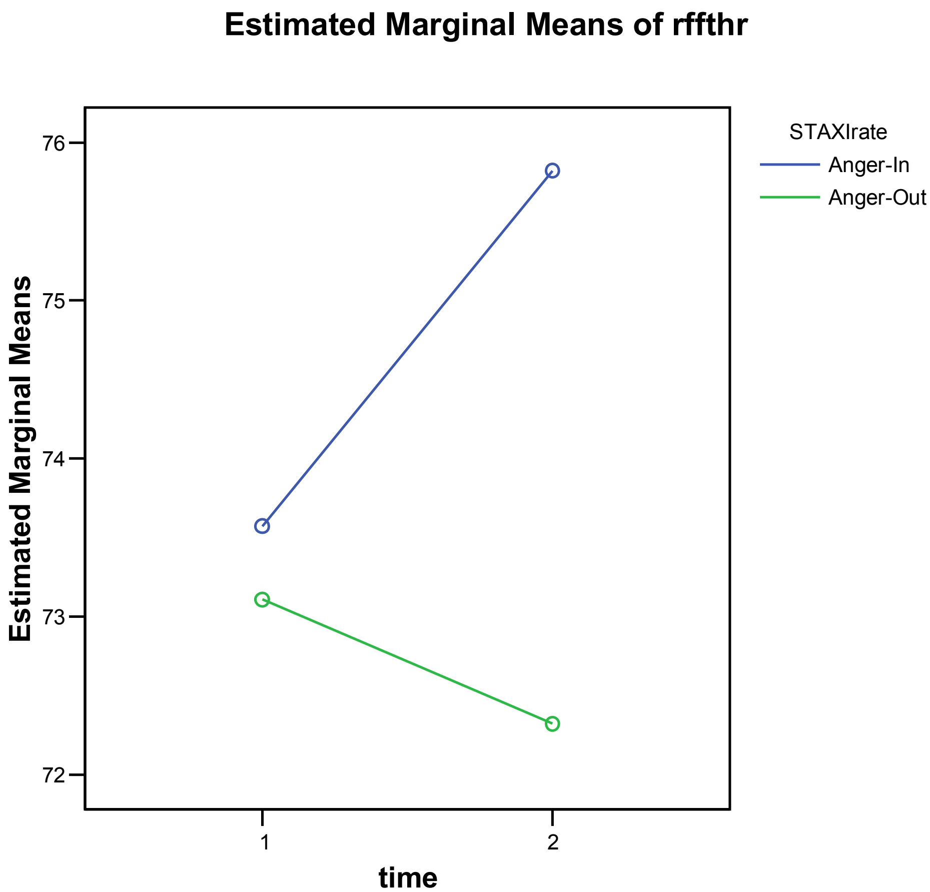
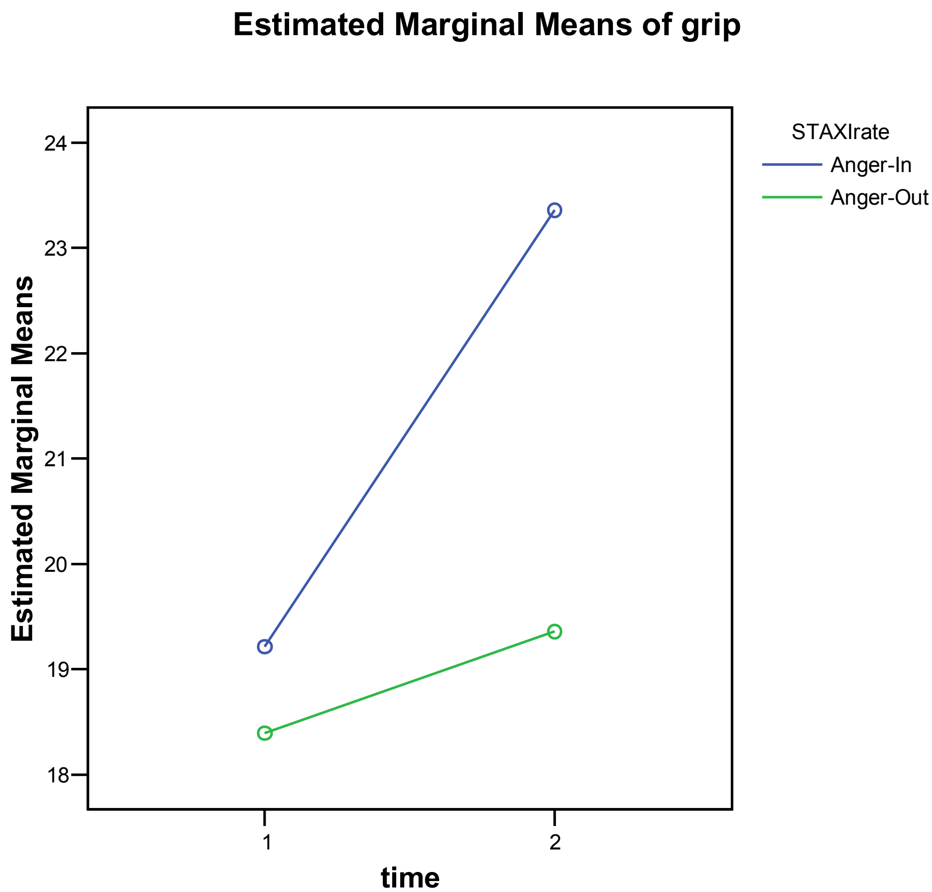


Figure 6: Grip Strength, Group by Time Interaction



APPENDIX A

Cook Medley Hostility Scale

Direction: If a statement is true or mostly true, as pertaining to you, circle the letter T.
If a statement is false, or usually not true about you, circle the letter F.
Try to give a response to every statement.

1. When I take a new job, I like to be tipped off on who should be gotten next to.	T	F
2. When someone does me wrong, I feel I should pay him back if I can, just for the principle of the thing.	T	F
3. I prefer to pass by school friends, or people I know but have not seen for a long time, unless they speak to me first.	T	F
4. I often had to take orders from someone who did not know as much as I did.	T	F
5. I think a great many people exaggerate their misfortunes in order to gain the sympathy and help of others.	T	F
6. It takes a lot of argument to convince most people of the truth.	T	F
7. I think most people lie to get ahead.	T	F
8. Someone has it in for me.	T	F
9. Most people are honest chiefly through the fear of getting caught.	T	F
10. Most people will use somewhat unfair means to gain profit or an advantage, rather than lose it.	T	F
11. I commonly wonder what hidden reason another person may have for doing something nice for me.	T	F
12. It makes me impatient to have people ask my advice or otherwise interrupt me when I am working on something important.	T	F
13. I feel that I have often been punished without cause.	T	F
14. I am against giving money to beggars.	T	F
15. Some of my family have habits that bother me very much.	T	F
16. My relatives are nearly all in sympathy with me.	T	F
17. My way of doing things is apt to be misunderstood by others.	T	F
18. I don't blame anyone for trying to grab everything they can get in this world.	T	F
19. No one cares what happens to you.	T	F
20. I can be friendly with people who do things I consider wrong.	T	F
21. It is safer to trust nobody.	T	F
22. I do not blame a person for taking advantage of someone who lays himself open to it.	T	F
23. I have often felt that strangers were looking at me critically.	T	F
24. Most people make friends because friends are likely to be useful to them.	T	F
25. I am sure that I am being talked about.	T	F
26. I am likely not to speak to people until they speak to me.	T	F
27. Most people inwardly dislike putting themselves out to help other people.	T	F

28. I tend to be on guard with people who are somewhat more friendly than I had expected.	T	F
29. I have sometimes stayed away from another person because I feared doing or saying something that I might regret afterwards.	T	F
30. People often disappoint me.	T	F
31. I like to keep people guessing what I'm going to do next.	T	F
32. I frequently ask people for advice.	T	F
33. I am not easily angered.	T	F
34. I have often met people who are supposed to be experts who were no better than I.	T	F
35. It makes me think of failure when I hear of the success of someone I know well.	T	F
36. I would certainly enjoy beating a crook at his own game.	T	F
37. I have at times had to be rough with people who were rude or annoying.	T	F
38. People generally demand more respect for their own rights than they are willing to allow for others.	T	F
39. There are certain people whom I dislike so much I am inwardly pleased when they are catching it for something they have done.	T	F
40. I am often inclined to go out of my way to win a point with someone who has opposed me.	T	F
41. I am quite often not in on the gossip and talk of the group I belong to.	T	F
42. The man who had the most to do with me when I was a child (such as my father, step- father, etc.) was very strict with me.	T	F
43. I have often found people jealous of my good ideas just because they had not thought of them first.	T	F
44.When a man is with a woman, he is usually thinking of things related to her sex.	T	F
45. I do not try to cover up my poor opinion or pity of a person so that he won't know how I feel.	T	F
46. I have frequently worked under people who seem to have things arranged so that they get credit for good work, but are able to pass off mistakes to those under them.	T	F
47. I strongly defend my own opinions as a rule.	T	F
48. People can pretty easily change me even though I thought that my mind was made up on a subject.	T	F
49.Sometimes I am sure that other people can tell what I'm thinking.	T	F
50. A large number of people are guilty of bad sexual conduct.	T	F

APPENDIX B

Medical History Questionnaire

1	Do you have any history of congenital or developmental problems ?	Yes	No
2	Do you have any history of learning disabilities or special education?	Yes	No
3	Have you ever suffered a head injury resulting in a hospital stay longer than 24 hours?	Yes	No
4	Have you ever been knocked out or rendered unconscious (more than 5 minutes)?	Yes	No
5	Have you ever suffered "black-out" or fainting spells?	Yes	No
6	Do you have a history of other neurological disorders (e.g. stroke or brain tumor)?	Yes	No
7	Have you ever received psychiatric/psychological care or counseling?	Yes	No
8	Have you ever been hospitalized in a psychiatric facility/hospital?	Yes	No
9	Have you ever been diagnosed with a psychiatric/psychological disorder?	Yes	No
10	Do you have a history of high blood pressure?	Yes	No
11	Do you have any uncorrected visual or hearing impairments?	Yes	No
12	Are you able to read, write, and speak English effectively?	Yes	No
13	Have you ever experienced a medical or psychiatric condition that could potentially affect cognitive functioning, such as stroke, electroconvulsive treatment, epilepsy, brain surgery, encephalitis, meningitis, multiple sclerosis, Parkinson's Disease, Huntington's Chorea, Alzheimer's dementia, Schizophrenia, Bipolar Disorder ?		
14	Are you taking any of the following medications: antidepressant, anti-anxiety, antipsychotic?	Yes	No

If you answered "yes" to any of the above please explain fully:

____

____

____

____

APPENDIX C

Laterality Questionnaire

Participant #: ___________________________

Circle the appropriate number after each item.

With which hand would you throw a ball to hit a target?	1	-1	0
With which hand do you draw?	1	-1	0
With which hand do you use an eraser on paper?	1	-1	0
With which hand do you remove the top card when dealing?	1	-1	0
With which foot do you kick a ball?	1	-1	0
If you had to pick up a pebble with your toes, which foot would you use?	1	-1	0
If you had to step up on a chair, which foot would you place on the chair first?	1	-1	0
Which eye would you use to peep through a keyhole?	1	-1	0
If you had to look into a dark bottle to see how full it was which eye would you use?	1	-1	9
Which eye would you use to sight down a rifle?	1	-1	0
If you wanted to listen to a conversation going on behind a closed door, which ear would you place against the door?	1	-1	0
If you wanted to listen to someone's heartbeat, which ear would you place against his or her chest?	1	-1	0
Into which ear would you place you earphone of a transistor radio?	1	-1	0

# of Right + # of Left = Total Score

_________ + ________ = ___________

Is mother right or left hand dominant? __________

Is father right or left hand dominant? ___________

APPENDIX D

STAXI – 2 Anger Expression Scale

Directions: Everyone feels angry or furious from time to time, but people differ in the ways that they react when they are angry. A number of statements are listed below which people use to describe their reactions when they feel angry or furious. Read each statement and then blacken the appropriate circle to indicate how often you generally react or behave in the manner described when you are feeling angry or furious. There are no right or wrong answers. Do not spend too much time on any one statement.

WHEN ANGRY OR FURIOUS…

	Almost never	**Sometimes**	**Often**	**Almost Always**
1) I express my anger	0	0	0	0
2) I keep things in	0	0	0	0
3) If someone annoys me I am apt to tell them how I feel	0	0	0	0
4) I pout or sulk	0	0	0	0
5) I lose my temper	0	0	0	0
6) I withdraw from people	0	0	0	0
7) I make sarcastic remarks to others	0	0	0	0
8) I boil inside but I don't show it	0	0	0	0
9) I do things like slam doors	0	0	0	0
10) I tend to harbor grudges that I don't tell anyone about	0	0	0	0
11) I argue with others	0	0	0	0
12) I am secretly critical of others	0	0	0	0
13) I strike out at whatever infuriates me	0	0	0	0
14) I am angrier than I am willing to admit	0	0	0	0
15) I say nasty things	0	0	0	0
16) I am irritated a great deal more than people are aware	0	0	0	0