ACADEMIC PRESS

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Brain and Cognition 52 (2003) 167–174

Brain and Cognition

www.elsevier.com/locate/b&c

Functional cerebral asymmetry in hostility: A dual task approach with fluency and cardiovascular regulation

John B. Williamson and David W. Harrison*

Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA

Accepted 10 December 2002

Abstract

The influence of hostility levels on verbal and nonverbal fluency, and the concurrent cerebral regulation of autonomic nervous system functioning was examined in 48 right-handed males, half classified as low-hostile, and half as high-hostile. Recent research has supported inhibitory roles for the anterior right cerebrum in sympathetic regulation, and the anterior left cerebrum in parasympathetic regulation. Two neuropsychological tests purportedly mediated by left and right anterior cerebral systems, respectively, are the Controlled Oral Word Association Test and the Ruff Figural Fluency Test. Fluency and perseverative errors were assessed using these measures. Systolic and diastolic blood pressure, and heart rate were assessed with a digital blood pressure meter. It was predicted that high-hostile men would evidence interference on cardiovascular regulation concurrent with the nonverbal fluency task in comparison to low-hostile males. Further, interference was expected to manifest in the cognitive variable with more perseverative errors on the nonverbal fluency task in high-hostile males than in low-hostile males. The results support a capacity-limited prediction. High-hostile males evidenced significantly heightened systolic blood pressure during the nonverbal fluency task in comparison with low-hostile males. Further, high-hostile males displayed more perseverative errors in nonverbal fluency than did the low-hostile males. These results support the expectation that differences exist between high- and low-hostile males for right frontal functioning. These findings were discussed within the proposed anterior–posterior inhibition model of hostility.

Keywords: Hostility; Anger; Fluency; Cerebral asymmetry; Autonomic nervous system

1. Introduction

Recurrent cardiovascular reactivity to stress is positively linked with the development of cardiovascular disease (Manuck & Krantz, 1986). Concurrently, a literature exists in neuropsychology dedicated to the examination of emotional valence and the cerebral lateralization of negative affect. Negative affect has been associated with increased autonomic arousal (Heilman & Valenstein, 1993). The negative affect, hostility, has been associated with increased cardiovascular reactivity (Demaree & Harrison, 1997; Shenal & Harrison, 2003; Demaree, Higgins, Williamson, & Harrison, 2002). This reactivity has corresponded with dynamic changes in functional cerebral laterality (e.g., Demaree & Harrison, 1997).

The bulk of research on CNS control of the heart has focused on brainstem mechanisms and baroceptor reflexes. However, there is evidence for cerebral mechanisms in the regulation of the cardiovascular system (Hachinsky, Oppenheimer, Wilson, Guiraudon, & Cechetto, 1992; Heller, Lindsay, Metz, & Farnum, 1990; Oppenheimer, Gelb, Girvin, & Hachinski, 1992; Wittling, Block, Scweiger, & Genzel, 1998; Yoon, Morillo, Cechetto, & Hachinski, 1997). Therefore, there is precedent to analyze these systems from a functional cerebral systems approach. This approach delineates localized cerebral systems contributing to the regulation and to the performance of specialized functions. Intracerebral systems have been extensively described with a regulatory role posited for the anterior cerebral regions over the posterior cerebral regions (e.g., Luria, Teuber, & Pribram, 1966). It has been purported that the right

* Corresponding author. Fax: 1-540-231-3652.
E-mail address: jowilli9@vt.edu (D.W. Harrison).

0278-2626/03/$ - see front matter © 2003 Elsevier Science (USA). All rights reserved.
doi:10.1016/S0278-2626(03)00038-1

cerebral hemisphere predominantly modulates the sympathetic nervous system and that the left cerebral hemisphere predominantly modulates the parasympathetic nervous system (Wittling, Block, Genzel, & Schweiger, 1997; Yoon et al., 1997). Anterior cerebral regions may be responsible for the inhibition or regulation of these cerebral systems (Demaree & Harrison, 1997).

1.1. The functional cerebral systems model of hostility

The weight of research to date has implicated the right cerebrum in the reception, comprehension, expression, and regulation of negative emotions. Research on the lateralization of positive emotions has been more controversial (Heilman & Valenstein, 1993). Research on emotions may benefit through the systematic use of a functional cerebral systems approach. The following research illustrates the use of the functional systems model in the study of the emotional valence, hostility. Specifically, the impact of emotional disposition is explored across each sensory and motor modality in a systematic fashion providing for replication and extension of findings across modalities.

Research on hostility and anger has shown that several brain areas are integral. Specifically, the orbital frontal cortex has been implicated in the expression of anger. Supporting this notion of the involvement of this region in anger, increasing intensity of angry facial expressions is associated with increased activation of the orbital frontal cortex (Blair, Morris, Frith, Perrett, & Dolan, 1999). Specifically, using Eckman and Friesan's (1978) standardized set of pictures of facial affect, it was found that in healthy males perception of angry facial expressions is associated with increased glucose metabolic rate in the right orbital frontal cortex. Interestingly, the differentiation and similarity between processing sad and angry affective pictures in glucose metabolic rate was demonstrated across regions. While angry faces elicited right orbital frontal activation, sad faces did not. Sad faces and angry faces did both elicit activation in the anterior cingulate cortex and the right temporal pole, demonstrating a right hemisphere dominance in processing both sets of negative affective information.

Given that asymmetry exists with a purported advantage in the expression and processing of hostility in the right hemisphere, research might produce results indicative of this lateralization across multiple functional systems such as vision, audition, somatosensory, motor, premotor, vestibular, and their associated processing systems. Lateralized differences between males designated high-hostile and males designated low-hostile have been found for visual identification tasks. Harrison, Gorelczenko, and Cook (1990) found at rest (no stressor) differences between these groups in the identification of the emotional valence of faces. Specifically, high-hostile males were less accurate in identifying neutral faces and in the perceptual processing of emotional faces presented within the contralaterally-controlled left-visual field. Neutral faces projected to the right cerebrum were reliably identified as "angry" faces by high-hostile males, whereas low-hostile males were more accurate in their identification. In subsequent research a stressor was applied, a cold-pressor task, and it was shown to have a deleterious effect on the identification of emotional faces by high-hostile males compared with low-hostile males (Herridge & Harrison, 1996).

Extending this systematic approach among the sensory systems, similar asymmetries have been observed during auditory affective processing. Following administration of a cold-pressor task, high-hostile males displayed an enhanced left ear advantage in the identification of speech sounds presented through a dichotic listening task. Further, high-hostile males displayed increased cardiovascular reactivity (blood pressure and heart rate) following the cold-pressor task, whereas low-hostile males demonstrated cardiovascular stability. Diametrically opposite functional cerebral activation patterns were found in low-hostile males, with an enhanced right ear advantage in the identification of the dichotic speech stimuli as a function of cold-pressor stress. These results suggest greater right-cerebrum reactivity to stress among high-hostile males and diametrically opposite effects with left cerebral activation to the cold-pressor stress among low-hostile males (Demaree & Harrison, 1997).

Further research on the somatosensory system yields similar conclusions for hemispheric lateralization and hostility. Intentional facial affect configuration differentially alters skin conductance and tone among high and low-hostiles. High-hostile males display increased skin conductance at the left hemibody, reduced rate of habituation at the left hemibody, and enhanced sympathetic tone. Low-hostile males display increased skin conductance at the right hemibody, diminished sympathetic tone, and rapid habituation at the left hemibody (Herridge, Harrison, & Demaree, 1997). These results are consistent with increased right cerebral activation in high-hostile males.

Consistency is also evident in the motor systems, supporting the notion of right anterior cerebral region activation differences as a function of hostility. Contralateral control by the motor strip approaches 90% for the distal extremities with ipsilateral projections approaching 10% for the proximal body regions, making it ideal for the evaluation of group differences in cerebral laterality (Harrison, 1991). Grip strength was assessed by Demaree et al. (2002) among right-handed high- and low-hostile males. The right-handed high-hostile males were significantly stronger at the left hand and significantly

weaker at the right hand compared to low-hostile males. These results provide direct behavioral evidence through grip strength of both increased right anterior activation and decreased left anterior activation among high-hostile males using low-hostile males as a comparison group.

Thus, far these results support the "balance model" (e.g., Tucker & Williamson, 1984) positing general right hemispheric activation with hostility. However, a more refined inhibitory model of anterior cerebral regions providing regulatory control over the posterior cerebral regions could potentially prove more useful in terms of prediction, control, and the comprehension of functional cerebral systems involved in the regulation of anger and cardiovascular responsivity.

The orbital frontal cortex exhibits intimate connections with the post-central fissure subcortical structure, the amygdala (Kandel, Schwartz, & Jessell, 1991), a component of the basal ganglia and the limbic system. Amygdalar projections to the temporal cortex are also evident as part of this system. The dorsolateral prefrontal cortex and the anterior cingulate cortex appear to have a role in the expression of hostility. Davidson, Putnam, and Larson (2000) state that abnormalities in any of these regions or within the interconnections are associated with failures in emotional regulation and also in an increased propensity for impulsive aggression and violence.

1.2. Dual task research

Dual task research can provide a powerful framework for the evaluation of the functional cerebral systems in emotion. Distributed attention among concurrent activities has been a topic of concern and debate within cognitive psychology for decades. This is also true of the neuropsychological approaches to brain–behavior relationships. Filimonov (as cited in Luria et al., 1966) postulated that no cerebral formation is responsible for one unique action and that multiple tasks are carried out by the same tissue. Relatedly, Kinsbourne and Hicks (1978) proposed the concept of functional cerebral space. Essentially, the extent of inhibitory interference of one task on others varies inversely with the functional distance between the cerebral regions involved with the performance of each task. It is thought that interference occurs when concurrent tasks are attempted that compete for similar or adjacent cerebral areas within the same hemisphere. Although controversial, Kinsbourne's model has been successfully applied to the study of concurrent activities.

1.3. Fluency

Fluency tasks, during confrontational challenges, may provide an excellent way to evaluate anterior cerebral regions and, moreover, to investigate the role of frontal systems in the dynamic regulation of cardiovascular systems. With anxious-depressed subjects, Everhart (1997) used fluency as a dual task concurrent with the ongoing regulation of the cardiovascular system. Nonverbal fluency, arguably, interfered with the ongoing regulation of the sympathetic nervous system, yielding an increase in heart rate and blood pressure, whereas the verbal fluency test did not. This finding is consistent with the hypothesized interference in sympathetic cardiovascular regulation secondary to concurrent administration of the purported right frontal challenge of the nonverbal fluency test.

Fluency is a neuropsychological construct referring to the quantitative output, or generativity, of verbal and/or nonverbal material to confrontation under timed and limited search conditions (Strub & Black, 1985). Verbal fluency tests require listing of words that begin with a pre-specified letter or categorical item whereas nonverbal fluency tests require the generation of unnamable designs or figures. Performance is dependent on the intentional processes of organization, problem-solving, strategy development and implementation, and the ability to quickly shift to other strategies or "cognitive flexibility." Without these capabilities, fluency output can be impacted. Individuals with frontal lobe damage have been demonstrated to produce reduced output on these tasks (Lezak, 1983). Further, such deficits are dependent upon the lateralization of damage, with right frontal damage yielding decrements in nonverbal fluency performance (Jones-Gotman & Milner, 1977) and left frontal damage yielding decrements in verbal fluency performance (Borokowski, Benton, & Spren, 1981). Perseverative errors are also assessable using fluency measures. A perseverative error, in the context of fluency, can be quantified as a repetition of a word or a design. Fluency performance in individuals with frontal damage is not only low in terms of frequency, or generativity, but also it is marked by consistent perseverative errors (Jones-Gotman & Milner, 1977).

2. Rationale

The present experiment advances research on the cerebral mediation of the heart and interactions with cognitive tasks. Understanding of the cerebral lateralization of cardiac regulation in high- and in low-hostile men is investigated through the application of dual-task methodology with the extent of interference expected to correspond to the proximity of the functional tasks and hostility level.

The concurrent tasks in this experiment consist of fluency (one verbal test purported to be mediated by the anterior left cerebrum and one nonverbal test purported to be mediated by the anterior right cerebrum), and

maintenance of ongoing cardiovascular control (parasympametic, a task regulated by the left anterior cerebral regions, and sympathetic, a task regulated by the right anterior cerebral regions). It should be noted that the application of the functional cerebral distance theory to the cerebral maintenance of the autonomic nervous system is a relatively novel idea within the literature. Usually classic activation tasks are used in dual task research (i.e., finger tapping and reading). To the author's knowledge, this methodology has only been applied once before in a similar study on anxiety concurrent with regulation of the ANS (Everhart, 1997).

It was expected that both the cognitive and physiological measures would support right-frontal anterior regulatory differences as a function of hostility. The nonverbal fluency test was expected to interfere with the right anterior cerebrum resulting in a diminution of that region's inhibitory function yielding sympathetic activation and cardiac de-regulation in high-hostile males. Specifically, an increase in blood pressure was predicted with the concurrent nonverbal fluency tests. Further, more perseverative errors were expected in the nonverbal fluency task in hostile males than in low-hostile males.

3. Method

3.1. Participants

Participants were right-handed men acquired from the undergraduate psychology pool. Participants had no prior history of hearing problems, uncorrectable visual acuity, major illness, or head injury (assessed through a neurological screening questionnaire). Only men were used because it was essential that homogeneity be maintained in order for conclusions to be solely attributable to the independent variable manipulation. Participants with significant right hemibody preference based on the Coren, Porac, and Duncan laterality test (Coran, Porac, & Duncan, 1979), who additionally met the criteria on the Cook-Medley Hostility Scale (CMHS) (Cook & Medley, 1954) were selected for further participation.

There were 25 participants recruited for each category. One participant was removed from each category due to history of head injury for a total of 24 participants in each group.

3.2. Self-report

During group testing, participants were required to complete a questionnaire assessing their medical history (neurological screening questionnaire). Participants were then administered the Coren, Porac, and Duncan laterality test to determine hemibody preference. This is a self-report measure that assesses right (−1) and left (+1) hemibody preference based on preferred use of either eye, ear, arm, and leg. The test ranges from scores of −13 to +13, denoting left and right hemibody preference, respectively. A score of +6 or above was required for continued participation in the experiment.

Participants who met the aforementioned criteria were then administered the Cook-Medley Hostility Scale (CMHS). This test is the most frequently utilized measure of hostility and has been shown to be a valid predictor of medical, psychological, and interpersonal outcomes (Contrada & Jussim, 1992). Participants who scored 19 or below on the scale (CMHS), and who met the above criteria were asked to continue with the experimental phase and comprised the low-hostile group. Participants who scored in the range of 20–28 points were notified that they would not be asked to participate in the experimental phase of the experiment. Participants who scored 29 or above on the CMHS, and who met the above criteria, comprised the high-hostile group. The participants chosen for the experimental phase were scheduled for further testing.

3.2.1. Apparatus

The laboratory chamber was comprised of a chair facing a one-way mirror within a flat white curtain enclosure. Located in this chamber were the paper materials and blood pressure cuff.

Physiological. SBP, DBP, and HR were assessed using the Norelco Healthcare Electronic Digital Blood Pressure/Pulse Meter with Microphoneless Cuff and oscillometric technique (1985; Model HC3030). Accuracy of this device has been obtained in previous work (Harrison & Kelley, 1987).

Verbal fluency. The Controlled Oral Word Association Test (COWAT) assesses the oral or written production of words beginning with a designated letter (Benton & Hamsher, 1976). It consists of three trials in which participants are instructed to write as many words as possible in one minute beginning with a specified letter (e.g., F, A, or S). Proper names, numbers, and the same word with different endings are not permitted. The final score is the sum of all acceptable words produced across trials. The letters F, A, and S are the most frequently utilized, however, the present experiment used a variation of the protocol. Specifically, the letters F, S, and T were used. These letters were chosen based on the tendency of normals to produce an equal number of responses for each letter (approximately 11–12 words per minute) (Everhart, 1997).

Nonverbal fluency. For nonverbal fluency the Ruff Figural Fluency Test (RFTT) was used. It consists of five parts, each containing different stimulus presentations. Each part has 35 dot matrices arranged in a 5×7 array. Participants were instructed to connect the dots in as many unique ways that they can conceive within a

one-minute period. It is scored by counting the number of unique designs and number of perseverations for each trial. A perseveration is any repetition of a previous design within the participant's responses. Nonverbal fluency is then considered the total number of unique designs minus the number of perseverations within each part. Three sheets, instead of the standard five, were used in this experiment in order to maintain consistency with the COWAT (Everhart, 1997).

3.3. Procedure

Upon arrival at the testing center, participants were administered the CMHS to check for test-retest reliability of the hostility grouping. Participants were only tested if the score was consistent. They were then fitted with the blood pressure monitor. The researcher left the testing room and gave the following instructions over the intercom: "Please take about one minute to become accustomed to your surroundings. Please sit still in the chair and face forward." Participants were then informed that they would be asked to complete the verbal and the nonverbal fluency tests. Following a 90 s adaptation period, baseline SBP, DBP, and HR were recorded. Immediately following the recording of the physiological data, the subject was asked to complete the RFFT (or the COWAT) using the appropriate instruction set for the test. Order of the fluency tests was administered in a counterbalanced fashion. Upon completion of the fluency task SBP, DBP, and HR was recorded again. Following 90 s of adaptation, presentation of the second test was administered following the same procedures.

3.4. Data analysis

Data analyses for the dependent measures of systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) consisted of a mixed design ANOVA with the fixed effects of group (2) and condition (2) and the repeated measure of trial (2). In order to test the hypothesis that high-hostile men have more difficulty than low-hostile men regulating cardiovascular functioning when performing a nonverbal fluency test (RUFF) an ANOVA consisting of group (high and low) X condition (1 and 2) with the repeated measure of trial (2) was performed.

In order to test the hypothesis that high-hostile males would have more difficulty with nonverbal fluency than low-hostile males an analysis of fluency was conducted with a mixed design ANOVA with the fixed effects of group (2) (high hostility and low hostility) and condition (2) (verbal and nonverbal fluency) and with the repeated measure of trial (3). The dependent variable was the total number of words produced (fluency score). Further, an analysis of the perseverative errors was performed with a mixed design ANOVA with group (2) (high hostility and low hostility) and condition (2) (nonverbal or verbal) with the repeated measure of trial (3). The total number of perseverative errors was the dependent variable. All post-hoc analyses were completed utilizing Tukey's Studentized Range Test to control for experimentwise error rate (Winer, 1971).

4. Results

It was hypothesized that high-hostile men would evidence increased cardiovascular reactivity following administration of a nonverbal fluency test (condition 2). A significant group X condition X trial interaction was found for systolic blood pressure (SBP), $F(1,46) = 3.96$, $p \leqslant .05$ (see Fig. 1). Systolic blood pressure increased following the nonverbal fluency confrontation test in high-hostile males. Systolic blood pressure decreased following the verbal fluency confrontation test in high-hostile males. No change was evident in systolic blood pressure following the nonverbal fluency confrontation test in low-hostile males. Finally, verbal fluency produced an increase in systolic blood pressure following the verbal fluency test in low-hostile males. Post-hoc analyses indicate that the rise in systolic blood pressure following administration of the nonverbal fluency test to high-hostile males is the only significant change by itself within the interaction.

A significant main effect for group was found for diastolic blood pressure (DBP), $F(1,46) = 4.34$, $p \leqslant .05$. Post-hoc analyses on the main effect of group using Tukey's HSD test demonstrated that low-hostile males DBF (68.83 mmHg) was significantly lower than high-hostile

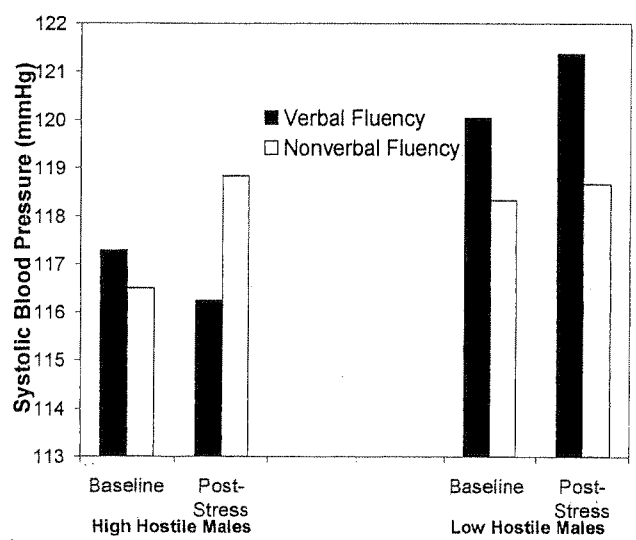

Fig. 1. Systolic Blood Pressure in mmHg as a function of group (high- and low-hostile males), condition (Verbal and Nonverbal Fluency tests), and trial (baseline and post-stress).

males DBF (73.677) taken immediately following fluency task administration.

In order to test the hypothesis that high-hostile men evidence decreased performance on nonverbal fluency during ongoing mediation of cardiovascular activities an ANOVA consisting of the fixed effects of group and condition with the repeated measure of trial was performed on the fluency data. For this analysis, group = high- and low-hostile participants, trial = 3, and fluency = verbal fluency and nonverbal fluency tests.

No significant interactions were found. A significant main effect was found for condition, $F(1,46) = 28.52$, $p \leqslant .05$. Post-hoc analyses revealed that nonverbal fluency scores were significantly higher than verbal fluency scores collapsed across groups. Further, a significant main effect for trial was found across both conditions, $F(2,92) = 8.95$, $p \leqslant .05$. Post-hoc analyses revealed that trial 1 scores were significantly lower than trials 2 and 3 collapsed across group.

In order to further test the hypothesis that high-hostile men evidence decreased performance on nonverbal fluency during ongoing mediation of cardiovascular activities, an ANOVA consisting of the fixed effects of group and condition with the repeated measure of trial was performed using perseverative errors on the fluency tests as data. A significant group X condition interaction was found. High-hostile males, as predicted, produced more perseverative errors on nonverbal fluency than did the low-hostile males, $F(1,46) = 8.99$, $p \leqslant .05$ (see Fig. 2).

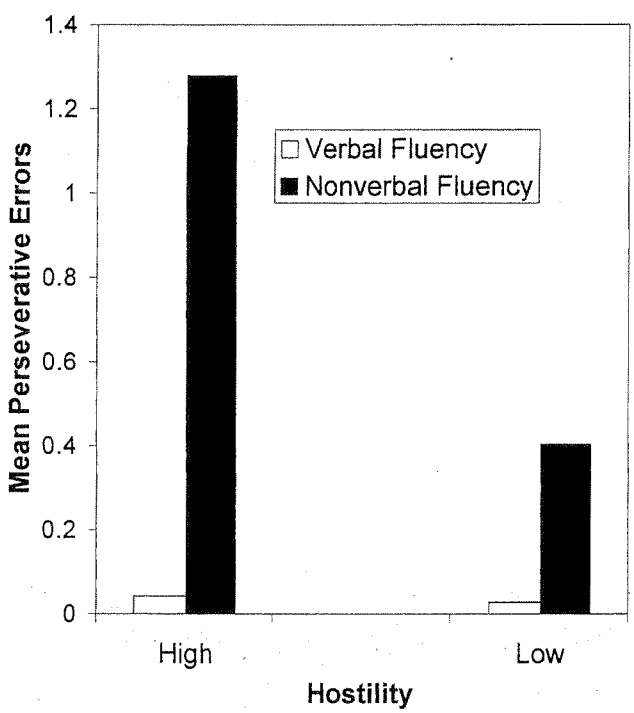

Fig. 2. Mean number of perseverative errors as a function of group (high- and low-hostile males) and condition (Verbal and Nonverbal Fluency).

Overall, there was a main effect for Group with high-hostile males displaying more perseverative errors than low-hostile males, $F(1,46) = 10.07$, $p \leqslant .05$.

This variance is mostly attributable to the large number of nonverbal fluency perseverative errors produced by high-hostile males. Post-hoc analyses revealed that errors were significantly more frequent among high-hostile males. Further, there was a main effect for condition with more perseverative errors made on the nonverbal fluency tests than on the verbal fluency tests for both groups, $F(1,46) = 31.48$, $p \leqslant .05$. Post-hoc analyses revealed that condition 1 scores were significantly lower than condition 2 scores. Specifically, an average of .84 perseverative errors was found on the nonverbal fluency test in comparison to .03 perseverative errors on the verbal fluency test.

5. Discussion

The primary findings of the experiment are as follows. Verbal and nonverbal fluency tests produced diametrically opposite effects on systolic blood pressure in high-hostile males. Specifically, nonverbal fluency yielded heightened systolic blood pressure, whereas verbal fluency resulted in decreased systolic blood pressure in this group. Second, verbal fluency produced opposite effects among the groups with decreased systolic blood pressure in the high-hostile group in contrast to increased systolic blood pressure in the low-hostile group. Low-hostile males tolerated the nonverbal fluency test with stability across blood pressure measures. It is important to note that this is a complicated interaction effect. We approach this interaction effect with an emphasis on the functional cerebral systems of emotion and arousal.

An interesting cognitive effect was displayed in conjunction with the physiological interaction. High-hostile males produced perseverative or organizational errors on the, arguably, right frontal mediated nonverbal fluency test not found in the low-hostile males. As predicted by the functional cerebral systems approach, the functional cerebral distance principle, and the presented hostility model, high-hostile males demonstrated increased interference and potentially reduced capacity within right frontal systems when compared with low-hostile males.

Functional systems analyses of hostility have shown that, at rest, high-hostile males have heightened right cerebral activation in comparison to low-hostile males with differences in behavioral output evident across multiple sensory and motor systems. One neuropsychological explanation of hostility would suggest that the anterior-right cerebrum is responsible for the inhibition or the regulation of sympathetic cardiovascular

functioning as well as the expression of heightened hostility (Demaree & Harrison, 1997; Everhart and Harrison, 1995). The orbital-frontal region has extensive interconnections with the amygdaloid bodies of the anterior temporal region via the uncinate fasiculus. Activation in the later region has been correlated with increasing hostility. These regions interact to produce relatively stable aggression levels among normal individuals (Heilman & Valenstein, 1993).

Prior to this experiment, intentional/premotor systems had yet to be explored through our functional systems analyses of hostility. Fluency tests present as an established method of evaluating these systems. The fluency tests theoretically were concurrent tasks involving anterior cerebral systems also involved with the inhibition of cardiovascular responses.

It was hypothesized that high-hostile males would display increased interference on sympathetic cardiovascular regulation with the concurrent performance of a nonverbal fluency confrontation challenge (purportedly a right frontal challenge). Specifically, it was expected that high-hostile males would display increased blood pressure subsequent to the completion of the nonverbal fluency test. High-hostile males did show an increase in blood pressure following the completion of the nonverbal fluency confrontation challenge. Specifically, systolic blood pressure increased reliably in this group as a function of nonverbal fluency. This was a significant effect outside of the discussed interaction. Studies have previously shown that right frontal damage is associated with difficulties in self-regulation or self-modulation of ongoing behaviors (Teuber, Battersby, & Bender, 1951).

Further, it was hypothesized that high-hostile males would produce more perseverative errors on the nonverbal fluency test than low-hostile males. As predicted, high-hostile males displayed more perseverative errors than low-hostile males on the nonverbal fluency confrontational test. Output of nonverbal fluency on patients with right frontal lobe lesions has been marked by perseverative errors (Jones-Gotman & Milner, 1977). Taken together (i.e., increased blood pressure and more perseverative errors in high-hostile males) these results lend validity to the use of cardiovascular functions and cognitive tasks such as fluency as concurrent tasks within an experimental model.

One possible result that was expected was the high-hostile men might show reduced design output on the nonverbal fluency task. However, this did not occur. The failure to support this expectation may have resulted from restricted time allocation for the completion of the fluency tests. One-minute intervals, as used in this experiment, are relatively short. Research on the frontal lobe in generativity and organizational regulation has generally indicated increased sensitivity to so called "frontal lobe tests" with extended duration. This has been related by some to vigilance or concentration difficulties or dysfunction within the intentional regulation systems over time (e.g., Demakis & Harrison, 1994).

In contrast, low-hostile males did not show any evidence of reduced right-frontal capacity. As predicted, low-hostile males did not display an increase in blood pressure subsequent to the completion of the nonverbal fluency test. Interestingly, compared to high-hostile males, low-hostile males did show a diametrically opposite increase in systolic blood pressure subsequent to completion of the verbal fluency test (part of the interaction effect). Post-hoc analysis revealed that compared to low-hostile males' systolic blood pressure baseline this increase was not significant, but this interaction effect may suggest differential cerebral cardiovascular regulation in low-hostile males.

The fluency confrontation test scores did not provide any consistency with the increased blood pressure response in low-hostile males to the verbal fluency test. Low-hostile males did not show a significant amount of perseverative errors in comparison to high-hostile males on either fluency test. Further, there were no output differences on either fluency test between the two groups. The tasks may have simply been more taxing for the high-hostile males due to already increased anterior cerebral region arousal.

This experiment uncovered results consistent with the proposed hypotheses. High-hostile males evidenced both cognitive and physiological differences in comparison to their low-hostile counterparts. These results suggest general differences in right-frontal lobe capacity in high-hostile males relative to low-hostile males. This may help explain the link between hostility and cardiovascular disease (Kubany, Gino, Denny, & Torigoe, 1994). That is, high-hostile males experience more interference effects on tasks that require right-frontal lobe resources due to increased at-rest arousal, perhaps producing increased right posterior hemispheric activation resulting in increased physiological lability and possibly contributing to cardiovascular disease.

This dual task methodology may also aid in the development of cognitive intervention strategies for this population. Dual tasks may be identified specifically for interference of inhibitory left-frontal systems to promote parasympathetic arousal and increased vagal tone. For example, verbal fluency confrontation did have the effect of slightly reducing systolic blood pressure in the high hostile group. Further stressing the left-frontal lobe might produce a more significant effect, perhaps through exercise and range of motion of the right hemibody, through propositional speech, or through pleasant learning tasks that may be beneficial (Harrison & Kelley, 1987; Snyder, Harrison, & Shenal, 1997).

References

Benton, A., & de Hamsher, K. S. (1976). *Multilingual aphasia examination*. Iowa City: University of Iowa.

Blair, R. J., Morris, J. S., Frith, C. D., Perrett, D. I., & Dolan, R. J. (1999). Dissociable neural responses to facial expressions of sadness and anger. *Brain: A Journal of Neurology, 122*(5), 883–893.

Borokowski, J. G., Benton, A. L., & Spren, O. (1981). Word fluency measure. In F. L. Darley (Ed.), *Evaluation of appraisal techniques in speech and language pathology*. Reading, MA: Addison-Wesley.

Cook, W. W., & Medley, D. M. (1954). Proposed hostility and pharisaic-virtue scaled for the MMPI. *Journal of Applied Psychology, 238*, 414–418.

Contrada, R. J., & Jussim, L. (1992). What does the Cook-Medley hostility scale measure? In search of an adequate measurement model. *Journal of Applied Social Psychology, 22*, 615–627.

Coran, S. P., Porac, C., & Duncan, O. (1979). A behaviorally validated self-report inventory to assess 4 types of lateral preferences. *Journal of Clinical Neuropsychology, 1*, 55–64.

Davidson, R. J., Putnam, K. M., & Larson, C. L. (2000). Dysfunction in the neural circuitry of emotional regulation: A possible prelude to violence. *Science Magazine, 289*, 591–597.

Demakis, G. J., & Harrison, D. W. (1994). Subvocal rehearsal of neutral and affective words interferes with left-hemisphere performance and facilitates right-hemisphere performance. *Psychobiology, 22*, 238–243.

Demaree, H. A., & Harrison, D. W. (1997). Behavioral, physiological, and neuropsychological correlates of hostility. *Neuropsychologia, 35*(10), 1405–1411.

Demaree, H. A., Higgins, D., Williamson, J. B., & Harrison, D. W. (2002). Asymmetry in hand grip strength and fatigue in low- and high-hostile men. *International Journal of Neuroscience, 112*(4), 415–428.

Eckman, P., & Friesan, W. V. (1978). *Facial action coding system*. Palo Alto (CA): Consulting Psychologists Press.

Everhart, D. E. (1997). Cerebral Regulation of Cardiovascular Functioning and fluency among anxious and nonanxious men. Dissertation.

Hachinsky, V. C., Oppenheimer, S. M., Wilson, J. X., Guiraudon, C., & Cechetto, D. F. (1992). Asymmetry of sympathetic consequences of experimental stroke. *Archives of Neurology, 49*, 697–702.

Harrison, D. W. (1991). Concurrent verbal interference of right and left proximal and distal upper extremity tapping. *Acta Psychologica, 76*, 21–132.

Harrison, D. W., Gorelczenko, P. M., & Cook, J. (1990). Sex differences in the functional asymmetry for facial affect perception. *International Journal of Neuroscience, 52*, 11–16.

Harrison, D. W., & Kelley, P. L. (1987). Home health care: Accuracy, calibration, exhaust, and failure rate comparisons of digital blood pressure monitors. *Medical Instrumentation, 21*, 323–326.

Heilman, K. M., & Valenstein, E. (1993). *Clinical NeuroPsychology* (3rd ed.). New York: Oxford University Press.

Heller, W., Lindsay, D. L., Metz, J., & Farnum, D. M. (1990). Individual differences in right hemisphere activation are associated with arousal and autonomic response to lateralized stimuli. *Journal of Clinical and Experimental Neuropsychology, 13*, 95.

Herridge, M. L., & Harrison, D. W. (1996). The effects of hostility and arousal on facial affect perception: A test of a neuropsychological model of hostility. Dissertation.

Herridge, M. L., Harrison, D. W., & Demaree, H. A. (1997). Hostility, facial configuration, and bilateral asymmetry on galvanic skin response. *Psychobiology, 25*, 71–76.

Jones-Gotman, M., & Milner, B. (1977). Design fluency: The invention of nonsense drawings after focal cortical lesions. *Neuropsychobiologia, 15*, 653–674.

Kandel, E. R., Schwartz, J. H., & Jessell, T. M. (1991). *Principles of neural science* (3rd ed.). Norwalk, Connecticut: Appleton & Lange.

Kinsbourne, M., & Hicks, R. E. (1978). Functional cerebral space: A model for overflow, transfer, and interference effects in human performance. In J. Requin (Ed.), *Attention and performance VII*. Hillsdale: Erlbaum.

Kubany, E. S., Gino, A., Denny, N. R., & Torigoe, R. Y. (1994). Relationship of cynbical hostility and PTSD amon Vietnam veterans. *Journal of Traumatic Stress, 7*, 21–31.

Lezak, M. (1983). *Neuropsychological assessment*. New York: Oxford University Press.

Luria, A. R., Teuber, H. L., & Pribram, K. H. (1966). Higher Corticol Functions in Man. *Consultants Bureau*, New York. 1980.

Manuck, S. B., & Krantz, D. S. (1986). Psychophysiologic reactivity in coronary heart disease and essential hypertension. In K. A. Matthews, S. W. Weiss, T. Detres, T. M. Dembroski, B. Falkner, S. B. Manuck, & R. B. Williams (Eds.), *Handbook of stress, reactivity, and cardiovascular disease* (pp. 11–34). New York: Wiley.

Oppenheimer, S. M., Gelb, A., Girvin, J. P., & Hachinski, V. C. (1992). Cardiovascular effects of human insular cortex stimulation. *Neurology, 42*, 1727–1732.

Shenal, B. V., & Harrison, D. W. (2003). Investigation of the laterality of hostility, cardiovascular regulation, and auditory recognition. *International Journal of Neuroscience, 113*(2), 205–222.

Snyder, K. A., Harrison, D. W., & Shenal, B. V. (1997). An affective auditory verbal learning test: Psychophysiological correlates. *The Archives of Clinical Neuropsychology, 12*, 5.

Strub, R. L., & Black, F. W. (1985). *The mental status examination in neurology*. Philadelphia: F.A. Davis Company.

Teuber, H. L., Battersby, W. S., & Bender (1951). Performance of complex visual tasks after cerebral lesions. *Journal of Nervous and Mental Disease, 114*, 413–429.

Tucker, D. M., & Williamson, P. A. (1984). Asymmetric neural control systems in human self regulation. *Psychological Review, 91*, 185–215.

Winer, B. J. (1971). *Statistical principles in experimental design* (2nd ed.). New York: McGraw Hill.

Wittling, W., Block, A., Genzel, S., & Schweiger, E. (1997). Hemisphere asymmetry in parasympathetic control of the heart. *Neuropsychologia, 36*, 461–468.

Wittling, W., Block, A., Sceweiger, E., & Genzel, S. (1998). Hemisphere asymmetry in sympathetic control of the human myocardium. *Brain and Cognition, 38*, 17–35.

Yoon, B. W., Morillo, C. A., Cechetto, D. F., & Hachinski, V. (1997). Cerebral hemispheric lateralization in cardiac autonomic control. *Archives of Neurology, 54*, 741–744.

Further reading

Filimonov, I. N. (1940). Localization of functions in the cerebral cortex. *Nevropat. I Psikhiat, 9*.