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Physiological and neuropsychological correlates of hostility

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Abstract—This experiment tested two hypotheses linking right cerebral arousal to hostility and physiological arousal. A replication of previous research supporting heightened physiological (systolic blood pressure, diastolic blood pressure and heart rate) reactivity among high-hostility subjects was partially successful. Hemispheric lateralization of cerebral activity in response to stress was also measured. Low- and high-hostility subjects were identified using the Cook–Medley Hostility Scale (CMHS). Physiological measures (systolic blood pressure, diastolic blood pressure and heart rate) were recorded and dichotic listening procedures were administered before and after administration of the cold-pressor paradigm. The primary finding of this research was greater right cerebral activation to stress among high-hostility subjects, as indicated by their enhanced ability to identify syllables presented to the left ear. Data further supported previous findings of heightened physiological reactivity to stress among high-hostility subjects and suggest a positive relationship between right cerebral activity and cardiovascular arousal. © 1997 Elsevier Science Ltd

Key Words: stress; asymmetry; cardiovascular disease.

Introduction

Hostility has been theorized as central to right cerebrum activity [20]. Indeed, examination of lateralized neuropsychological impairments yielded a better than 84% correct identification rate of aggressive psychopaths, depressive patients and normal controls under double blind conditions [33]. Criminal psychopaths may have left cerebrum damage purportedly leading to a predominantly right cerebrum mediation of affect.

One neuropsychological explanation of hostility suggests that the anterior right cerebrum may be responsible for the inhibition or regulation of autonomic functioning, as well as the expression of hostility. The frontal lobe, and orbital–frontal cortex in particular, appears to decrease hostility levels [1]. The orbital–frontal cortex has extensive interconnections with amygdaloid bodies of the anterior temporal region. The latter region has been frequently described as responsible for increasing hostility. Heilman *et al.* [17] hypothesized that these two extensively interconnected regions interact with each other to yield a relatively conservative and stable aggression level among normals. Thus, ablation of right orbitofrontal regions or stimulation of right anteriomedial temporal regions may yield anger, aggression. Passivity or flattened affective expression may result from stimulation of right orbitofrontal regions or ablation of right anteriomedial temporal regions [20].

Previous experimental research supported the notion of positive and negative affective processing within the left and right cerebrums, respectively. The earliest investigations reported that left hemisphere damage was more likely to result in a catastrophic reaction than comparable right hemisphere damage [15]. Similarly, depressive symptomatology has been associated with left-frontal dysfunction [7, 27], while anosognosia or even euphoria corresponded with right anterior damage [13]. This distinction between left and right cerebral dominance for positive and negative emotional processing has been supported for even brief periods of facial expression. Using film clips to elicit happiness and disgust, electroencephalographic data were correlated with facial expressions of different valences, coded with Ekman and Friesen's Facial Action Coding System [6, 10, 11]. These researchers found heightened right anterior arousal, within both the right frontal and anterior temporal regions, during the expression of disgust relative to happiness.

The right cerebrum is apparently dominant in the regu-

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lation of physiological arousal and reactivity to stress. Wittling [32] showed subjects experimentally an emotionally positive film to either their right or left visual field. Right cerebrum (left hemispace) presentation of the emotionally laden film resulted in heightened systolic blood pressure (SBP) beyond that which followed presentation to the left cerebrum. Herridge *et al.* [18] also found that subjects showed increased Galvanic skin response (GSR) on the left hemibody relative to the right when making posed emotional faces (including anger). These findings implicated the right cerebrum in cardiovascular regulation and have been replicated. Clinical studies have also supported right cerebrum superiority in the mediation of physiological reactivity. Using GSR, Heilman *et al.* [17] determined that subjects with right cerebrum dysfunction experienced reduced arousal and reactivity. These researchers hypothesized that the right cerebrum is more closely associated with the subcortical systems responsible for arousal and affective intention.

Particularly pertinent to this study is the lateralization of heart rate (HR) control. Given the above research, it is not surprising that the right cerebrum has been found to be an important component to HR elevation. Interestingly, however, decreased HR has corresponded with arousal of the left cerebrum. This left hemisphere arousal has been theorized to suppress the right hemisphere, thereby effectively decreasing HR [34]. Hugdahl *et al.* [19] presented visual stimuli to the right hemisphere of half the subjects and to the left hemisphere of the other half. They found an anticipatory HR acceleration in the right hemisphere group and an anticipatory deceleration in the left hemisphere group 3–5 sec before stimulus presentation. Similarly, using intracarotid barbiturate injection (WADA), Zamrini *et al.* [34] found that injection to the left and right intracarotid artery corresponded with increased and decreased HR, respectively.

The specific cerebral regions most important to autonomic regulation are the insula, medial prefrontal cortex, cingulate gyrus and temporal poles [2, 24]. These anatomical regions appear central to HR regulation because of their direct projections to subcortical structures (including the hypothalamus, nucleus tractus solitarius, dorsal vagal nucleus and nucleus ambiguus), as well as neurophysiological studies showing HR changes with their stimulation or ablation [21]. Lane *et al.* [22] used WADA testing on subjects with temporal lobe epilepsy. Like Zamrini *et al.* [34], injection into the left intracarotid artery corresponded with increased HR. However, this effect was significant only among patients with left, but not right, temporal lobe epilepsy. These researchers concluded that both amobarbital and a left temporal epileptic focus may have similar suppressing effects on the right hemisphere and HR. Similarly, Oppenheimer *et al.* [26] found that, during surgery for epilepsy, stimulation of the left and right insular region was associated with decreased and increased HR, respectively.

High-hostility subjects have also been found to exhibit greater physiological arousal to the cold-pressor test relative to low-hostility subjects, perhaps suggesting increased right cerebral arousal. For example, Dembroski *et al.* [9] found that high-hostility subjects showed greater HR and blood pressure reactivity to the cold pressor than low-hostility subjects. Glass *et al.* [14] echoed these results by finding a positive association between hostility level and physiological reactivity (as indicated by HR, blood pressure, total systemic resistance and stroke volume index) to the cold-pressor test.

The dichotic listening paradigm was designed to assess cerebral asymmetry, particularly for language. An ear advantage is found when a greater proportion of stimuli presented to that ear is correctly reported by a subject. Contralateral cerebral superiority may be inferred for that type of stimulus [29]. For example, several studies have found that the left hemisphere (right ear) is generally superior at processing auditorally presented verbal stimuli for those without hearing disabilities [23, 28]. More importantly, this research suggested that individuals have an advantage in the ear contralateral to a 'primed' cerebrum, which purportedly has heightened arousal.

As suggested by previous research, subjects with high hostility levels should have heightened right cerebrum activity to stress relative to low hostility subjects. It remains uncertain, however, whether stress produces greater activity levels among hostiles across both cerebrums or mainly within the right cerebrum. The dichotic listening paradigm is used in conjunction with autonomic variables (SBP, diastolic blood pressure, HR) to help determine whether high-hostility subjects show greater overall cerebral or primarily right cerebrum reactivity to stress relative to their low-hostility counterparts. Moreover, this paradigm is used to determine whether the exaggerated cardiovascular reactivity typically found among high-hostility men occurs with general cerebral or primarily right cerebrum reactivity to the cold pressor stress.

Variables

The independent variable was self-reported hostility level (high or low) using a traditionally used measure of hostility.

Two sets of dependent variables were used in this experiment: (i) physiological indicators were SBP, diastolic blood pressure (DBP) and HR, and (ii) lateralization of brain activity was measured by ear advantages observed using a dichotic listening paradigm.

Hypotheses

Hypothesis 1

High-hostility subjects will show greater physiological (SBP, DBP, HR) reactivity to stress than low-hostility subjects.

Hypothesis 2

High-hostility subjects will show an increased left ear advantage following stress than low-hostility subjects, indicating heightened right cerebral arousal.

Methods

Subjects

Fifty (25 low-hostility and 25 high-hostility) right-handed male participants were recruited from the undergraduate Psychology pool. Subjects must have self-reported no history of hearing aids, hearing problems (e.g., tubes in the ears or infections), major illness or head injury. Only males were used because it was essential to ensure as much homogeneity as possible within the experiment to draw conclusions based solely on independent variable differences. Subjects with sufficient right hemibody preference based on the Coren–Porac–Duncan laterality test [5], who additionally tested in both the top and bottom third on the Cook–Medley Hostility Scale (CMHS) [4] were classified as high- or low-hostility level subjects, respectively.

Self-report

During group testing, subjects were first required to complete a questionnaire assessing medical history. Subjects were then administered the Coren–Porac–Duncan laterality test to determine hemibody preference. This self-report assessed right (−1) and left (+1) hemibody preference based on reported preferred use of either eye, ear, arm and leg. Scores on the test range from a possible −13 to +13, indicating extreme left and right 'handedness', respectively. A score of +5 was required for further participation in the experiment.

Subjects were then administered the CMHS. The CMHS is the most often used measure of hostility and shows validity as a predictor of medical, psychological and interpersonal outcomes [3]. Given the measures predictive utility and global nature of its questions (e.g., "I have, at times, had to be rough with people who were rude or annoying"), the CMHS has been considered a trait, rather than state, indicator of hostility. Fifty subjects (25 each) were classified as low- or high-hostility based on their answers on the CMHS and eligibility criteria.

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 cold-pressor and dichotic listening apparati. HR and blood pressure assessment equipment were also located in this room.

Physiological. SBP, DBP and HR were assessed using the Norelco Healthcare Electronic Digital Blood Pressure Pulse Meter With Microphoneless Cuff (1985; Model HC3030). The accuracy of this device has been obtained in previous work [16]. SBP and DBP were assessed using the oscillometric method. The accuracy of HR is reported to be within 2% or 1 beat per minute, while blood pressure is ±3 mm Hg of those auscultated [25].

Hearing. Auditory acuity was assessed using the Qualitone Acoustic Appraiser (Model WR-C) and lightweight portable Qualitone TD-39 headphones.

Perceptual. A computer-synthesized audiotape, made by the Kresge Hearing Research Laboratory, of 30 pairs of concurrently voiced consonant vowels (CVs: ba, da, ga, ka, pa, ta) were played for each subject. This tape has been used as a dichotic listening device in numerous studies. Stimuli were presented at about 75 dB by a Sony WM-F57 dual channel tape player using pioneer SE-30D(BK) headphones. The interstimulus interval was 6 sec. The six CVs were printed as 2-cm black upper case letters on a $96 \times 144\ cm^2$ index card displayed about 0.5 m in front of the subject.

Cold pressor. The ice water for the cold-pressor test was maintained in a small ice cooler (Gott Corporation, model 1916 2) at 4°C. Water temperature was measured using a standard mercury thermometer (Fisher Scientific, model 14-985E).

Procedure

High- and low-hostility subjects were invited back for further participation in the experiment within a 1-month time period. Auditory acuity was assessed by a pure-tone test using the Qualitone Acoustic Appraiser and lightweight portable Qualitone TD-39 headphones. To continue in the experiment, subjects had to correctly identify 10 of 12 two-syllable words presented individually to each ear at 20 dB.

The experiment consisted of three parts [1]—Prestress, Stress and Poststress phases.

Prestress phase. Participants were fitted for blood pressure and HR readings. The blood pressure monitor was strapped to each subject's right upper arm. The researcher left the laboratory and gave the following instructions: "Please take about one minute to become accustomed to your surroundings. Please sit still in the chair and face forward towards the opening in the screen before you." HR, SBP and DBP data were collected twice in succession at the end of the 2-min baseline period. To determine the accurate reading, a third reading was taken if the first two readings differed by 6 beats per minute (HR) or 20 mm Hg for either SBP or DBP.

A brief training phase introduced the dichotic listening procedures. The experimenter read and pointed to each of the six phonemes on the index card and had the subject repeat each phoneme. Headphones were then used for the auditory presentation of the phonemes and the subject was instructed to state the phoneme that they heard. The researcher provided corrective feedback. The subject had to correctly identify five of the six phonemes to continue participation.

Subjects were then told:

> "You are about to hear 30 trials of syllables. You will hear a syllable in one ear and another syllable in the opposite ear, and it will sound like two people talking to you at the same time. Your job is to listen very carefully and point to the syllable on the chart that you hear most clearly."

After 30 trials, the experimenter gave the following instructions:

> "You are about to hear 30 trials of words. You will hear a syllable in one ear and another syllable in the opposite ear, and it will sound like two people talking to you at the same time. Your job is to listen very carefully and point to the syllable on the chart that you hear in your *left* ear."

The experimenter tapped lightly on the left earphone to ensure that the subject understood the instructions. After 30 trials, the experimenter gave the following instructions:

> "You are about to hear 30 trials of words. You will hear a syllable in one ear and another syllable in the opposite ear, and it will sound like two people talking to you at

the same time. Your job is to listen very carefully and point to the syllable on the chart that you hear in your *right* ear."

The experimenter, as before, tapped lightly on the subject's right earphone to ensure his understanding of the instructions. All responses were recorded.

Stress phase. Subjects were then given the following instructions:

"When you are instructed, please place your left hand in the water to a point about one inch above your wrist. You will be asked to keep your hand in the water for 45 seconds. Although this may be difficult, please try your hardest to keep your hand in the water until instructed to take it out. Do you have any questions? O.K., begin."

After 45 sec, the subjects were asked to remove their hand from the water.

Poststress phase. The subjects were then asked to "Please take about one minute to relax. Please sit still in your chair and face forward towards the opening in the screen in front of you." Subjects' HR, SBP and DBP were then assessed and recorded following the procedures in the Prestress phase.

The dichotic listening procedure was performed according to the procedures outlined in the Prestress phase and, again, using the separate conditions (no focus, focus right and focus left).

Both the headphone position and the directions to 'focus left' and 'focus right' were counterbalanced between subjects. The 'focus' conditions were included to determine subjects' ability to shift attention from an unfocused to a focused location. The order of directions (focus left and focus right) were maintained within each subject, throughout Baseline and Post-test phases.

At the completion of the experiment, subjects indicated (i) the perceived intensity of the cold-pressor paradigm (1 = not intense, 3 = moderately intense, 5 = extremely intense) and (ii) whether they felt low or high hostility relative to other undergraduates in the subject pool. The latter variable was coded for accuracy (1 = accurate identification, 0 = inaccurate identification).

Results

To compare groups (low and high hostility) on descriptive measures, t-tests were conducted on scores obtained on the CMHS and the Laterality Questionnaire. The high-hostility group scored significantly higher on the CMHS (mean = 31.56, S.D. = 2.97) than did the low-hostility group (mean = 14.88, S.D. = 3.7) [$t(48) = 17.57$, $P < 0.05$]. On the Coren–Porac–Duncan Laterality Questionnaire, the high-hostility group (mean = 8.2, S.D. = 2.83) did not have significantly different scores relative to the low-hostility group (mean = 9.32, S.D. = 2.81) [$t(48) = 1.4$, $P > 0.05$].

Independent analyses of variance (ANOVAs) were performed on three dependent variables obtained during the dichotic listening paradigm—laterality index (LI) score, number of correctly identified stimuli in the left ear and number of correctly identified stimuli in the right ear. LI scores were first analysed to help assess general trends of ear dominance. The number of syllables identified at each ear were then analysed to more specifically test for altered cerebral arousal. All pairwise comparisons were made

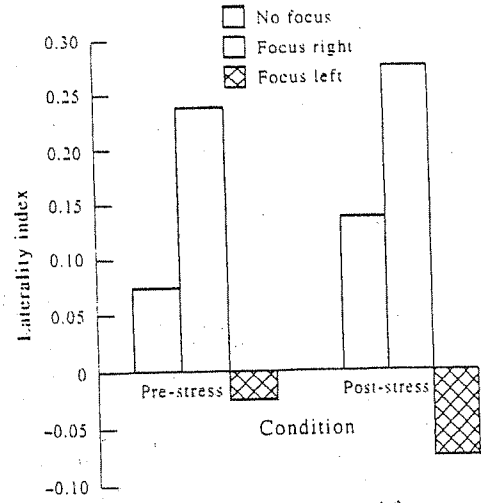

Fig. 1. LI score by condition and focus.

using Tukey's Studentized Range Test [31] to control for experimentwise error rate.

LI scores were obtained by the calculation below:

$$LI = (pR - pL)/(pR + pL),$$

where pR = proportion of correctly identified right ear stimuli and pL = proportion of correctly identified left ear stimuli. The LI score ranges from +1 (perfect right ear advantage) to −1 (perfect left ear advantage).

For LI scores, the condition × focus interaction was significant [$F(2,94) = 5.8$, $P < 0.05$; see Fig. 1].

A main effect of focus was also significant [$F(2,96) = 18.76$, $P < 0.05$]. Specifically, all three mean LI scores for each focus were significantly different from each other. Finally, the group × condition interaction approached significance [$F(1,48) = 3.96$, $P = 0.0524$; see Fig. 2]. A *post-hoc* analysis, using change scores of LI and HR data, found a correlation between these measures of $r = 0.07$ ($P > 0.05$).

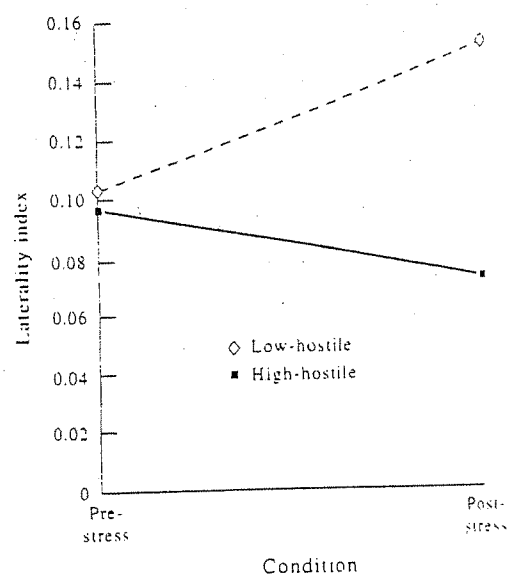

Fig. 2. LI score by group and condition.

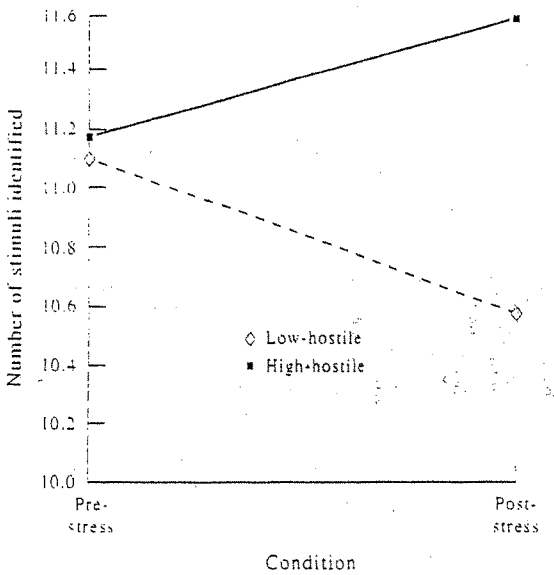

Fig. 3. Number of stimuli correctly identified by left ear by group and condition.

For the number of correctly identified stimuli presented to the left ear, the main effect of focus was significant [$F(2,96)=17.48$, $P<0.05$]. Specifically, the number of correctly identified stimuli by the left ear during each focus was significantly different relative to the number identified during the other two focus conditions. As seen in Fig. 3, the group × condition interaction was also significant [$F(1,48)=7.01$, $P<0.05$], suggesting a greater ability to accurately perceive stimuli presented to the left ear among the high-hostility group after stress induction.

For right ear syllable identification, only a main effect of focus was statistically significant [$F(2,96)=18.54$, $P<0.05$]. Specifically, the number of correctly identified stimuli by the right ear during each focus was significantly different relative to the number identified during the other two focus conditions.

Group means and standard deviations of physiological measures (SBP, DBP and HR) are displayed in Table 1. Independent ANOVAs were performed on these variables.

For SBP, the main effect of condition was statistically significant [$F(1,48)=43.94$, $P<0.05$]. That is, SBP was significantly higher during the poststress condition. In addition, the main effect of group approached significance [$F(1,48)=3.43$, $P=0.0703$], with the high-hostility group having the greater SBP. For DBP, the main effect of condition was significant [$F(1,47)=10.25$, $P<0.05$], with subjects having greater DBP during the poststress condition.

The main effect of condition was statistically significant for HR [$F(1,47)=8.86$, $P<0.05$], with subjects having greater HR during the poststress condition. A group × condition interaction was also found to be significant [$F(1,47)=7.07$, $P<0.05$]. Paired contrasts of group × condition data showed that non-significant differences existed between the low- and high-hostility groups during the Prestress condition (68.04 and 69.08 beats per minute, respectively). However, significant differences were established during the Poststress phase (68.40 and 75.48 beats per minute, respectively; Tukey's HSD = 2.85).

Correct assessment of hostility level was determined by calculating the percentage of low- and high-hostility subjects who accurately identified their own hostility level ('low' or 'high'). Relative to low-hostility subjects (mean = 0.88, S.D. = 0.332), high-hostility subjects (mean = 0.20, S.D. = 0.408), were significantly less accurate when assessing their own hostility level [$t(48)=6.46$, $P<0.05$]. Low- (mean = 2.72, S.D. = 0.792) and high-hostility subjects (mean = 2.72, S.D. = 1.137) did not differ on self-reported intensity of the cold-pressor paradigm using a 1–5 Likert scale [$t(48)=0.00$, $P>0.05$].

Discussion

Analysis of data collected from the dichotic listening procedure supported the *a priori* hypothesis of greater right cerebrum reactivity to stress among high-hostility subjects. As seen in Fig. 2, high-hostility subjects showed heightened left ear dominance after stress relative to low-hostility subjects. This enhanced left ear dominance, particularly after stress, may suggest heightened right cerebral arousal among high-hostility subjects [29]. Because of the greater number of contralateral bifurcations in the auditory pathway, the number of identified stimuli presented to the left ear may have been the strongest indicator of right cerebrum arousal used in this research. For LI scores, the group × condition interaction approached significance (see Fig. 2). This interaction may have been statistically insignificant because of the limited reactivity of right ear syllable identification to stress, thereby reducing the variability of LI scores.

Excluding the aforementioned main effect of focus, no other significant effects were found when analysing the number of correctly identified stimuli presented to the

Table 1. Group means and S.D. on physiological measures

	HR		SBP		DBP	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Low hostility	68.22	8.13	127.3	7.05	80.42	9.37
High hostility	72.28	9.68	131.6	8.78	81.74	9.30

right ear. Specifically, both groups showed small, non-significant increases in the number of identified right ear syllables after stress. This may suggest similar left cerebrum activity between groups.

Taken together, these dichotic listening data may support greater right cerebral reactivity to stress among high-hostility subjects. This may be supported by the group × condition interaction of LI scores, especially given the deflation of the effects significance due to similar right ear syllable identification between groups. Furthermore, the strong group × condition interaction of left ear syllable identification (see Fig. 3) may best indicate heightened right cerebral reactivity among high-hostility subjects.

The significant group × condition interaction on HR may support heightened physiological reactivity to stress among high-hostility subjects. Unexpectedly, however, these results were not strengthened by the non-significant group × condition interaction effects for SBP and DBP. This non-significance may partially result from the law of initial values [30], with high-hostility subjects showing reduced reactivity due to higher initial values [12]. With respect to previous research, positively relating right cerebrum arousal and physiological reactivity, these data may further suggest heightened right cerebral reactivity to stress.

This study uncovered data consistent with the proposed hypotheses. High-hostility subjects had a consistent left ear bias after stress when compared to their low-hostility counterparts. Further, both groups showed heightened physiological arousal after stress, and high-hostility subjects had statistically greater HR reactivity to the cold pressor. Taken together, these data suggest that cerebral reactivity to stress among high-hostility subjects may be primarily centered in the right cerebrum, purportedly within the right insula, medial prefrontal cortex, cingulate gyrus and temporal poles.

Finally, high-hostility subjects were significantly less accurate when identifying their own hostility level. These data, consistent with poor self-awareness, are perhaps attributable to right posterior dysfunction [20] proximal to the amygdaloid bodies, purportedly responsible for increased aggression. Poor self-awareness, perhaps from right posterior overactivation, may be an interesting correlate (and perhaps causal agent) of heightened hostility [8]. These self-report data must be evaluated extremely critically, as subject response may be affected by self-presentation bias.

References

1. Butter, C. M., Snyder, D. R. and McDonald, J. A. Effects of orbital frontal lesions on aversive and aggressive behaviors in rhesus monkeys. *Journal of Comparative Physiology and Psychology* **72**, 132–144, 1970.
2. Cechetto, D. and Saper, C. In *Central Regulation of Autonomic Functions*, ed. A. Loewy and K. Spyer, Oxford University Press, New York, 1990, pp. 208–223.
3. Contrada, R. J. and Jussim, L. What does the Cook–Medley hostility scale measure? In search of an adequate measurement model. *Journal of Applied Social Psychology* **22**, 615–627, 1992.
4. Cook, W. W. and Medley, D. M. Proposed hostility and pharasaic-virtue scales for the MMPI. *Journal of Applied Psychology* **238**, 414–418, 1954.
5. Coren, S. P., Porac, C. and Duncan, P. A behaviorally validated self-report inventory to assess 4 types of lateral preferences. *Journal of Clinical Neuropsychology* **1**, 55–64, 1979.
6. Davidson, R. J., Ekman, P., Saron, C. D., Senulis, J. A. and Friesen, W. V. Approach withdrawal and cerebral asymmetry: emotional expression and brain physiology. I. *Journal of Personality and Social Psychology* **58**, 330–341, 1990.
7. Demaree, H. A., Crews, W. D. and Harrison, D. W. Topographical brain mapping in depression following mild closed head injury: a case study. *Journal of Neurotherapy* **1**, 38–43, 1995.
8. Demaree, H. A. and Harrison, D. W. A neuropsychological model relating hostility to self-awareness. *Neuropsychology Review* **7**, 1997.
9. Dembroski, T. M., MacDougall, J. M., Herd, J. A. and Shields, J. L. Effect of level of challenge on pressor and heart rate responses in Type A and B subjects. *Journal of Applied Social Psychology* **9**, 209–228, 1979.
10. Ekman, P., Davidson, R. J. and Friesen, W. V. The Duchenne smile: emotional expression and brain physiology. II. *Journal of Personality and Social Psychology* **58**, 342–353, 1990.
11. Ekman, P. and Friesen, W. V. *The Facial Action Coding System: A Technique for the Measurement of Facial Movement*. Consulting Psychologists Press, Palo Alto, CA, 1978.
12. Furedy, J. J. and Scher, H. The law of initial values: differentiated testing as an empirical generalization versus enshrinement as a methodological rule. *Psychophysiology* **26**, 120–121, 1989.
13. Gainotti, G. Emotional behavior and hemispheric side of lesion. *Cortex* **8**, 41–55, 1972.
14. Glass, J. C., McKinney, M. E., Hofschire, P. J. and Fedorko, S. Cardiovascular reactivity to stress: an examination of familial trends. *International Journal of Psychophysiology* **9**, 1–11, 1990.
15. Goldstein, K. *The Organism*. American Books, New York, 1939.
16. Harrison, D. W. and Kelly, P. L. Home health care: accuracy, calibration, exhaust, and failure rate comparisons of digital blood pressure monitors. *Medical Instrumentation* **21**, 323–326, 1987.
17. Heilman, K. M., Bowers, D. and Valenstein, E. In *Clinical Neuropsychology*, ed. K. M. Heilman and E. Valenstein, Oxford University Press, New York, 1993, pp. 461–498.
18. Herridge, M., Harrison, D. W. and Demaree, H. A. Differential effects of facial configuration on bilateral skin conductance as a function of hostility. *Psychobiology* **25**, 71–76, 1997.

19. Hugdahl, K., Franzen, M., Andersson, B. and Walldebo, G. Heart-rate responses (HRR) to lateralized visual stimuli. *Pavlovian Journal of Biological Science* **18**, 186–198, 1983.
20. Kolb, B. and Wishaw, I. Q. *Human Neuropsychology*. W. H. Freeman, New York, 1990.
21. Lane, R. D. and Jennings, J. R. In *Brain Asymmetry*, ed. R.J. Davidson and K. Hugdahl. MIT Press, Cambridge, MA, 1995, pp 271–304.
22. Lane, R., Novelly, R., Cornell, C., Zeitlin, S. and Schwartz, G. Asymmetrical hemispheric control of heart rate. Paper presented at the Annual Meeting of the Society for Psychophysiological Research, San Francisco, CA, October 1988, and the Annual Meeting of the American Psychiatric Association, San Francisco, CA.
23. Ley, R. G. and Bryden, M. P. A dissociation of right and left hemispheric effects for recognizing emotional tone and verbal content. *Brain and Cognition* **1**, 3–9, 1982.
24. Mesulam, M. M. *Principles of Behavioral Neurology*. F. A. Davis, Philadelphia, PA, 1985.
25. Norelco, *Norelco Healthcare*. North American Philips Corporation, Stamford, CT, 1985.
26. Oppenheimer, S. M., Gelb, A., Girvin, J. P. and Hachinski, V. C. Cardiovascular effects of human insular cortex stimulation. *Neurology* **42**, 1727–1732, 1992.
27. Robinson, R. G., Kubos, K. L., Starr, L. B., Rao, K. and Price, T. R. Mood disorders in stroke patients: importance of location of lesion. *Brain* **107**, 81–93, 1984.
28. Snyder, K., Harrison, D. W. and Gorman, W. Auditory affect perception in a dichotic listening paradigm as a function of verbal fluency classifications. *The International Journal of Neuroscience* **84**, 65–75, 1996.
29. Springer, S. P. In *Experimental Techniques in Human Neuropsychology*, ed. J. Hannay, Oxford University Press, New York, 1987, pp. 138–166.
30. Wilder, J. In *Psychophysiology*, ed. S. W. Porges and M. G. H. Coles, Dowden, Hutchingson & Ross, Stroudsburg, PA, 1931/1957, pp. 38–46.
31. Winer, B. J. *Statistical Principles in Experimental Design*, 2nd edn, McGraw-Hill, New York, 1971.
32. Wittling, W. Psychophysiological correlates of human brain asymmetry: blood pressure changes during lateralized presentation of an emotionally laden film. *Neuropsychologia* **28**, 457–470, 1990.
33. Yeudall, L. T. Neuropsychological assessment of forensic disorders. *Canada's Mental Health* **25**, 7–15, 1977.
34. Zamrini, E. Y., Meador, K. J., Loring, D. W., Nichols, F. T., Lee, G. P., Figueroa, R. E. and Thompson, W. O. Unilateral cerebral inactivation produces differential left/right heart rate responses. *Neurology* **40**, 1408–1411, 1990.