University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

Faculty Publications, Department of Psychology | Psychology, Department of

January 1987

The Relationship of Temperament to Tolerance of Cold and Heat: Beyond "Cold Hands-Warm Heart"

Richard A. Dienstbier
University of Nebraska-Lincoln, rdienstbier2@unl.edu

Robert L. LaGuardia
University of Nebraska-Lincoln

Noreen S. Wilcox
University of Nebraska-Lincoln

Follow this and additional works at: http://digitalcommons.unl.edu/psychfacpub

Part of the Psychiatry and Psychology Commons

Dienstbier, Richard A.; LaGuardia, Robert L.; and Wilcox, Noreen S., "The Relationship of Temperament to Tolerance of Cold and Heat: Beyond "Cold Hands-Warm Heart"" (1987). *Faculty Publications, Department of Psychology*. 108.
http://digitalcommons.unl.edu/psychfacpub/108

This Article is brought to you for free and open access by the Psychology, Department of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Faculty Publications, Department of Psychology by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Published in *Motivation and Emotion, Vol.* 11, *No.3,* (1987). Copyright © 1987 Plenum Publishing Corporation. Used by permission.

The Relationship of Temperament to Tolerance of Cold and Heat: Beyond "Cold Hands-Warm Heart"[1]

Richard A. Dienstbier,[2] Robert L. LaGuardia,[3] and Noreen S. Wilcox[4]

University of Nebraska-Lincoln

Thermal regulation and peripheral arousal in episodes of emotion are dependent upon similar autonomic and hormonal processes. Thermal-tolerance measure were developed and validated in order to indirectly assess adrenergic (cold tolerance) and cholinergic (heat tolerance) responsivity. We hypothesized that cold tolerance would correlate with reduced emotionality (largely fear and anxiety) and depression, and with increased stimulus seeking and dispositions toward activity; those hypotheses were confirmed. Tentatively advanced hypotheses that heat tolerance would correlate with reduced depression and emotional states were not confirmed, but heat tolerance was positively associated with activity and (weakly) with some of the same dimensions of temperament that correlated with cold tolerance. Concepts of synergistic rather than oppositional relationships of adrenergic and cholinergic systems are discussed. The roles of autonomic strength and responsivity in positive temperament dispositions and in coping with stress and challenge are discussed, and a theoretical system is sketched that is derived from these and related findings.

[1] We are grateful to Doris Weimer for assistance in the statistical analyses.

[2] Address all correspondence to Richard A. Dienstbier, Department of Psychology, University of Nebraska-Lincoln, Lincoln, Nebraska 68588-0308.

[3] Robert LaGuardia is now at the Department of Psychology, Hobart and William Smith Colleges, Geneva, New York.

[4] Noreen Wilcox is now at Northrop Aircraft Corp., Los Angeles, California.

Stanley-Jones (1966, 1970) suggested that thermal regulation and temperament must be interrelated owing to their being dependent upon a common underlying physiological system. He noted that the sympathetic (SNS) and parasympathetic (PNS) branches of the autonomic nervous system (ANS) evolved primarily as thermal regulators, only later to serve the multiple functions of energization and inervation during emotional episodes. While the specifics of the theory proposed by Stanley-Jones seem oversimplified and are not generally accepted (i.e., that two prototypical emotions exist, consisting of rage dominated by SNS arousal, and lust dominated by PNS), his suggestion of interrelationship between the two systems is seminal and is the point from which we begin.

A significant amount is known about the physiological structures and functions of thermal regulation. By determining how temperament correlates with thermal-regulation abilities, we may infer relationships between temperament and the underlying physiological processes.

Our specific hypotheses are very different from those of Stanley-Jones and were based on the following premises: First, a primary indicator that the SNS (and associated hormonal function) is strong and responsive is an individual's ability to remain comfortable in cold temperatures; with much less certainty, the same relationship was suggested between PNS and hot temperatures. Second, when a portion of the ANS is strong and responsive, temperament is affected because the negative emotions that are associated with those autonomic functions (i.e., as anxiety with SNS function) will be reduced and controlled. Since this second point is counter to the "common sense" of some modern thought, we will spend some introductory space in its justification.

A word about our definitions: *Temperament* implies chronic tendencies to experience certain emotions readily, with little provocation, or in a wide variety of situations. A secondary aspect of our use of *temperament* implies a preference for situations that stimulate a specific emotional tone or level of arousal. *Emotionality* implies tendencies toward, primarily, fear and anxiety, and, secondarily, anger; it also implies the avoidance of fear-evoking situations. A "negative emotion," like anxiety or fear, is one that people usually prefer to avoid or eliminate.

We begin with brief summaries of the physiology of thermal regulation, on the one hand, and of emotion and temperament, on the other. Those summaries establish the dependence of those two proceses on the same physiological system, and form the basis for our hypotheses.

THE PHYSIOLOGY OF THERMAL REGULATION

Although the primary human response to changing ambient temperature is behavioral (e.g., building a fire *or* dressing warmly), *our* analysis concerns only physiological adaptations. (See Gale, 1973, for a more extensive review.)

The hypothalamus is sensitive to both increases and decreases in internal body temperature. While the hypothalamic Aronson and Sachs Center is directly responsive to increases in core body temperature, sensitivity to cold is mainly achieved through afferent stimulation from cooling skin to hypothalamus (Benzinger, 1970). The hypothalamic Krehl-Isenshmidt Center governs efferent processes by stimulating peripheral vasodilation and reducing energy output when cooling is required, *or* acts through the SNS to stimulated peripheral vasoconstriction and energy production when warming is needed (Altman, 1966, p. 296; Ogata, 1970; Cabanac, 1970).

In cold adaptation, the portion of the SNS using noradrenaline as neural transmitter and the associated hormones adrenaline and noradrenaline play a major role, as do the thyroid hormones and the adrenal-cortical steroids (hereafter, *adrenergic* will imply that portions of SNS utilizing noradrenaline as neural transmitter and the hormonal functioning of adrenaline and noradrenaline). Through various means, all of those neural and chemical agents affect cold tolerance by increasing energy production (or arousal), though noradrenaline is generaly seen as the "primary" hormone in adaptation to cold (Itoh & Kuroshima, 1977).

Cold tolerance leads to increased sensitivity to noradrenaline (LeBlanc et al., 1977), and increased adrenaline and noradrenaline generation capacity peripherally (increased availability of tyrosine hydroxylase - the rate-limiting enzyme in noradrenaline production; Bhagat & Horenstein, 1976) and centrally (Sklar & Anisman, 1981). In some species, long-term cold adaptation results in the enlargement of the adrenals and thyroid as continued high-level hormonal output is required (Chaffee & Roberts, 1971). In cold-tolerant humans, despite increased adrenergic sensitivity and capacity, resting SNS arousal rates generally appear to be suppressed, in contrast to controls who are not cold-tolerant (or exercise trained; LeBlanc, Cote, Dulac, & Dulong-Turcot, 1978).

PNS involvement in heat tolerance remains an unsettled issue, so that a heat tolerance measure cannot be assumed to assess PNS responsivity. While some investigators (e.g., Ogata, 1970; Cabanac, 1970) invoke an active PNS in peripheral vasodilation, others (e.g., Hemingway & Price, 1968) suggest merely a ceasing of SNS activity. The SNS becomes involved in heat tolerance by regulating sweating, but this is accomplished by utilizing the neural transmitter acetylcholine rather than noradrenaline, the usual (postganglionic) SNS transmitter (hereafter, the term *cholinergic* will refer to the functioning of the PNS, and to that portion of the SNS dependent upon only acetylcholine as neural transmitter). During prolonged heat adaptation in some species, the shrinking of adrenals and thyroid results in reduced synthesis of adrenaline, noradrenaline, and adrenal-cortical steriods (Chaffee & Roberts, 1971); those changes fit with the assumption that energy-stimulating hormones should be reduced during heat adaptation. Despite the logic of this relationship, Petrovic, Davidovic, and Janic-Sibalic (1976) found adrenaline rates to remain around 300070 over resting base rate (in contrast to noradrenaline and cortisol levels below base rate) in rats that were heat adapting for 10 days. Thus, the strong identification of heat tolerance with either PNS or cholinergic arousal cannot be cleanly made.

Because it is more consistent with these facts of thermal regulation, we focus upon cholinergic and adrenergic systems (instead of the PNS and SNS). (Studies with drugs that stimulate or inhibit those transmitters support the association of the adrenergic stimulation with arousal and of cholinergic ascendance with arousal reduction-e.g., Porges, 1976.)

THE PHYSIOLOGY OF EMOTION

Two major approaches have been used to explore the physiology of emotion in humans. The first involves analyzing physiological arousal following the induction of emotion by psychological manipulations. The second assesses changes in behavioral indicators of emotion or in the reported experience of emotion following the induction of physiological arousal.

Using a systematic emotion-induction approach, Levi (1972) established that any of a wide variety of emotions (Le., anger, fright, amusement), stimulated through movies, result in increases in urinary adrenaline and noradrenaline. Other research using physiological indicators of SNS arousal (e.g., heart rate, GSR, blood pressure, capillary constriction) has generally supported those findings of SNS involvement in a broad range of emotional states (e.g., in Schwartz, Weinberger, & Singer, 1981, happiness, fear, and anger). Suggestions of PNS involvement in emotions are far more tentative. Averill (1969) suggested that sadness may depend upon PNS functioning, and Schwartz, et al. (1981) noted that patterns of blood pressure and heart rate were very different for sadness, with sad affect even attenuating the arousal response induced by exercise. Whether such responses during sadness (and, by implication during depression) represent PNS or cholinergic ascendance or merely a suppression of adrenergic response is not clear, however.

Research on the physiology of stress in humans and animals using comparable approaches (e.g., Mason, 1975) has led to detailed findings, but these do not illuminate differences between emotional states. Research on facial-muscle configurations in different emotions (e.g., Schwartz, Fair, Salt, Mandel & Klerman, 1976) has also been fruitful but does not relate to our questions concerning autonomic and hormonal arousal.

Researches investigating arousal-induction techniques, ranging from artificial to natural, have shown effects upon both emotional experiences and related behavioral responses. Various emotional states have been increased by adrenaline injection (Schachter & Singer, 1962; Marshall & Zimbardo, 1979), startle (Dienstbier, 1979a), exercise (Cantor, Zillmann, & Bryant, 1975), and the induction of other emotional states (e.g., Dutton & Aron, 1974). On the other hand, attenuation of emotion and related behavioral effects has been shown with the tranquilizers chlorpromazine (Schachter & Wheeler, 1962) and phenobarbital (Cooper, Zanna, & Taves, 1978), and by the imposition of delays between events that stimulate arousal and the measurement of the resulting emotion or behavior (e.g., Dutton & Aron, 1974; Dienstbier, 1979a). Collectively, these procedures have suggested that adrenergic or SNS arousal enhances most emotional states, but, since all of the drugs used cross the blood-brain barrier, and since the psychological inductions eventually have both central and peripheral effects, it has been difficult to know what has had an effect on emotional experience.

The only consistent finding of affective increases with arousal reduction is that of depression (and possibly sadness); depression is reduced by some adrenergic stimulants and increased by some tranquilizers (e.g., Mason, 1975). The association of depression with a lack of CNS noradrenaline (e.g., Schildkraut & Kety, 1967) may imply PNS or cholinergic ascendance.

THE PHYSIOLOGY OF TEMPERAMENT

The question of types of temperament associated with balance between the divisions in the ANS is almost as old as the discovery of the SNS and PNS (e.g., Eppinger & Hess, 1910/1915). In work spanning three decades from 1940, Wenger espoused "autonomic balance" as a key to temperament. Yet the concept is seldom used in contemporary psychology (Levenson, 1983). Perhaps the lack of recent popularity of the concept stems from the low and inconsistent correlations between the composite score of physiological indices taken during rest periods with indices of personality (Wenger, 1966); nevertheless, despite minor inconsistencies in findings, high resting levels of such SNS indices as heart rate, blood pressure, and skin conductance were correlated with trait anxiety or emotionality. A more modern approach, using heartbeat patterns to ascertain SNS-PNS balance (Porges, 1976), has shown similar relationships between ANS balance at rest and temperament.

Initially appearing to be contradictory to the research cited above, an excellent body of (largerly) Scandinavian research has shown that increases in urinary adrenaline and noradrenaline (hereafter, *catecholamines)* in the context of challenge/stress situations are associated with superior performance in those situations (e.g., Q'Hanlon & Beatty, 1976). Similarly, such positive temperament characteristics as low anxiety and emotionality, and high achievement in school and life situations, are associated with greater increases in urinary catecholamines in challenge/stress contexts (e.g., Roessler, Burch, Mefferd, 1967; Johansson, Frankenhaeuser, & Magnusson, Rauste-von Wright, von Wright, & Frankenhaeuser, 1981). While large catecholamine increases are therefore associated with positive adjustment, so are rapid catecholamine reductions following the challenge/stress situations (e.g., Johansson & Frankenhaeuser, 1973; Forsman, 1980).

It is the Scandinavian research that forms the basis for our major hypotheses. Specifically, we conclude that when an underlying physiological system is strong and responsive (though not chronically "turned on"), negative emotional states and negative dispositions of temperament associated with that physiological system are controllable and attenuated. From the research on the physiology of emotion, we conclude that SNS and adrenergic involvement underlies most emotional states, with exception only of sadness, depression, and possibly sentimentality.

THERMAL RELATIONSHIPS WITH EMOTION - OTHER EVIDENCE

Given the involvement of the ANS and associated hormones in both thermal regulation, on the one hand, and emotion and temperament, on the other, we should except to see some evidence of thermal-emotional in terrelationships in existing literatures. Two such areas are summarized briefly below.

Davitz (1969) had subjects define 50 emotional experiences by selecting relevant phrases from a pool of 556 descriptive phrases. He compiled a "dictionary" of emotional definitions by using those phrases agreed upon by 33070 or more of his subjects. The phrases "warm," "warm glow," "warm excitement," or "warmth" were part of the definitions of 20 emotions (e.g., affection, contentment, delight, surprise). Cold-relevant phrases occurred in the definitions of fear and embarrassment. While such associations suggest the thermal-emotional interrelationships of interest, since we are unsure of specifically what they may mean, they did not form the basis for our hypotheses.

Relationships between thermal states and emotion have been observed by physiologists interested primarily in thermal adaption. Shepherd and Webb-Peploe (1970) noted that when human core temperature is elevated, emotion-evoking stimuli that would normally stimulate skin vasoconstriction no longer affected such vascular changes; the possibility that emotional states may be exaggerated or attenuated in thermally extreme environments is suggested. Stone (1968) found that rats rated high in "emotionality" were less able to regulate their body temperature when subjected to high and low ambient temperatures. This finding is remarkably similar to our hypotheses and our findings.

HYPOTHESES

In order to test our hypotheses, questionnaires to measure cold tolerance and heat tolerance (hereafter CT and HT when referring to scores) were developed and validated, as described below. Since cold tolerance is clearly associated with high responsivity of the SNS and with the capacity for high levels of adrenaline, noradrenaline, and related energy-stimulating hormones and steroids, we assumed that CT would provide an approximate measure of those processes. Since heat tolerance is associated with a reduction of some of those responses and the likely involvement of cholinergic processes, we assumed that HT would provide an approximate assessment of those processes. However, given that ambiguity and the lack of association of specific emotions or temperaments with cholinergic processes, our hypotheses relevant to HT are speculative.

The first five hypotheses were based upon our interpretation of the Scandinavian research, that a strong underlying neural system leads to attenuated negative emotions and dispositions of temperament; the final hypothesis has a more traditional basis.

1.Given the similar physiological substrate between cold tolerance and emotionality, we predicted that CT would be associated with reduced emotionality in general, but primarily with the emotionality components of fear and anxiety, and secondarily with anger.

2. We hypothesized that CT would correlate with a preference for fearful and suspenseful entertainment, and with stimulation seeking in general. This hypothesis is based on the principle that individuals who have a responsive physiological capability, and who can therefore easily control a specific emotional response, will more willingly select situations that evoke that response.

3. This hypothesis was derived from observations of SNS involvement in exercise and of increased adrenergic responsivity following an aerobic training program (Dienstbier, LaGuardia, Barnes, Tharp, & Schmidt, 1987). It was predicted that CT would be positively related to feelings of vigor and to seeking

high levels of activity, and negatively related to chronic fatigue.

4. If sadness, sentimentality, and depression are dependent upon cholinergic processes, they should correlate negatively with HT. Insofar as empathy may be dependent upon sentimentality, it should correlate negatively with HT as well.

5. We similarly hypothesized a positive relationship between HT and preference for sentimental entertainment.

6. We predicted that, since depression has been associated with low CNS noradrenaline, CT scores (reflecting peripheral and central adrenergic capacity) would correlate negatively with depression.

Development of Cold Tolerance and Heat Tolerance Scales

There being no previously developed thermal adaptability measures, we assumed (and saw evidence in early pilot research) that cold and heat tolerance were two separate and independent dimensions. We created a large number of statements that reflected either good or poor adjustment to either cold or hot temperatures. Prototypical poor adjustment statements in each area are "I get overheated easily in hot weather" and "I get chilled easily in very cold weather." Prototypical positive statements are "In summer, I can be comfortable in warmer clothing than most people" and "On cool nights, I do not use as many blankets as other people." Individuals were instructed to respond to each item with one of three levels of agreement, or one of three levels of disagreement. After preliminary item analyses allowed a reduction to 13 cold and 15 heat tolerance items, a final item analysis was performed in which item scores from 117 male and female college students were correlated with the cold and heat tolerance factors scores. Each scale was reduced to 9 items by eliminating those items that did not correlate with the factor scores at a level of a least $r = .40$.

Reliability. The average correlations between cold tolerance items and CT for the nine retained cold tolerance items was $r = .52$, while the corresponding average correlation for the heat tolerance items with HT was $r = .57$. Mean inter-item correlations were $r = .21$ for CT and $r = .29$ for HT, with odd-even split-half reliabilities of $r(59) = .72$ and $r(59) = .73$ for CT and HT, respectively. (Split-half reliability data were obtained from a random sample of 60 individuals from the subject pool described below.) Another independent sample of introductory psychology students, who were not involved in any other testing relevant to CT and HT, filled out the combined CT and HT inventory at two times separated by 4 weeks. In order to disguise the reliability testing, at the second testing two dummy items were added and the group was informed that since several new items had been added, retesting was required. In all, 21 males and females completed both pre- and posttests, with pre to post reliabilities of *r(20)* = .68 for CT and *r(20)* = .84 for HT.

Factorial Independence. Two principal-components factor analyses with orthogonal rotation were completed; one was done with data from the first semester and the other from second semester data, as described below. The factor structure of the second analysis essentially replicated the first, with the first factor ("general cold tolerance") composed exclusively of six CT items, and the second ("hot outside activities") and third ("dressing cool and liking air conditioning") factors composed of all nine HT items. The remaining three Ct items constituted the final factor ("stimulation with cold -i.e., liking cold showers, cold mornings, and washing in cold water).

Sex Differences. In pilot research, slightly different temperatures were determined to be needed for males and females to maintain equal discomfort at cool and warm temperatures; males were more comfortable than females at cool temperatures and less comfortable at warm temperatures. These sex differences also appear as mean differences between the sexes on the CT scale; the means were - .12 for males and - 6.69 for females *(F(I,* 286) = 30.0, *p* < 001) with a possible range of - 27 to + 27 (the higher score indicating greater tolerance for cold). The HT means were almost identical, however, being .27 for men and .02 for women.

Validity. The dimension of thermal tolerance we wished to capture with the CT and HT scales was that of a feeling of comfort in the context of low and high ambient temperatures. Validity of CT and HT was therefore established by correlating the discomfort ratings from subjects in either cool (590 F for males and 620 F for females) or warm (890 F for men and 920 F for females) ambient temperatures with their CT and HT. Correlations obtained, in the context of procedures discussed below, between CT and HT, on the one hand, and a single rating of discomfort after 20 minutes in a cool or warm environment, on the other hand, were *r(144)* = - .50, and *r(150)* = - .38, respectively. The cool and warm environment were equally uncomfortable.

While the validity correlations are only moderate, it must be considered that the correlations were based upon a single environmental discomfort rating, rather than upon a multitude of measures of discomfort taken from numerous thermal conditions.

The issue of whether CT and HT reflected different dimensions was also addressed by the data derived from the sample described below. The correlations between those dimensions for all subjects approached significance but was nevertheless very small *(r(295)* = - .09, *p* < .07); it appears, however, that the relationship between those dimensions may be different for males *(r(138)* = -.20, *p* < .01) than for females *(r(156)* = - .02, n.s.).

Having developed satisfactory measures of tolerance for heat and cold, the following research was conducted to test the hypotheses outlined above concerning an interrelationship betwee temperament and heat and cold tolerance. [5]

METHOD

Subjects

Subjects volunteered for this study to fulfill the research or library option of the basic psychology course. In order to avoid subject selection bias, the research sign-up sheet always indicated that subjects would be in a "cool (590 F) or warm (910 F) room" for 25 minutes. In the first (spring) semester, 77 male and 82 female students participated in only the cool condition in single-sex groups of 7 to 10 individuals. During the second semester (fall) of the project, 69 male and 82 female subjects participated in the warm condition. (The design did not require random assignment to temperature condition.)

In response to the postexperimental questionnaire described below, the data of seven male and seven female subjects in the cool condition were dropped owing to suspicion (that the study was a validity check for the temperature tolerance scales), leaving 145 subjects. No subjects were lost during the second (fall) semester owing to suspicion. More suspicion in the spring semester was probably due to increased sophistication about research in those second-semester students; most subjects were freshmen.

Measures of Temperament

The HT and CT scales and some of the temperament measures were integrated into a single questionnaire with a single-answer format. Subjects entered a 1, 2, or 3 to represent slight, moderate, or strong agreement, or -1, -2, or - 3 to represent similar levels of disagreement. The items were intermixed, so that at least two unrelated items were placed between any two items from the same measure.

The following inventories, modified to the 6 response format were included: The Buss and Plomin (1975) EASI temperament inventory assesses the four temperament dimensions of emotionality (with subscales of general

[5] CT and HT scales may be obtained from the first author upon request.

emotionality, fear, and anger), activity (subscales of tempo and vigor), sociability, and impulsivity (with subscales of inhibitory control, decision time, sensation seeking, and persistence).

The Mehrabian and Epstein (1972) scale of empathic tendency was included.

A modified version of Izard's (1972) discrete emotion scale plus anxiety (DES + A) was included. In Izard's format, and emotion (e.g., joy) was indicated by several individual items (e.g." delighted, happy and pleasant). Our 6-point scale format made each item into a statement indicating temperament, rather than an episodic mood or emotion state. Thus, joy was indicated by 'I am easily delighted," "I am usually happy," and "I usually feel pleasant." In addition to items indicating fatigue (not in Izard's DES + A) and anxiety (a mix of primary emotions for Izard), the following 10 DES + A factors were assessed: excitement, joy, surprise, distress, disgust, anger, guilt, shyness, fear, and contempt. Three other temperament factors, of sexual arousability, depressive tendencies, and sentimentality, were assessed, respectively, by one (Le., "I easily become sexually aroused"), two (e.g., "I get depressed a lot"), and six items (e.g., "I easily get 'choked up' with sentimental feelings").

Five items, blocked together in the questionnaire, asked about preference for movies and TV programs that were "sentimental," "scary," "sexy," "with lots of violence," or "with lots of action."

Two inventories were administered separately in their original formats. These were the' Eysenck (1963) Personality Inventory (consisting of factors of extraversion, neuroticism, and a lie scale), and the Zuckerman (1979) Sensations Seeking Scale (SSS, Form V, consisting of the four factors of thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility).

Procedure

To reward participation and to induce a set to respond honestly and carefully, subjects were given envelopes to self-address and were told that they could receive feedback about the personality inventories they were to take; over 980,10 of the subjects chose to take advantage of that (fulfilled) promise.

Subjects had been instructed to come to the lab dressed in long pants and short-sleeved shirts (or equivalent). Those not dressed accordingly made appropriate adjustments, and all were then guided into the temperature-controlled environment, a 12' x 11' x 8' (high) enclosure within the main laboratory room. (An electric heater or a pair of air-conditioners maintained the temperature within 1 degree of the temperature specified in the Validity section, above.)

Each subject was visually and auditorially isolated by booths and headphones (through which taped instructions were given). Once seated, subjects worked on their inventories. After 20 minutes in the temperature-controlled environment, subjects filled out the "discomfort rating" form, using a 6-point scale with options labeled (1) "quite comfortable," (2) "slightly uncomfortable," (3) "somewhat uncomfortable,". . . through (6) "as uncomfortable as possible." Subjects then left the temperature-controlled room to complete their questionnaires in comfort.

Subjects completed a postexperimental questionnaire, constructed in a "funnel" format, to assess from a general to specific level the degree of hypothesis-related suspicion (e.g., whether subjects felt that we were studying the validity of CT or HT by comparing it with their discomfort ratings). Since we did not expect that subjects would form specific hypotheses about the relationship between CT or HT and temperament, we asked no questions about those topics.

Subjects were debriefed, sworn to silence, and thanked.

RESULTS

The 9-item CT and HT scales were both given to all subjects in both warm and cold conditions. On the other hand, the temperature discomfort index was a single item with a different meaning, depending upon whether obtained in the warm or cool environment. Thus, it is the correlations of the temperament scales with CT and HT (rather than with the discomfort index) that provide the best data for evaluation of our hypotheses.[6]

We had predicted that CT would correlated negatively with measures of emotionality, particularly the components of anxiety and fear, and secondarily, negatively with the component of anger. The first seven lines in Table I represent various measures relevant to the anxiety and fear components, and show the predicted negative relationship between CT and measures of emotionality; the mean correlations of CT with the emotionality measures is r = .28 for all subjects (r = - .15 for men, and r = - .27 for women). The first part of hypothesis 1 is thus confirmed.

[6] Since the CT and HT scales consisted of only nine items each, and since split-half reliability data were generated, corrections for attenuation of the CT and HT scales were applied to the raw correlations. Those corrections provide a better estimate of the correlations of the underlying factor of cold and heat tolerance with the scores obtained from the temperament indices. Those corrected figures are given in the data Table I through IV. The correction results in correlation figures that are only 18% greater in magnitude than the uncorrected correlations.

Table I. Correlations Between CT and HT and indices of Emotionality, Anxiety, and Fear, and of Anger

Emotionality scales items	Cold tolerance: All *Ss*[a] (*N* = 296)	Cold tolerance: Males (*N* = 139)	Cold tolerance: Females (*N* = 157)	Heat tolerance: All *Ss* (*N* = 296)	Heat tolerance: Males (*N* = 139)	Heat tolerance: Females (*N* = 157)
Neuroticism (Eysenck)	−.20[c]	−.20[b]	−.13	−.14[b]	−.02	−.22[c]
Anxiety (Izard, 13-item)	−.19[c]	−.13	−.19[b]	−.20[c]	−.11	−.26[c]
Surprise (Izard, 3-item)	−.31[d]	−.21[c]	−.28[d]	−.02	−.14	+.09
Fear (Izard, 3-item)	−.24[d]	−.06	−.27[c]	−.09	−.12	−.09
Emotionality total score (Buss & Plomin, EASI)	−.34[d]	−.15	−.36[d]	−.16[c]	−.19[b]	−.14
Fear subscale (EASI)	−.39[d]	−.27[c]	−.34[d]	−.12	−.11	−.12
General emotionality Subscale (EASI)	−.26[d]	−.01	−.31[d]	−.11	−.12	−.09
Anger Scale Items						
Contempt Izard, 6-item)	.02	.07	−.12	−.15[b]	−.22[b]	−.11
Anger (Izard, 3-item)	−.12[b]	−.12	−.15	−.09	−.11	−.09
Anger subscale (from EASI emotionality scale)	−.12[b]	−.04	−.19[b]	−.14[b]	−.19[b]	−.11

[a]It may be noted that correlations of emotion measures with CT for males and females combined are often higher than the mean correlation that would be obtained from a combination of the separate male and female correlations. This is due to a sex effect caused by females being lower on CT (as indicated above) and higher on the emotionality-anxiety-fear-neuroticism measures; e.g., on the 13-item Izard anxiety measure, the mean for males is −13.1 and −10.6 for females. Thus, the best estimate of the size of the correlations across the sexes may usually be the average of the correlations for the two sexes rather than the "All *Ss*" correlation.

[b]$p < .05$.

[c]$p < .01$.

[d]$p < .001$.

The last three scales of Table I represent the anger component of emotionality. Correlations between CT and the anger measures are considerably weaker, with the mean correlation across the three measures being r = -.10 for all subjects (r = - .03 for males and r = - .15 for females). The second section of hypothesis 1 is not confirmed.

There were no predictions concerning correlations of those temperament dimensions with HT. The mean correlation for all subjects of HT with the anxiety and fear scales was an insubstantial r = - .12 (with the same correlation for men and for women). Comparable mean correlations of HT with the anger measures reveal a similar weak pattern of r = -.13 for all subjects (r = -.17 for males and r = -.10 for females).

We had predicted a positive association between CT and stimulation-or emotion-seeking. The first four scales in Table II represent sensation- or emotion-seeking inventories. The pattern of correlations with CT indicates a small but consistently significant relationship, as indicated by a mean correlation across the four inventories of r = .21 for all subjects. That relationship may be strong for women (r = .22) than for men (r = .12), but it may not be substantially greater than similar relationships between HI ans stimulation-seeking (with a mean for all subjects for r = .15; r = .17 for men and r = .14 for women).

As indicated in the lower section of Table II, correlations between CI and preference for "scary" or "action" entertainment were modest but consistent, while comparable correlations with HT were small and inconsistent. The correlation for all subjects between CT and aggressive movies is largely the result of sex differences (males being more cold-tolerant and higher in preference for aggressive entertainment). The second hypothesis is largely supported.

We predicted that CT would correlate positively with indicators of activity or vigor and negatively with fatigue. As indicated by the data in Table III, that third hypothesis was confirmed; unexpectedly, however, the correlations of those variables with HT were similar in strength and direction.

Our tentatively advanced fourth hypothesis was that HT would correlate negatively with sadness, depression, and sentimentality, since those emotions may depend upon cholinergic processe. The first three scales of Table IV indicate a pattern of weak and inconsistent relationships between HT and those variables, with one of the statistically significant correlations (albeit small, for men, the correlation of depression and HT) being in the direction opposite to the hypothesis.

An empathy scale was included since it was thought the empathy may depend somewhat on dispositions toward sentimentality, and hence be similarly related to HT. While the correlational patterns of sentimentality and empathy are similar, the correlations with HT are too insignificant to allow meaningful conclusions. The fourth hypothesis is not confirmed.

Table II. Correlations[a] Between CT and HT and Indices of Sensation and Emotion Seeking

Personality scale items	Cold tolerance: All *Ss* ($N = 296$)	Cold tolerance: Males ($N = 139$)	Cold tolerance: Females ($N = 157$)	Heat tolerance: All *SS* ($N = 296$)	Heat tolerance: Males ($N = 139$)	Heat tolerance: Females ($N = 157$)
Thrill and adventure seeking (Zuckerman SSS)[a]	.31[d]	.13	.33[d]	.17[b]	.15	.19[b]
Experience seeking (Zuckerman SSS)[a]	.21[c]	.16	.27[b]	.22[c]	.27[b]	.19
Total SSS (Zuckerman)[a]	.18[c]	.10	.13	.10	.12	.09
Sensation seeking (from Buss & Plomin EASI, impulsivity factor)	.16[c]	.11	.16[b]	.12[b]	.14	.09
Thrill and suspense entertainment preference						
Scary movies and TV (1-item)	.25[d]	.19[b]	.28[d]	.05	.07	.04
Action movies and TV (1-item)	.16[c]	.14	.11	.01	−.18[b]	.15
Anger-relevant entertainment						
Aggressive movie and TV (1-item)	.25[d]	.14	.04	−.04	−.09	−.01

[a]Since the split-half reliabilities of the subscales of the Zuckerman SSS were readily available, the correlations are corrected for attenuation of both the Zuckerman SSS and the CT and HT scales.
[b]$p < .05$.
[c]$p < .01$.
[d]$p < .001$.

Table III. Correlations Between CT and HT and Indices of Energy and Fatigue

Scale items	Cold tolerance			Heat tolerance		
	All *Ss* (N = 296)	Males (N = 139)	Females (N = 157)	All *Ss* (N = 296)	Males (N = 139)	Females (N = 157)
Fatigue (Izard, 4-item)	$-.24^{c}$	$-.19^{a}$	$-.25^{b}$	$-.34^{c}$	$-.27^{b}$	$-.40^{c}$
Activity total score (Buss & Plomin, EASI)	$.19^{b}$	$.18^{a}$	$.18^{a}$	$.14^{a}$	.08	$.19^{b}$
Activity subscale (EASI)	.09	.14	.07	.07	.02	.11
Vigor subscale (EASI)	$.24^{c}$	.16	$.22^{b}$	$.18^{b}$	.13	$.22^{b}$

$^{a}p < .05$.
$^{b}p < .05$.
$^{c}p < .001$.

Table IV. Correlations Between CT and HT and Indices of Sadness, Depression, Sentimentality, and Empathy

Scale items	Cold tolerance			Heat tolerance		
	All *Ss* (N = 296)	Males (N = 139)	Females (N = 157)	All *Ss* (N = 296)	Males (N = 139)	Females (N = 157)
Sadness (Izard, 4-item)	.07	.04	$-.22^{b}$	$-.13^{a}$	−.06	$-.18^{a}$
Depression (Izard, 2-item)	$-.20^{b}$	−.22	$-.21^{a}$	.01	$.19^{a}$	−.13
Sentimentality (3-item)	$-.25^{c}$	−.05	−.13	.08	−.09	−.07
Empathy (Mehrabian & Epstein)	$-.21^{c}$	−.02	−.09	−.02	.08	−.01
Seeking sentimental movies and TV (1-item)	$-.18^{b}$	.06	−.08	−.06	−.08	−.01

$^{a}p < .05$.
$^{b}p < .05$.
$^{c}p < .001$.

In hypothesis 5 we predicted a positive correlation of HT with seeking sentimental entertainment. The final scale on Table IV addresses that issue with essentially null findings. (The only substantial correlation is due to a sex difference in the means on the two correlated variables, as discussed above.) All hypotheses concerning HT were therefore discomfirmed.

Concerning the sixth hypothesis, as indicated in Table IV, depression shows the predicted negative correlation with CT.

The statistically significant correlations between CT, on the one hand, and sentimentality, empathy, and seeking sentimental entertainment, on the other, are all products of sex differences in mean scores on CT (males higher) and on sentimentality, empathy, and sentiment seeking (women higher).

Factor Structure. For a final look at the relationship between thermal tolerance and temperament, all of the measures of those constructs were subjected to principal componepts factor analyses with varimax (orthogonal) rotation. Owing to the occasional influence of sex differences on overall correlations (as explained above), separate factor analyses were done for females and males, in addition to the analysis of all subjects combined.

The number of factors was determined principally from examination of the combined data. Five factors were rotated owing to eigenvalues past Factors 5 (1.34) leveling toward asymptote (i.e., Factor 6 at 1.17, at 1.09, 8 at 1.00, etc.).

The first factor was clearly Emotionality, with all of the fear, neuroticism, sadness, and anxiety items included. This factor was similar for the combined data and for the male and female data separately.

The second factor for the combined data and for males and the fourth factor for women was Sentiment, combining the sentimentality measures with the preference for sentimental entertainment and empathy measure.

The third factor for combined data and for men, and the second for women was Activity, consisting of the main activity and vigor scores, with "fatigue" negatively related.

The fourth factor for the combined data and for males consisted of the major Sensation-Seeking items. For women, those items were joined by preference for "scary" and "aggressive" entertainment, and by the CT score, to form the third factor for women.

The fifth factor women combined heat tolerance with "action" entertainment preference and the temperament label of "surprise." The three component were all positively related to the factor. For all data and for men,' this was the major entertainment factor, with both CT and HT combined with "action," "scary," and "aggressive" entertainment preference. However, HT is the only item negatively associated with the factor.

It is interesting that the factor analyses have shown the CT score to be more strongly related to entertainment preference items than typical emotionality-temperament items. And it is symptomatic of the weaker relationships between HT and the other major dimensions of interest that it differed substantially between the sexes in factor positioning and in valence on its factors.

CONCLUSIONS

Possible Alternative Explanations

Even the larger correlations reported above are modest. This underlines the necessity for considering possible alternative explanations for our findings. Two types of alternatives seem plausible. First, our correlations could be due to shared "method variance." Second, other extraneous "third" factors could account for our correlations by consistently biasing responses on the two correlated dimensions. Both questions are answered by the same observations.

When broad third factors, such as wishing to present oneself in a socially desirable manner, subject intelligence, or desiring to appear capable or masculine or feminine, are considered, it seems unlikely that any would bias responses more on CT than HT. Thus, if either shared method variance or correlated third factors were credible alternatives, then positive correlations should be found between CT and HT themselves, and the pattern of correlations between CT and the other variables should be like the pattern of HT with the others.

The data do not conform to those patterns. The correlation of HT with CT is small *(r(295)* = - .09), nonsignificant, and negative. Detailed examination of other areas of the correlation matrix yields similar conclusions. For example, if consistencies between CT and preference for "scary" and "action" entertainment were to be explained as mediated by "bravado," or a set to appear "tolerant of all things," then a positive relationship between CT and liking "sexy movies and TV programs" should also occur, but it does not *(r(295)* = .04, n.s.). While the correlations about which we had no hypotheses tend to be small and nonsignificant, the correlations between CT and the emotionality indicators are among the highest in our matrix (except for those that are essentially reliability coefficients).

Thus, although it is.4mpossible to rule out absolutely all explanations based upon shared method variance or third factors, our data do provide some evidence against the general applicability of such explanations to these correlations.

Validity Reconsidered. The validity and reliability data reported above for CT and HT establish them as reasonable measures of comfort in response to thermal variation. The broader validity issues considered here concern (I) whether temperament inventories and our thermal comfort scales assess underlying physiological processes, (2) what those underlying physiological processes are, and (3) what implications these answers and our data have for conceptualizations of the ANS.

Do CT and HT assess physiological processes? An answer is suggested by both the older literature on autonomic balance and the newer Scandinavian literature on the relationships of the catecholamines to temperament. In both traditions, direct measures of physiological processes (SNS and PNS indicators, on the one hand, and catecholamines assays, on the other) do correlate with self-assessments (and assessments made by others) on temperament inventories. Furthermore, our findings of substantial correlations between thermal tolerance measure and temperament indicators suggests that both may owe some variance to underlying physiology, for alternative explanations for the correlations are not compelling. At best, however, CT and HT assess underlying physiological processes very indirectly. Thus, it is understandable that correlations between our thermal-tolerance measures and temperament are small. No corrections for attenuation due to any form of unreliability can compensate for such indirectness of measurement.

What physiological functions are measured by CT and HT? The dependence of cold tolerance upon adrenergic hormones and upon the adrenergic portion of the SNS is well established by research on the physiology of thermal adaptation and is not brought into question by our data. We have no reason to doubt CT as a measure of neural and hormonal adrenergic responsivity or capacity.

With respect to heat tolerance, we began with uncertainty concerning whether to emphasize decline in the adrenergic processes of cold tolerance or the active involment of PNS cholinergic processes (in addition to the cholinergic SNS process of sweating). Since our data provide no direct information, we remain uncertain of the underlying physiological processes the HT score may assess. However, indirect interpretations of our findings point toward tentative conclusions.

The lack of a substantial negative correlation between CT and HT, and their factorial independence from each other, was not created by purposeful item selection; it is therefore a meaningful null finding. It suggests that HT does not index adrenergic weakness, since such weakness should be associated with poor cold tolerance. We noted above (in the review of the Scandinavian research) that optimal adrenergic responsivity includes (within the same person) both strong adrenergic responsivity and quick adrenergic decline in response to an episode of stress/challenge. This implies that if heat tolerance depends upon suppressing adrenergic functioning, such an ability is not necessarily antagonistic to adrenergic responsivity, as assessed by CT. Thus, while HT is probably not an indicator of adrenergic weakness, it may be an indicator of adrenergic suppression. But HT as an indicator of cholinergic function also remains a possibility. We have narrowed the options for the physiological meaning of HT very little.

What are the implications for the nature of the ANS? We began by conceptualizing tolerance of heat and of cold as essentially opposite functions, depending upon opposed physiological systems; such thinking follows naturally from traditional ideas of SNS-PNS antagonism and of "autonomic balance"; seeing adrenergic and cholinergic functions as oppositional follows easily.

There are reasons to reject this view of systemic antagonism. Historically, not all scholars of the ANS have shared the view of the majority. Stöhr (cited in VanToller, 1979) was not alone in suggesting that no anatomical basis existed for the assuption of PNS-SNS opposition. Other researchers found evidence for both PNS and SNS involment within single emotions (as in anger; Arnold, 1945; Ax, 1953). Finally, both noradrenaline and acetylcholine are essential in SNS functions, since the latter is the preganglionic transmitter throughout the SNS. Together, these observations suggest cooperative rather than oppositional systems.

In concert with this moderated view, we offer three observations. First, as indicated above, we found factorial independence (and no substantial negative correlation) between CT and HT. Second, we have (informally) observed may people who are very tolerant of both heat and cold, and other individuals who are tolerant of neither (as is common for the elderly); the negative correlation, which did not appear in our research, seems missing outside of the lab as well. Third (as elaborated below), our data reveal several areas where substantial correlations of temperament variables exist equally with CT and HT. These observations are incompatible with a view of oppositional forces in cold and heat tolerance, but not to a more synergistic relationship.

Immediate Implications of the Findings. We believe that physiological processes of interest here are more likely to cause differences in temperament than vice versa. While our discussion, below, will often imply causality, the nature of correlational data precludes their acceptance as proof of any causality, and we do not offer these data as such proof.

The correlations between the variables of interest are generally stronger for women than for men We had the impression (though no data) that the women filled out their long personality inventories more carefully; the men often appeared hurried and careless. It may be that there is less error variance in the women's data.

The confirmation of our first two hypotheses suggests that greater adrenergic responsibility or capacity is associated with reduced emotionality and with stimulation seeking; while such relationships were stronger for the female subjects, we suspect that our sex differences may be illusory. We regard this findings as providing clear support for the Scandinavian research, which has shown reduced emotionality to correlate with catecholamine availability in challenge/stress situations.

We were surprised to find directionally consistent (albeit somewhat weaker) correlations between the emotionality dimensions and HT. As discussed above, such observations bring into question the concept of oppositional physiological forces underlying HT and CT. The findings mentioned above, of high adrenaline levels maintained (in rats) for 10 days during heat adaptation, reflects this ambiguity in HT (Petrovic et al., 1976).

No conclusions are possible regarding anger; the small and occasionally statistically significant correlations with anger were in the direction predicted.

Confirmation of the third hypothesis suggests adrenergic association with activity (and opposed to fatigue) and in general energy and alertness systems. Dienstbier et al., (1987) noted increased urinary catecholamines (following mental challenge/stress situations but not following rest) after a semester-long program of aerobic training. Together, these two sets of fin. dings suggest mutual causality between those systems; adrenergic responsivity stimulates activity, and, in the long term, activity stimulates adrenergic responsivity.

The findings of similar relationships between HT and indices of activity and vigor (and the negative correlation with fatigue) were not predicted and are more difficult to interpret. However, if HT is (in part) an index of acetylcholine availability or responsivity, the relationship with activity is understandable, since acetylcholine is the neural transmitter in the efferent stimulation of voluntary muscles.

Confirmation of the sixth hypothesis suggests that greater adrenergic capacity leads to reduced depression. While CT undoubtedly indicates peripheral more than CNS adrenergic functioning, recent findings that the catecholamines cross the blood-brain barrier suggest that CNS noradrenergic levels may correspond with peripheral availability, and that central levels may increase with cold tolerance. The finding of higher noradrenaline levels it the brains of cold-tolerant animals (Sklar & Anisman, 1981) supports this view. This finding is consistent with the above relationships of activity and stimulation seeking, both associated with high adrenergic responsivity, since depression is usually characterized by lower activity and lowered stimulation seeking.

With respect to our hypotheses concerning tolerance for heat, the pat. tern and size of the correlations between HT and sadness, sentimentality, depression, and empathy prevent acceptance of our hypotheses.

The imaginative writings of Stanley-Jones, suggesting two basic emotions of SNS-mediated anger and PNS-mediated lust, did not form the basis of our hypotheses. Nevertheless, the relevant correlations were zero-order and nonsignificant between the thermal tolerance scales, on the one hand, and self-ratings of sexuality and of seeking sexual entertainment, on the other hand. The small negative correlations between anger and CT suggest relationships opposite of the Stanley-Jones hypothesis. While the more specific predictions of Stanley-Jones were not supported, his basic idea of a connection between emotion and thermal adaptability is supported by these data.

A Broader Theoretical Perspective. Motivation is a central function of emotion (after Izard & Tomkins, 1966). The experience of emotion motivates selective information search, energizes the organism for situation-appropriate responses, and stimulates the learning of skills to be applied in similar future situations. The keys to responding in crucial situations without a large emotional response are the acquisition of the necessary skill and the availability of the necessary energy to cope successfully.

Consider, first, the relationship between skill acquisition and emotional response—a relationship discussed more extensively elsewhere (Dienstbier, 1979b) and summarized here. It is a common and well-documented observation that once successful coping responses are learned, those responses may be executed calmaly, even in situations that originally evoked intense emotion. The calm avoidance responses of experienced dogs in timed-shock situations (e.g.; Solomon & Wynne, 1954) provide laboratory examples of this transition from unskilled and highly emotional responses to skilled and cool responses later. People learning to ride bicycles undergo similar transitions from fearful, poorly skilled beginners to cool navigators through potentially lethal automobile traffic. Once the organism has acquired the necessary skills, large emotional responses are unnecessary and undoubtedly maladaptive.

The availability of sufficient energy to cope will often be as important as the availability of skill. Those situations that are sufficiently threatening that they once evoked a strong emotional response may require major muscle responses or sustained concentration (the brain is a major energy consumer). When the body's arousal system is capable and responsive, so that it is easy to generate the energy needed to cope with the current crisis, then there is no need for strong emotional responses to stimulate arousal. Thus, the individual with the well-developed and highly responsive arousal capability has more potential energy to meet life's challenges, and will find fewer situations that evoke strong negative emotional responses; such an individual will be label, by self and other, as "unemotional."

With the above in mind, we advance the following broad but simple concept to integrate the findings of this research, the work of the Scandinavian researchers reviewed above, and the findings by Dienstbier et al. (1987) of increased catecholamine responsivity following aerobic training. (Remember that HT and CT represent orthogonal factors and yet each correlates negatively with emotionality (though HT much less than CT) and positively with sensation-seeking and activity dimensions.) Within normal limits, increased responsivity or "strength" of the autonomic nervous system (at a minimum those components indexed by CT, HT, and urinary catecholamines) is adaptive, where "adaptive" implies an ability to control the negative responses (emotionality, depression, etc.) associate with ANS functioning and to benefit from the positive functions (e.g., dispositions toward activity and stimulation).

Implications in Other Areas

Sex Differences in Temperament. Several intriguing questions are raised by the relationship of temperament to thermal adaptability. For example, given that males and females differ in tolerance for cold, males by implication may have more responsive adrenergic capacities. (This cold-tolerance difference favoring males should cause temperament differences between the sexes, even when the temperament dimension is equally related to HT and CT.). If so, we should expect corresponding sex differences in temperament; such differences would include, for females, greater susceptibility to depression,[7] increased tendencies toward emotionality, and reduced dispositions toward sensation seeking and toward highly active endeavors.

Effects of Climate and Season on Mood and Temperament. We should expect seasonal variations in temperament beyond those induced by seasonal changes in life-style, and even the possibility of short-term changes in mood and emotional state influenced by episodic fluctuations in temperature. (A literature exists in modern social psychology of studies on the impact of, usually, heat on aggression, mood, behavior in crowded circumstances, etc., but that work has not been cited here because that research has never isolated the impact of thermal effects from the stress of discomfort by using equally uncomfortable control groups.)

We should also expect that people from different climates will differ in temperament, with those from cold regions displaying reduced emotionality. While common stereotypes of European temperament fit this prediction, no controlled data are likely ever to become available.

[7]In their review of national studies, Weissman and Klerman (1977) note that the 2-to-1 ratio of women to men suffering from severe depression holds for all industrialized countries for which data were available, except for Finland and Norway. It is conceivable that the necessity of adapting to that cold climate would stimulate women to achieve SNS capacity approaching that of males (assuming a ceilling effect for males). The more even sex ratio of depression noted in those countries would follow.

REFERENCES

Altman, 1. (1966). *Organic foundations of animal behavior*. New York: Holt.

Arnold, M. B. (1945). Physiological differentiation of emotional states. *Psychological Review,* 52, 35-48.

Averill, J. R. (1969). Autonomic response patterns during sadness and mirth. *Psychophysiology,* 5, 399-414.

Ax, A. F. (1953). The physiological differentiation between fear and anger in humans. *Psychosomatic Medicine,* 15, 433-42.

Benzinger, T. H. (1970). Peripheral cold reception and central warm reception; sensory mechanisms of behavioral and autonomic thermostasis. In J. D. Hardy, A. P. Gagge, & J. A. J. Stolwijk (Eds.), *Physiological and behavioral temperature regulation.* Springfield, Illinois: Charles C Thomas.

Bhagat, B. D., & Horenstein, S. (1976). Modulation of adrenal medullary enzymes by stress. In E. Usdin, R. Kvetnansky, & I. J. Kopin (Eds.), *Catecholamines and stress.* Oxford: Pergamon.

Buss, A. H., & Plomin, R. (1975). *A temperament theory of personality development.* New York: Wiley.

Cabanac, M. (1970). Interaction of cold and warm temperature signals in the brain stem. In J. D. Hardy, A. P. Gagge, & J. A. J. Stolwijk (Eds.), *Physiological and behavioral temperature regulation.* Springfield Illinois: Charles C Thomas.

Cantor, J. R., Zillmann, D., & Bryant, J. (1975). Enhancement of experienced sexual arousal in response to erotic stimuli through misattribution of unrelated residual excitation. *Journal of Personality and Social Psychology,* 32, 69-75.

Chaffee, R. R. J., & Roberts, J. C. (1971). Temperature acclimation in birds and mammals. *Annual Review of Psychology,* 33, 155-202. Cooper, J., Zanna, M. P., & Taves, P. A. (1978). Arousal as a necessary condition for attitude change following induced compliance. *Journal of Personality and Social Psychology,* 36, 1101-1106.

Davitz, J. R. (1969). *The language of emotion. New York: McGraw-Hill.*

Dienstbier, R. A. (1979a). Attraction increases and decreases as a function of emotion-attribution and appropriate social cues. *Motivation and Emotion,* 3, 201-218.

Dienstbier, R. A. (1979b). Emotion-attribution theory: Establishing roots and exploring future perspectives. In H. E. Howe, Jr., & R. A. Dienstbier (Eds.), *Nebraska symposium on motivation: Human emotion,* 1978 (Vol. 26). Lincoln: University of Nebraska Press.

Dienstbier, R. A., LaGuardia, R., Barnes, M., Tharp, G., & Schmidt, R. (1987). Catecholamine training effects from exercise programs: A bridge to exercise-temperament relationships. *Motivation and Emotion,* 11, 297-318.

Dutton, D. G., & Aron, A. P. (1974). Some evidence for heightened sexual attraction under conditions of high anxiety. *Journal of Personality and Social Psychology, 30,* 510-517.

Eppinger, H., & Hess, L. (1915). Die Vagotonie [Vagotonia]. *Mental and Nervous Disorders Monograph.* No. 20. (original work Published 1910)

Eysenck, H. J. (1963). *Eysenck Personality lventory.* San Diego: Educational and Industrial Testing Service.

Forsman, L. (1980). Habitual catecholamine excretion and its relation to habitual distress. *Biological Psychology,* 11, 83-97.

Gale, C. C. (1973). Neuroendocrine aspects of thermoregulation. *Annual Review of Physiology,* 35, 391-430.

Hemingway, A., & Price, W. M:'(l968). The atonomic nervous system and regulation of body temperature. *Anesthesiology,* 29, 693-701.

Itoh, S., & Kuroshima, A. (1977). Metabolic aspects of human adaptation to cold. In B. Bhatia, G. S. Chhina, and B. Singh (Eds.), *Selected topics in environmental biology.* Oxford: Pergamon Press.

Izard, C. E. (1972). *Patterns of emotions.* New York: Academic Press.

Izard, C. E., & Tomkins, S. S. (1966). Affect and behavior: Anxiety as a negative affect. In C. D. Spielberger (Ed.), *Anxiety and behavior.* New York: Academic Press.

Johansson, G., & Frankenhaeuser, M. (1973). Temporal factors in sympatho-adrenomedullary activity following acute behavioral activation. *Biological Psychology,* 1, 63-73.

Johansson, G., Frankenhaeuser, M., & Magnusson, D. (1973). Catecholamine output in school children as related to performance and adjustment. *Scandinavian Journal of Psychology,* 14, 20-28.

LeBlanc, J., Boulay, M., Dulac, S., Jobin, M., Labrie, A., & Rousseau-Migneron, S. (1977). Metabolic and cardiovascular responses to norepinephrine in trained and nontrained human subjects. *Journal of Applied Psychology,* 42, 166-173.

LeBlanc, J., Cote, J., Dulac, S., & Dulong-Turcot, F. (1978). Effects of age, sex, and physical fitness on responses to local cooling. Journal of Applied Psychology, 44, 813-817.

Levenson, R. W. (1983). Personality research and psychophysiology: General considerations. *Journal of Research in Personality,* 17, 1-21. Levi, L. (1972). *Stress and distress in response to psychological stimuli. Laboratory and real life studies on sympathoadrenomedu//ary and related reactions.* Oxford: Pergamon Press.

Marshall, G., & Zimbardo, P. G. (1979). Affective consequences of inadequately explained physiological arousal. *Journal of Personality and Social Psychology,* 37, 970-988.

Mason, J. W. (1975). Emotion as reflected in patterns of endocrine integration. In L. Levi (Ed.), *Emotions: Their parameters and measurement.* New York: Raven Press.

Mehrabian, A., & Epstein, N. (1972). A measure of emotional empathy. *Journal of Personali ty, 40,* 525-543.

Ogata, K. (1970). A review of Japanese research on the body temperature regulation. In J. D. Hardy, A. P. Gagge, and J. A. J. Stolwijk (Eds.), *Physiological and behavioral . temperature regulation.* Springfield, Illinois: Charles C Thomas.

O'Hanlon, J. F., & Beatty, J. (1976). Catecholamine correlates of radar monitoring performance. *Biological Psychology,* 4, 293-304.

Petrovic, V. M., Davidovic, V., & Janic-Sibalic, V. (1976). Catecholamine synthesis, release and excretion and adrenocortical activity in the heat stressed rat. In E. Usdin, R. Kvet nansky, & I. J. Kopin (Eds.), *Catecholamines and stress.* Oxford: Pergamon Press.

Porges, S. W. (1976). Peripheral and neurochemical parallels of .psychopathology: A psychophysiological model relating autonomic imbalance in hyperactivity, psychopathy and autism. In H. W. Reese (Ed.), *Advances in child development and behav-*

ior (Vol. II). New York: Academic Press.

Rauste-von Wright, M., von Wright, J., & Frankenhaeuser, M. (1981). Relationships between sex-related psychological characteristics during adolescence and catecholamine excretion during achievement stress. *Psychophysiology,* 18, 362-370.

Roessler, R., Burch, N. R., & Mefferd, R. B. (1977). Personality correlates of catecholamine excretion under stress. *Journal of Psychosomatic Research,* 11, 181-185.

Schachter, S., & Singer, J. E. (1962). Cognitive, social and physiological determinants of emo tional state. *Psychological Review,* 69, 379-399.

Schachter, S., & Wheeler, L. (1962). Epinephrine, chlorpromazine, and amusement. *Journal of Abnormal and Social Psychology,* 65, 121-128.

Schildkraut, J. J., & Kety, S. S. (1967). Biogenic amines and emotion. *Science,* 156,21-30.

Schwartz, G. E., Fair, P. L., Salt, P., Mandel, M., & Klerman, G. L. (1976). Facial muscle patterning to affective imagery in depressed and nondepressed subjects. *Science,* 192, 489-491.

Schwartz, G. E., Weinberger, D. A., & Singer, J. A. (1981). Cardiovascular differentiation of happiness, sadness, anger, and fear following imagery and exercise. *Psychosomatic Medicine,* 43, 343-364.

Shepherd, J. T., & Webb-Peploe, M. M. (1970). Cardiac output, and blood flow distribution during work in heat. In J. D. Hardy, A. P. Gagge, & J. A. J. Stolwijk (Eds.) *Physiological and behavioral temperature regulation.* Springfield Illinois: Charles C Thomas.

Sklar, L. S., & Anisman, H. (1981). Stress and cancer. *Psychological Bulletin,* 89, 369-406.

Solomon, R. L., & Wynne, L. C. (1954). Traumatic avoidance learning: The principles of anx iety conservation and partial irreversibility. *Psychological Review,* 61, 353-385.

Stanley-Jones, D. (1966). The thermostatic theory of emotion: A study on kybernetics. *Progress in Biocybernetics,* 6, 1-20.

Stanley-Jones, D. (1970). The biological origin of love and hate. In Magda B. Arnold (Ed.), *Feelings and emotions.* New York: Academic Press.

Stone, E. A. (1968). The effects of emotionality on thermoregulation during stress. *Disserta tion Abstracts,* 28, II-B, 4785.

VanToller, C. (1979). *The nervous body: An introduction to the autonomic nervous system and behaviour.* Chichester: Wiley.

Weissman, M. M., & Klerman, L. (1977). Sex differences and the epidemiology of depression. *Archives of General Psychiatry,* 34, 98-111.

Wenger, M. A. (1966). Studies of autonomic balance: A summary. *Psychophysiology,* 2, 173-186.

Zuckerman, M. (1979). *Sensation seeking: Beyond the optimal level of arousal.* Hillsdale, New Jersey: Erlbaum.