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BRIEF REPORT

Respiratory Sinus Arrhythmia and Ambient Temperature at 5 Months

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Infants were tested in a clinical environment that did not control ambient temperature and assigned, post-hoc, into < 80°F and > 80°F groups. Respiratory sinus arrhythmia was suppressed in response to the elevated temperature. The findings suggest that temperature should be controlled during psychophysiological research with infants.

respiratory sinus arrhythmia vagal tone temperature infant thermoregulation stress

To our knowledge, the effects of ambient temperature during psychological research and behavioral data collection have not been explored in the infant population. Clinical evidence gathered during heat waves (Cardullo, 1949; Danks, Webb, & Allen, 1962; Ellis, Exton-Smith, Foster, & Weiner, 1976) and in desert climates (Shaker, 1966; Taj-Eldin & Falaki, 1968) has indicated that infants are vulnerable to fluctuations in internal temperatures. Van der Bogert and Moravec (1937), in a large clinical trial with children of various age groups exposed to moderate temperatures, demonstrated that stability of internal temperature control increases with age. Although human infants possess physiological thermoregulatory mechanisms, such as the ability to dissipate heat through evaporative water loss (Brück, 1961), infant temperature regulation systems are not fully mature (Veale, Cooper, & Pittman, 1979).

Because behavior is supported at the metabolic level by temperature-dependent biochemical reactions, maintenance of a constant core temperature provides humans with an internal environment that optimizes coordination among chemical reactions (Pough, Heiser, & McFarland, 1989). Factors believed to contribute to the unique vulnerability of infants to temperature shifts include small fluid volume (Hill, 1954), small body size and high surface to mass ratio (Brück, 1961), immature renal function and a large portion of fluids in the extracellular space (Taj-Eldin & Falaki, 1968), immaturity of the central nervous system (Veale et al., 1979), and a reliance upon caregivers for fluids. With the sensitivity of infants' internal environment to external temperature shifts and the potential dependance of performance and autonomic variables on temperature, the effects of failing to control the thermal environment during experimental data collection warrants further exploration.

The regulation of thermal equilibrium in humans is an ongoing dynamic process based upon the cumulative principle that heat production must equal heat loss to maintain a constant core temperature (Hygge, 1992). Because of this principle of heat gain, temperatures much lower than the normal core temperature of humans (98.6°F) activate heat loss mechanisms (Grether, 1973). In addition, many neurophysiological systems are involved in the maintenance of thermal equilibrium in response to elevated temperature including an increase in sweating, vasodilation, heart rate, cardiac output, and a reduction in central blood volume (Rowell, 1983).

From an evolutionary/comparative perspective, research has shown that moderate and/or severe changes in internal temperature not only alter underlying physiological responses, but also behavioral responses (Bennett & Ruben, 1979). Constraints placed on behavior by impre-

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cise regulation of core temperature are illustrated by species whose body temperature is maintained within wide limits. For example, a physiological optimum temperature for swimming speed has been identified in salmon (Brett, 1971); and in the wandering garter snake, maximal performance occurs within a limited temperature range (Stevenson, Peterson, & Tsuji, 1985). Additionally, desert lizards maintain a body temperature in a zone referred to as the "activity temperature range" that allows a full range of behaviors during the active portion of the day. Outside the limits of the activity temperature range, behavioral repertoires are severely constrained (Pough, Heiser, & McFarland, 1989). Paralleling the above mentioned literature is an accumulation of studies indicating that human behavior is altered when internal thermal conditions are challenged, perhaps reflecting an optimal activity temperature range in humans. Elevation in deep body temperature and behavioral changes (i.e., reduction in human performance) occur at temperatures starting above 85°F (Hancock, 1986), where the rate of performance decrement is determined by the duration and level of temperature exposure (Hancock, 1982).

The previously mentioned literature indicates that challenges to the internal thermal environment can alter physiological and behavioral responses at moderate temperatures far below the average core temperature in humans (98.6°F). Because the infant thermoregulatory system is not fully mature, this makes the investigation of moderate temperature changes in experimental situations an important issue that has, to our knowledge, received no attention in the recent literature. To investigate the potential changes in underlying physiology elicited by moderate shifts in temperature during an experimental evaluation in the infant population, a sensitive marker of physiological state with a short latency is needed. Respiratory sinus arrhythmia (RSA), a heart rate pattern determined by the parasympathetic nervous system via vagal pathways, has been used to evaluate infant responses to a variety of environmental demands (e.g., Porges, 1995a; Porges & Lipsitt, 1993; Porter, Porges, & Marshall, 1988; Richards & Casey, 1991), and decreases in the amplitude of RSA indexes an individual's rapid response to environmental challenges (Porges, 1995b).

The purpose of this paper is a post-hoc investigation testing the hypothesis that moderate temperature shifts can alter physiological state in 5-month-old infants when ambient temperature is not controlled during a developmental evaluation. It is hypothesized, because of the sensitivity of the infant's physiological temperature regulation system and the short latency of the vagal system in indexing changes to environmental demands, that short-term exposure to moderately elevated temperature will elicit an underlying change in physiological state, reflected by RSA suppression.

Thirty-six 5-month-old infants were classified into two groups based on the ambient temperature in the testing room of an infant evaluation clinic at the time of assessment. Test room temperatures were not able to be controlled, due to a central heating and cooling system, and varied during testing from 70–90°F during autumn and winter months, based upon outside ambient temperatures. Infants were assigned into < 80°F (n = 20) and > 80°F (n = 16) groups prior to statistical analyses based on a review of experimenter notes (verified from videotapes), which recorded temperature during testing conditions. All infants in the > 80°F group were exposed to central heating. Informed consent was obtained by the infant's caregiver immediately prior to testing.

Upon entering the testing room, ECG electrodes were placed on the infant's back, and the infant was situated in an infant seat. Following approximately 10–15 min of adaptation to the electrodes and the laboratory environment, the evaluation was started and physiological data were collected. A 2-min baseline following adaptation preceded the developmental evaluation designed to elicit emotional responses. A 2-min recovery condition followed the assessment 6 min after the conclusion of the baseline period. RSA was calculated using the Porges method which has been described in detail elsewhere (e.g., Porges, 1995a).

To determine if group and condition differences existed, RSA was analyzed using ANOVA. Time of recording (baseline, recovery) was used as the repeated within-subject variable and Group (< 80°F, > 80°F) as the between-subject variable. Follow-up procedures consisted of planned comparisons using a 95% confidence interval to estimate the observed difference between the sample means (Cohen, 1994).

A significant Time x Group interaction, $F(1, 34) = 5.54, p < .05$, was found as shown in Figure 1. Planned comparisons indicated no statistically significant differences between the < 80°F group ($M = 4.12$; $SD = .86$) and the > 80°F group ($M = 3.82$; $SD = .80$) during baseline, CI_{95} (–.865, .268), but comparisons during the recovery period showed that the group exposed to the higher temperature ($M = 3.16$; $SD = .82$) had lower RSA, CI_{95} (–1.328, –.231), compared with the < 80°F group ($M = 3.93$; $SD = .78$). The analysis also identified a significant main effect for Time of recording with RSA exhibiting an overall decrease during the recovery period, $F(1, 34) = 17.67, p < .05$. However, simple effects demonstrated that RSA in the < 80°F group showed no statistically significant differences between baseline and recovery CI_{95} (–.466, .090), while the > 80°F group suppressed RSA during recovery CI_{95} (–.997, –.335).

A chi square goodness-of-fit was used to further investigate the consistency of individual subject patterns within groups. Of the 20 < 80°F participants, 13 suppressed RSA from baseline to recovery, [$\chi^2(1) = 1.8, p > .05$]. Of the 16 > 80°F participants, 15 suppressed RSA from baseline to recovery [$\chi^2(1) = 12.25, p < .05$].

Consistent with our a priori hypothesis, the > 80°F group had significantly lower RSA compared to the < 80°F group during recovery. It is important to note that the duration of the overall temperature exposure was short (approximately 20 min for each participant), and the time between baseline and recovery was only 6 min. Additionally, a nonparametric approach confirmed that the RSA decrease (15 of 16 participants) in the > 80°F group was a reliable pattern. Since changes in physiology are often compared to baseline situations (e.g., Porges & Lipsitt, 1993), the results from this study provide initial evidence suggesting that failure to control temperature during data collection in the infant population is a potential confounding variable.

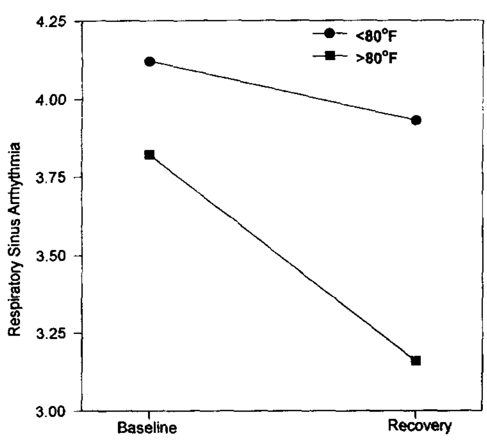

Figure 1

During the neonatal period, when neurophysiological mechanisms are immature, many mammals demonstrate behavioral thermoregulatory capabilities (Satinoff & Henderson, 1977). Human performance research with adults clearly shows a reduction in behavioral output (i.e., performance decrements) associated with exposure to elevated temperatures (Hancock, 1986). We speculate that stressing the thermoregulatory system in the human infant may result in a reduction of interactions with the environment as a behavioral strategy to maintain thermal equilibrium. If our speculation is accurate, this reduction of normal interactions can alter research results by suppressing experimental variance (i.e., restricting the range of behavior) resulting in a loss of statistical precision.

It should be noted that this study is limited because of its post-hoc nature. Ideally, we would have preferred to precisely control the thermal environment as well as variables strongly linked with the thermoregulatory system prior to testing, such as hydration levels and core temperature. Future research using a more rigorous experimental design might distinguish if the changes observed in this study were a direct result of moderate temperature differences and/or influenced by factors correlated with temperature shifts. Despite the limitations, this study provides an initial warning that failure to control temperature during psychophysiological research can alter research results in the infant population.

Authors' Notes

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