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# TEMPERATURE AND AGGRESSION

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The day drags by like a wounded animal  
The approaching disease, 92°  
The blood in our veins and the brains in our head  
The approaching unease, 92°  
("92°" by Siouxsie and the Banshees, *Tinderbox*,  
David Geffen Company, 1986)

## **I. Introduction**

Hot weather and violence go hand in hand. This fact can be derived from a variety of sources, from a variety of centuries, and from a variety of continents. For instance, languages are replete with heat-related imagery. Consider the following American English phrases: "hot headed," "hot tempers," "tempers flaring," "hot under the collar," "doing a slow burn." Social commentators have noted weather effects on human behavior and have used heat-related imagery for thousands of years. Cicero (106-43 B.C.) noted that, "The minds of men do in the weather share, Dark or serene as the day's foul or fair." Shakespeare noted (in *The Merchant of Venice*) that "the brain may devise laws for the blood, but a hot temper leaps o'er a cold decree."

Social philosophers, social geographers, and other students of behavior began to apply empirical methods to this theory in the middle 1700s. For

instance, based on his observations during his many travels Montesquieu (1748/1989) stated that, "You will find in the northern climates peoples who have few vices, enough virtues, and much sincerity and frankness. As you move toward the countries of the south, you will believe you have moved away from morality itself; the liveliest passions will increase crime . . ." (p. 234.) It was another hundred years or so before more objective empirical methods were used to examine this heat hypothesis. Leffingwell(1892) examined quarter-of-the-year effects on two broad categories of violent crime in England and Wales in 1878-1887. Other early studies of heat effects include those by Lombroso in Italy (1899/1911), Guerry in France (cited in Brearley, 1932), Dexter (1899) in New York City, and Aschaffenburg (1903/1913) in Germany and France. Despite use of empirical methods that are somewhat crude by modern standards, these early studies supported the prevailing theory that hot temperatures increase violent behavior (Anderson, 1989).

#### A. EPISTEMOLOGY: HOW TO ORGANIZE TEMPERATURE-AGGRESSION FINDINGS

The first major review of the empirical literature on temperature effects on aggression (Anderson, 1989) relied on two epistemological strategies—triangulation and meta-analysis. Those two strategies still provide a good approach to understanding this diverse literature. Triangulation is the strategy of examining an idea from several different perspectives in order to arrive at the best overall view of that idea. As Richard Cardinal Cushing noted when he was asked about the propriety of calling Fidel Castro a communist, "When I see a bird that walks like a duck and swims like a duck and quacks like a duck, I call that bird a duck" (*New York Times*, 1964). Our target idea here is not whether Mr. Castro is a communist, but whether there is a true relation between temperature and aggressive behavior. By examining the heat hypothesis from the perspectives of several very different methodologies, each of which has its particular strengths and weaknesses, we get a better overall view than if we confine ourselves to one methodology.

The second strategy—meta-analysis—refers to combining results of studies with the same methodologies whenever possible in order to improve the reliability of the conclusions. For example, data from multiple studies that report violent crime rates as a function of month were pooled and reanalyzed as a larger data set. Note that "meta-analysis" in this chapter refers to this general data-pooling strategy, not just to the more specific statistical techniques that now go by the name of "meta-analysis."

In this chapter we also adopt a third strategy, one that implicitly underlies much modern science but that has occasionally been ignored in articles on the temperature-aggression hypothesis, namely, parsimony. Theoretical explanations that are simple and that account for many observed phenomena are preferred over complex ones that account for only a portion of extant findings.

There has been considerable confusion in the terminology used in the temperature-aggression literature. We recently proposed a few standard definitions to help reduce such confusion, in our own writings as well as in the writings of other scholars working in this area (Anderson & Anderson, 1998). The *temperature-aggression hypothesis* is the theoretical statement that uncomfortable temperatures cause increases in aggressive motivation and, under the right conditions, in aggressive behavior. The *heat hypothesis* refers more specifically to the hot side of this hypothesis and is the most widely studied version. Obviously, there is a corresponding *cold hypothesis*, which states that uncomfortably cold temperatures cause increases in aggression. The *heat effect* refers to the empirical observation of an increase in aggressive behavior in hot (as compared to comfortable) temperatures. Again, one could refer to a *cold effect* as well, but it is quite rare in this literature.

## B. REVIEW OF PRIOR FINDINGS IN NATURALISTIC SETTINGS

Reviews of research on the heat hypothesis in naturalistic settings have confirmed the early views linking hot temperatures to high levels of aggression (Anderson, 1989; Anderson & Anderson, 1998; Anderson & DeNeve, 1992). The triangulation approach has identified three very different types of studies in this domain-geographic region studies, time period studies, and concomitant measurement studies. Data from all three types of studies support the heat hypothesis.

Geographic region studies examine aggression rates of geographic regions that are similar in some ways (e.g., part of the same country) but that differ in climate. For instance, recent archival studies have supported the heat hypothesis by showing that U.S. cities with hotter weather have higher violent crime rates than similar-sized cooler cities even when various social and cultural factors (e.g., poverty rate) are statistically controlled (Anderson & Anderson, 1996, 1998). Figure 1 displays a latent variable model of this effect. (See Anderson & Anderson, 1996, for a regression approach to analyzing these data and for more statistical control variables.)

In this model three latent factors-Temperature, Southernness, Low Socioeconomic Status (SES)-and one measured variable (Population size)

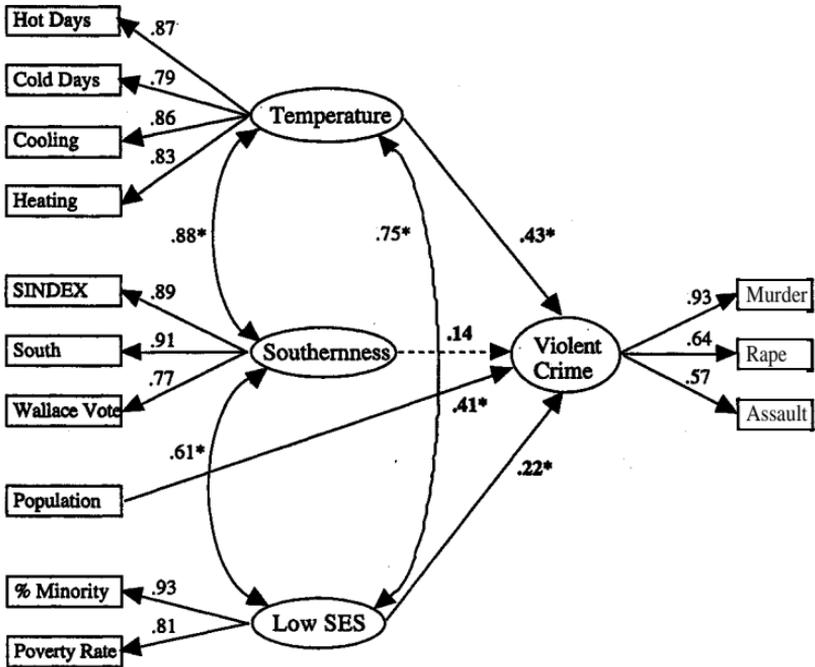


Fig. 1. Latent variable model of temperature and southernness (culture of honor) effects on violent crime in the United States in 1980. An asterisk indicates that the directional path weight to Violent Crime latent factor was statistically significant. Error terms and correlations among error terms are not displayed to simplify the picture:  $\chi^2 = 216$ ;  $df = 54$ ; comparative fit index = .94; goodness of fit index = .89; Bentler and Bonett's (1980) Non-normed Index = .92; Bentler and Bonett's Normed Fit Index (1980) = .92; cold days and heating were reverse coded. SINDEX is the southernness index by Gastil (1971).

were used to predict the latent Violent Crime rate factor. The southernness factor was indexed by three measured variables: a southernness index (SINDEX) created by Gastil (1971), which was based on migration patterns from the Old South; a North/South dichotomy based on U.S. Census Bureau classifications; and the percentage of voters who voted for George Wallace in the 1968 presidential election (Scammon, 1970). The results were quite clear. Temperature, population, and low SES were positively related to violent crime in U.S. cities. Southernness was also positively related, but not significantly so.

Time-period studies examine aggressive behavior rates within the same region but across time periods that differ in temperature. For example, assault rates are consistently higher in summer months than during the rest of the year. This has been found across a wide range of countries (France, Germany, United States) and eras (e.g., 19th and 20th centuries). Figure 2

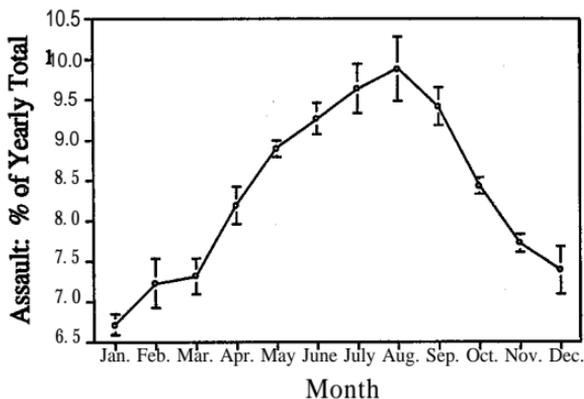


Fig. 2. Monthly distribution of assaults  $\pm 1$  SE. Adapted from Anderson and Anderson (1998).

displays this pattern of assaults, averaged across seven different data sets (all from the Northern Hemisphere). Similar time-period effects have been reported in studies in which the time period was longer (e.g., quarter of year) and shorter (day). For example, in a pair of studies Reifman, Larrick, and Fein (1991) showed that major-league baseball batters are more likely to get hit by pitched balls during hot games than during cool games, even after controlling for a variety of other factors (such as number of walks).

Concomitant measurement studies are a special case of time-period study—the indicator of temperature and the measure of aggression are taken simultaneously (more or less). For instance, Kenrick and MacFarlane (1984) assessed the effects of temperature on aggressive horn honking in Phoenix with temperatures ranging from 84° to 108°F. As expected, there was a significant linear effect of temperature on horn honking,  $p < .01$ . (Note that the authors reported that similar effects occurred whether latency to honk or duration of honking or number of honks was used.) Furthermore, this effect was significantly stronger for subjects without air-conditioned cars ( $r = .76$ ) than for subjects in cars with air conditioning ( $r = .12$ ),  $Z = 2.54$ ,  $p < .01$ . Similar effects of heat on aggression were reported by Vrij, van der Steen, and Koppelaar (1994) in their study of police officers' behavior in training exercises.

### C. ALTERNATIVE EXPLANATIONS

In sum, there is little doubt or controversy about the existence of a heat-violence relation in real-world data. Whether temperature plays a

direct causal role has been the question stimulating most recent research in this area. Alternative explanations can sometimes account for the particular results of a particular type of study. We turn our attention to two particularly interesting ones.

### *1. Routine Activity Theory (RAT)*

Cohen and Felson (1979) developed, Routine Activity Theory (RAT) to explain the link between increases in crime and increases in temperature. This sociological view states that opportunities to commit crimes increase in the summer because social behavior patterns change. For instance, the increase in violent crime during the summer might be an artifact of students being out of school or the increase in family vacations. In the summer people (potential victims as well as perpetrators) are more likely to leave their homes and their families. Increases in alcohol consumption and a reduction in guardianship have also been posited as crime-related warm weather behaviors (Cohn, 1990; Landau & Fridman, 1993).

The RAT has been supported by some archival studies of the temperature-aggression relation (Cohen & Felson, 1979; Field, 1992) and not by others (e.g., Michael & Zumpe, 1986). For example, the fact that violent crime increases during hotter days within summer months (e.g., Anderson & Anderson, 1984), that the size of the summer increase in violence is greater in hotter years than in cooler years (Anderson, Bushman, & Groom, 1997), and that major-league batters are more likely to be hit by pitched baseballs on hotter days (Reifman et al., 1991) all cast considerable doubt on the claim that routine activities associated with temperature fully account for the heat effect. There is no doubt that 'routine activities have a substantial impact on a wide variety of human behaviors, including aggression. But, by considering the total array of studies of the heat hypothesis we can rule out RAT as a sufficient explanation and offer a more parsimonious explanation for all of the findings in field settings: heat increases aggressive motivation.

### *2. Southern Culture of Violence (SCV)*

Social theorists have long noticed higher rates of violence in regions that are closer to the equator. Recent theories of a U.S. southern culture of violence range from the sociological to the evolutionary and economic (see Anderson & Anderson, 1998, for a review). Some focus on the relatively lengthy time period in which the U.S. South was an unsettled wilderness frontier, whereas others attribute the development of a southern culture of violence to swashbuckling Cavaliers who settled in the early South.

Of particular interest is Cohen and Nisbett's recent theory of a southern culture of honor (Cohen & Nisbett, 1994; Nisbett, 1990, 1993). They posit that the livelihood of people who settled in the South depended on a herding economy. In order to thrive in this economic system, male producers were required to be highly protective of their livestock from poachers. These frontier people (adaptively) socialized their offspring to hold these aggressive defensive attitudes toward potential intruders as well as taught them the behaviors necessary to fight effectively (e.g., how to operate a gun).

This approach has yielded a number of interesting results, some supportive of the SCV theories, some contradictory (see Anderson & Anderson, 1998, for a review). However, the claim that SCV explains away the heat effect on violent crime in U.S. cities is not well supported. For example, the city crime rate analyses of Anderson and Anderson (1996, 1998), as displayed earlier in Fig. 1, strongly contradict this claim; if it were true then the Southernness factor should have been strongly related to violent crime and the temperature link to violent crime should have been nonsignificant. Furthermore, although SCV theory (including the Nisbett and Cohen culture of honor version) and the temperature-aggression hypotheses both attempt to explain the high homicide rate often found in southern U.S. cities, these approaches need not be viewed as mutually exclusive. A southern culture of violence (or culture of honor) could have an effect on violence that is independent of temperature.

Alternatively, as posited by Anderson and Anderson (1996), SCV could have partially (or wholly) evolved because of the hot climate. Indeed, cross-cultural work by Pennebaker, Rime, and Blankenship (1994) suggests that emotionality in general may be increased by hot climates. More recently, Van de Vliert, Schwartz, Huisman, Hofstede, and Daan (1999) showed that cultural masculinity was related to climate and to domestic political violence and posed an interesting explanation based on parental investment theory. Societies high in cultural masculinity are those "...in which men are expected to be dominant, assertive, tough, and focused on material success ...," whereas societies low in cultural masculinity are those in which men "... are expected to be subordinate, modest, tender, and concerned with the quality of life" (p. 300). According to Van de Vliert et al., level of cultural masculinity is positively associated with amount of domestic political violence and accounts for the empirical link between climate (specifically, how hot it is) and domestic political violence. The parental investment theory explanation of these linkages is based on three postulates. First, climate influences males' decisions regarding investing time and effort in providing for a single family versus investing in fertilizing multiple partners to increase offspring. Second, in cold climates and extremely hot climates (e.g., desert climates rather than the mild U.S. South

climate) meeting the basic needs for food, safety, and security requires considerable parental investment in offspring, thus encouraging development of a less "masculine" set of norms for male behavior. Third, cultural masculinity influences competitiveness not only in the mating domain, but also influences conflicts at a broader societal level, including frequency of domestic political violence. In essence, cultural masculinity and domestic political violence are both expected to peak in climates that demand the least parental investment by males, i.e., climates much like that in the U.S. South. To be sure, other plausible explanations of links between climate and aggression-related cultural norms can be generated. And, domestic political violence may well be different from the more affective-based violence most studied in the heat-aggression literature (Anderson, 1989). Nonetheless, the Pennebaker et al. (1994) and the Van de Vliert et al. (1999) works suggest that temperature may causally influence the development of cultural differences that are linked to some forms of aggression and provide interesting avenues for future work on temperature effects on culture.

From an even broader view of the heat hypothesis, the SCV approach cannot explain several well-established heat effects. It is irrelevant to all of the time-period studies and the concomitant measures studies. For instance, it cannot explain why violent crime rates are higher during hot years than during cool years (Anderson et al, 1997). The simple heat hypothesis, however, accounts for all of these effects.

## **II. Contemporary Controversy**

Most naturalistic field studies of the heat hypothesis have found positive monotonic effects of temperature on aggression. However, some researchers claim that heat increases real-world violence only up to moderately hot temperatures (e.g., 80°F) and that further increases in temperature (e.g., 95°F) produce significant decreases in violence (e.g., Cohn & Rotton, 1997). This is an important issue for both theoretical and practical reasons. At a theoretical level, there are several reasons to expect hot temperatures (e.g., 90°F) to produce lower levels of aggression than moderately warm temperatures (e.g., 85°F). These theories are described in a later section. At a practical level, recommendations concerning issues such as police deployment and expected effects of global warming differ if, in fact, hot temperatures decrease aggression. In this section we show how nonstandard data analyses may have led to inappropriate conclusions in the one archival study that purportedly shows a downturn in aggression at high temperatures

(Cohn & Rotton, 1997) and how nonstandard data analyses may lead to misinterpretations of a related archival study (Cohn, 1993).

## A. ASSAULT IN MINNEAPOLIS

Cohn and Rotton (1997) conducted an analysis of the reported assaults in Minneapolis in 1987 and 1988 as a function of time of day, day of week, month, and temperature. Each day was divided into eight 3-h periods. Temperature and number of assaults (and several other variables) were recorded for each time period. The use of 3-h time periods distinguishes this research from conceptually similar research on violent crime in Chicago and Houston (e.g., Anderson & Anderson, 1984). One advantage of the shorter time period is that the aggressive behavior and the corresponding temperature are measured in closer proximity. However, it is also important to remember that people have memories and that the instigation to aggress may take place some time (hours, days, or weeks) prior to aggressive retaliation.

Two important findings reported by Cohn and Rotton (1997) were huge effects of time of day and day of week. Consistent with RAT, assaults were most frequent at times of day and days of week when most people's behaviors are not severely restricted by their present situations, that is, during leisure time. This finding is not surprising, because in order for an assault to occur there has to be both an opportunity to get angry enough to aggress and an opportunity to aggress; such opportunities vary by day of week and time of day. It is relatively harder to assault others when on the job or in school or at church, for example. So, assaults were higher on weekends (replicating an effect reported by Anderson & Anderson, 1984) and evenings. The time-of-day effect on assault rate is, of course, confounded with temperature because time of day is highly correlated with temperature. This confounding is very important to keep in mind because it is related to problems with the data analysis to be discussed shortly.

One of the main conclusions of the article involving the heat effect is simply not borne out by the reported results. Specifically, the claim that there was a significant downturn in assault as temperatures became hot was based on a series of problematic data analysis choices. Two of these choices are particularly important and the consequences of these two can be illustrated using results found in the tables and footnotes of the Cohn and Rotton (1997) article.

### *1. Problem 1: Overaggregation (or Undercontrol)*

Consider Fig. 3, which is adapted from Cohn and Rotton's Fig. 1. This figure appears to present overwhelming evidence of a significant downturn

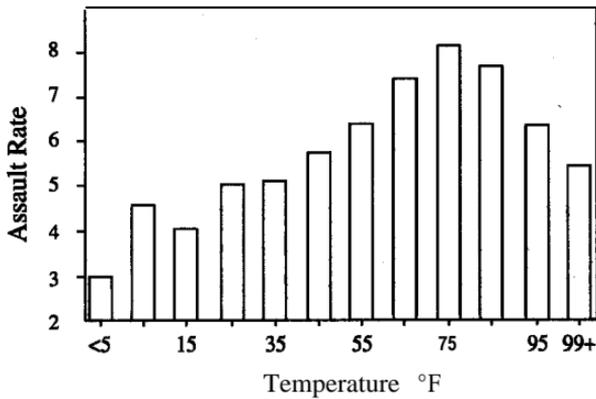


Fig. 3. Assault rate as a function of temperature (adapted from Cohn & Rotton, 1997, Fig. 1).

in assault as temperatures increase from about 75° to 99°F. But think for a minute of all the 3-h time periods that are at 85°F or hotter in Minneapolis, what proportion occur during the time of day when assaults are most possible, i.e., during the late evening and early morning hours? Obviously, only a small proportion of the uncomfortably hot time periods occurred after 9:00 P.M. In Minneapolis (and most other cities as well) the vast majority of hot time periods occur during periods of time when school and job activities drastically decrease the opportunities for assault. Think also about the time periods that fall in the 65°-75°F range. What proportion of them occur during the late evening and early morning hours? Obviously, a much greater proportion of them fall in the high assault hours than do hot time periods. Thus, this figure overaggregates the data by ignoring the RAT-expected time of day and day-of-week effects on assault rates. Aggregating over time of day is especially problematic because day is so strongly related to temperature. Aggregating over day of week is less problematic in testing the heat hypothesis because day of week is not related to temperature. However, because day of week also causally (theoretically) accounts for large assault rate differences (via opportunity), it too needs to be taken into account in the proper analysis of these data. In brief, this figure is misleading concerning the true effect of temperature on assault rate.

At a minimum, what is needed is an estimate of the effect of temperature on assault rate that partials out the effects of time of day and day of week. One way to do this is with a regression analysis estimating the linear and curvilinear effects of temperature on assault while including time-of-day and day-of-week terms in the statistical model. Then, one can plot the

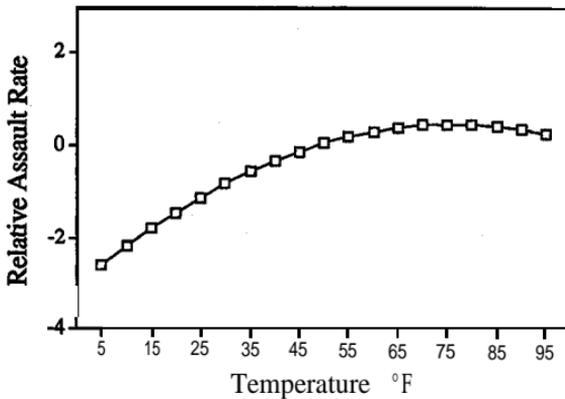


Fig. 4. Relative assault rate as a function of temperature, with time-of-day, day-of-week, and month controlled statistically. Based on slopes from Cohn and Rotton (1997).

resulting best fit regression line relating temperature to assault rate. Cohn and Rotton did such an analysis and included a number of other predictor variables as statistical controls. They reported the slope estimates in the text but did not graph the results. Figure 4 is based on their reported slopes.<sup>1</sup>

The shape of the temperature-assault function in Fig. 4 is different from the one presented by Cohn and Rotton's Fig. 1 (our Fig. 3). One can still see a bit of a downturn at the higher temperatures, but it is not nearly so pronounced as in our Fig. 3. Whether the downturn is significant was not reported; it seems unlikely given the relative scarcity of data points at 95°F or above in Minneapolis. But, we believe that even this figure does not give an accurate representation of the temperature effect on assault in Minneapolis. This is because one of the statistical controls used in this analysis was month of year. This is the second problem warranting attention.

## 2. Problem 2: Underaggregation (or Overcontrol)

By including month of year as a statistical control variable, Cohn and Rotton essentially discarded any true heat effect on monthly differences in assault rates. Thus, if temperature is truly causally related to assault in a linear (or a positive monotonic) way, controlling for month inappropriately partials out a major portion of the true linear heat effect. What happens if the same regression analysis is conducted but without month in the statistical model? Cohn and Rotton reported (in their footnote 2) that it

<sup>1</sup> In all figures in this chapter, centered and standardized temperature terms have been converted back to raw temperature for ease of exposition.

does not really change the results much. However, Fig. 5, which uses the reported slopes to graph the resulting function along with the same function obtained when month was partialled out, shows that partialing month does matter. The region where the two lines differ most—at the hot end—is exactly where it is most important theoretically. There is no hint of a downturn in aggression at the highest temperatures normally experienced in Minneapolis, *when month effects are not controlled*.

### 3. Overaggregation Revisited

Another way of avoiding the overaggregation problem caused by ignoring time-of-day and day-of-week effects is to do the regression analysis *separately* for each of the 56 day-of-week (7) X time-of-day (8 3-hour blocks) time periods. Cohn and Rotton provide this information in their Table 5. The linear temperature term was positively ( $ps < .05$ ) related to assault 29 times and was never negatively related. The curvilinear temperature term (a quadratic term) yielded a statistically significant effect in only 10 cases, but in 7 of those the slope was positive, indicating that at hotter temperatures assault rates increased more rapidly with further temperature increases. These findings clearly contradict the hypothesis that the general shape of the temperature-assault relation is an inverted U. In only 3 of 56 time periods (7 days/week, 8 periods/day) did a significant negative quadratic term occur; this may well happen by chance.

Furthermore, the fact that a quadratic temperature term produces a negative slope that differs significantly from zero does not mean that a significant downturn in aggression occurred. It may merely indicate that

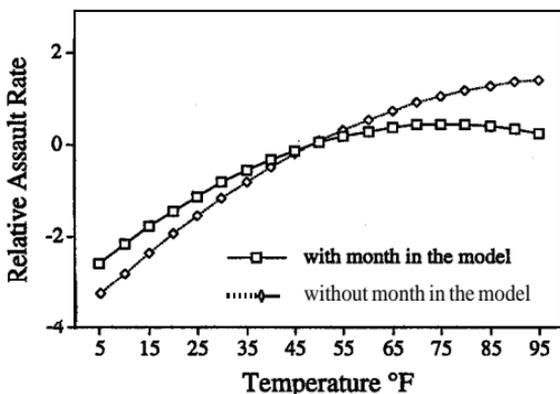


Fig. 5. Relative assault rate as a function of temperature, with and without month controlled statistically. Based on slopes from Cohn and Rotton (1997).

the rate of increase in aggression is smaller at hot temperatures than at cool temperatures, as in the Fig. 5 line with the diamonds (without month in the model)-i.e., there is an asymptote.

However, one might ask why we believe that ignoring time of day and day of week is inappropriate overaggregation (undercontrol), whereas statistically controlling for month is inappropriate underaggregation (overcontrol). The answer involves the theoretical status of the variables. Cohn and Rotton (1997) report that time-of-day and day-of-week effects on aggressive behavior are caused largely by known factors that are causally unrelated to temperature. Thus, time-of-day is spuriously correlated with temperature. We view Cohn and Rotton's RAT analysis as the most important contribution in that article. Specifically, the routine activities that engage people at different times of the day are such that assault-producing events and opportunities are relatively rare during the hottest times of day. These include such events as spousal or other family arguments and drinking in bars and other entertainment venues. It is therefore crucial that time-of-day effects be taken into account before examining temperature effects. However, there is no good theoretical justification for expecting big month effects on assault due to spurious (nontemperature) factors, but month is highly correlated with temperature in a causal way, especially in cities like Minneapolis. Thus, controlling for month artificially decreases the estimated effect of temperature on assault. One might argue that summer vacations from school and work might increase aggression opportunities. However, studies that have restricted their sampled days to summer months have yielded the same positive relation between temperature and violent crime, thereby ruling out this alternative explanation (Anderson & Anderson, 1984; Cotton, 1986; Harries & Stadler, 1988).

In sum, the Minneapolis assault data provide evidence of a downturn in assault at high temperatures only if key data analysis decisions are made in a way that appears to us to be suspect on both theoretical and empirical grounds. More complete and appropriate analyses of this data set are underway. If a significant downturn can be demonstrated for some time periods when more appropriate statistical approaches are used, and if they can be replicated in cities with hotter weather patterns, then it would be interesting to see which of several curvilinear theories (discussed later) best account for the downturn. At the moment, we believe the evidence for a downturn at hot temperatures in field settings is much too weak.

## B. RAPE AND DOMESTIC VIOLENCE IN MINNEAPOLIS

Cohn (1993) published another interesting article using the same basic sources of data as were later used in Cohn and Rotton (1997) but with

different statistical methods and focusing on rape and domestic violence instead of assault. There are many interesting results in this article, but the temperature results are difficult to interpret, in part because of the complexity of the analyses and in part because of some nonstandard methods.

Cohn reported that three temperature terms were used in the analyses, a linear term, a quadratic term, and a cubic term. She reported all results in terms of standardized beta weights, "... thus avoiding the issue of scaling and removing the need for centering the scale before prediction" (p. 76). Therefore, it appears that the quadratic and cubic temperature terms were created from the raw temperatures, rather than from centered temperatures. Methodologically, this is acceptable under some circumstances. However, it does create an artificially high correlation between the various temperature terms. This multicollinearity problem can be severe if the correlations are too high. Even if multicollinearity is not too big a problem, the standard procedure for testing such terms is to do so hierarchically. That is, the linear term cannot be estimated and tested with the quadratic or cubic terms in the model, the quadratic term must be estimated and tested with the linear but not the cubic term in the model, and the cubic term must be estimated and tested with both the linear and quadratic terms in the model. Otherwise, the interpretation of the slopes (in this case, betas) is problematic (e.g., Cohen & Cohen, 1983).<sup>2</sup>

Possible confusions arise from Cohn's (1993) results because in several models higher order temperature terms were tested and betas reported without lower order terms in the model. For instance, in her Table 7 Cohn reported a prediction model of domestic violence that included a significant quadratic temperature beta of .15, but the linear term was not in the model. Readers might be tempted to interpret this as meaning that the temperature effect on domestic violence is strictly a "U"-shaped function. That would be a misinterpretation. Similarly, Cohn's (1993) Table 8 reported a prediction model of rape that included significant linear ( $B = .15$ ) and cubic ( $B = .19$ ) temperature terms, but not the quadratic term. This can easily lead to the misinterpretation that the function linking temperature to rape is a generally upsweeping line with two inflection points. It is important to note that Cohn (1993) did not make these interpretations in that article and, in fact, said relatively little about the temperature functions. But how is one supposed to interpret these results?

<sup>2</sup>If the distribution of temperatures is symmetric, then centering prior to squaring will yield uncorrelated linear and quadratic terms. Under those circumstances, which typically occur only in laboratory studies where the temperature distribution is controlled, simultaneous testing of linear and quadratic terms would be acceptable. However, the linear and cubic terms are still highly correlated, and in the real world, the quadratic term is likely to be correlated with both the linear and cubic terms.

To get a clearer picture of the shape of the temperature-aggression function found in these data, we made a few simple computations displayed in Table I. We then applied the betas in the prediction models from Tables 7 and 8 from Cohn (1993) and plotted them in Fig. 6. Note that these models included time of day and a two-level weekend/weekday predictors, but did not include month. As can be seen, for both domestic violence and rape, the general shape of the temperature function is very similar to that found repeatedly in other studies, with hotter temperatures being associated with higher levels of aggression.

One might ask why we don't see a "U"-shaped function for domestic violence, which included only a quadratic temperature term. The answer is that given the distribution of temperatures found in almost all cities, when a quadratic term is created from raw temperatures, the quadratic term is artifactually highly correlated with the linear term, even when each is subsequently transformed into z scores. In our simplified example in

TABLE I

LINEAR, QUADRATIC, AND CUBIC TEMPERATURE TERMS BASED ON RAW TEMPERATURES (-5 TO 95°F), Z-SCORE TEMPERATURE TERMS, AND PREDICTED VALUES FOR DOMESTIC VIOLENCE AND RAPE USED TO INTERPRET RESULTS FROM COHN (1993)

Raw $T$	Z - raw $T$	$T^2$	Z - $T^2$	$T^3$	Z - $T^3$	Domestic violence	Rape
-5	-1.61	25	-1.00	-125	-0.8090	-0.15	-0.387
0	-1.45	0	-1.01	0	-0.8085	-0.15	-0.355
5	-1.29	25	-1.00	125	-0.8081	-0.15	-0.323
10	-1.13	100	-0.97	1000	-0.8048	-0.15	-0.290
15	-0.97	225	-0.93	3375	-0.7958	-0.14	-0.257
20	-0.81	400	-0.87	8000	-0.7784	-0.13	-0.223
25	-0.64	625	-0.79	15625	-0.7497	-0.12	-0.189
30	-0.48	900	-0.70	27000	-0.7069	-0.11	-0.153
35	-0.32	1225	-0.59	42875	-0.6472	-0.09	-0.116
40	-0.16	1600	-0.46	64000	-0.5677	-0.07	-0.078
45	0.00	2025	-0.31	91125	-0.4657	-0.05	-0.037
50	0.16	2500	-0.15	125000	-0.3382	0.02	0.005
55	0.32	3025	0.03	166375	-0.1825	0.00	0.050
60	0.48	3600	0.23	216000	0.0042	0.03	0.097
65	0.64	4225	0.44	274625	0.2248	0.07	0.147
70	0.81	4900	0.67	343000	0.4821	0.10	0.200
75	0.97	5625	0.92	421875	0.7789	0.14	0.256
80	1.13	6400	1.19	512000	1.1180	0.18	0.315
85	1.29	7225	1.47	614125	1.5023	0.22	0.378
90	1.45	8100	1.77	729000	1.9346	0.27	0.445
95	1.61	9025	2.09	857375	2.4176	0.31	0.516

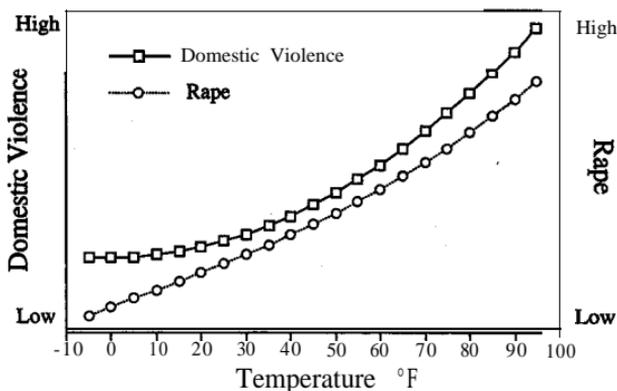


Fig. 6. Relative rape and domestic violence rates as a function of temperature. Based on slopes from Cohn (1993).

Table I for instance, the correlation between the linear and quadratic terms is .958. In other words, the two terms are highly confounded and artificially so. The quadratic term has both linear and quadratic components built into it, whereas the linear term has only a linear component. Thus, testing the linear term for significance when the quadratic term is in the model inappropriately partials out much (or most) of the true linear component. Estimating the magnitude of the quadratic component without the linear component in the model gives that quadratic estimate variance that properly belongs to the linear component. This latter problem, using only the quadratic component, is not terribly severe if one plots the resulting function as we have done in Fig. 6. Similar reasoning applies to the question of why the rape function in Fig. 6 doesn't show the two major bends one normally expects from a cubic term.

In sum, the Minneapolis studies do not contradict the pattern found in other studies of the shape of the temperature-aggression function. Indeed, they add support to prior research, in large part because they used the shorter time frame of 3-h time periods.

Finally, it is important to note that we believe that there may well be circumstances in which hot temperatures (within normal human tolerances) may produce a decline in aggression in naturalistic settings. However, to date there are no convincing data of such a relationship. (Obviously, finding a decrease in aggression at extremely high temperatures is uninformative. As pointed out by Anderson and Anderson (1984) aggression must decline at some high temperature point, "because at extremely high temperatures everyone gets sick and dies, precluding aggressive acts" (p. 96).

We next turn to a general theoretical model of human aggression, specific models of the relation between temperature and aggression, and laboratory

studies designed to shed some light on this ubiquitous phenomenon. Though there are still some unanswered puzzles, we will see that considerable progress has been made in recent years.

### III. General Affective Aggression Model

Before outlining specific theories about temperature effects on aggression, we briefly outline a general framework for understanding human aggression. Figure 7 presents a recent version of the basic theoretical model that we have been using for several years (Anderson, Anderson, & Deuser, 1996; Anderson, Deuser, & DeNeve, 1995; Anderson & Dill, in press; Lindsay & Anderson, in press). We focus on the "person in the situation," called an *episode*. Because social interactions are continuous, any dynamic model of social behavior is necessarily circular. Thus, one can enter and exit the model at any point, though some points seem more natural than others. An episode is one cycle of the ongoing social interaction. Figure 7 presents a simplified version of the main foci of the model. The four main foci concern: (a) inputs of various person and situational variables, (b) routes through which these variables have their impact, (c) appraisal

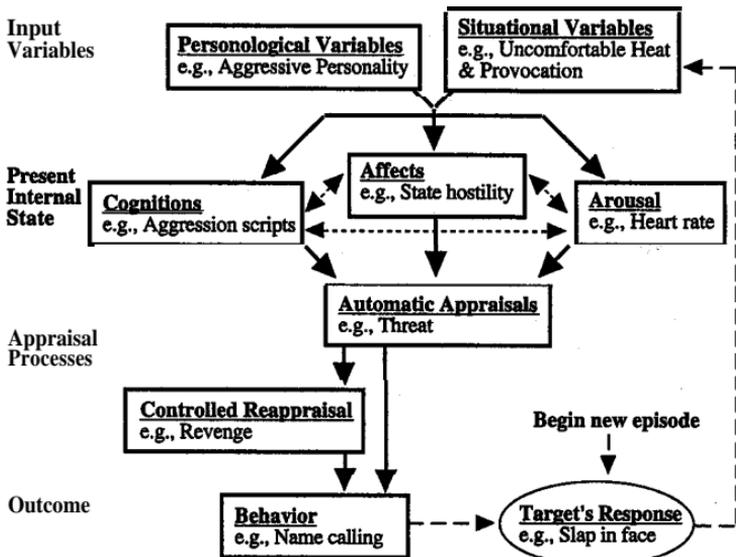


Fig. 7. A General Affective Aggression Model.

processes, and (d) behavioral outcomes of the underlying appraisal processes.

## A. INPUTS

Person factors include all the specific things that a person brings to the situation, such as personality traits and attitudes. For example, trait irritability is positively related to aggression (e.g., Caprara, Barbaranelli, Pastorelli, & Perugini, 1994). Situational factors include any important features of the situation, such as presence of a provocation, an aggressive cue, or, most importantly in the present context, uncomfortably hot (or cold) temperature. For example, the classic weapons effect (Berkowitz & LePage, 1967) shows that the mere presence of aggression-related cues in a situation can increase human aggression (see Carlson, Marcus-Newhall, & Miller, 1990, for a meta-analytic review).

## B. PRESENT INTERNAL STATE

Input variables combine, sometimes in interactive ways (e.g., Bushman & Geen, 1990), to influence the final outcome, but do so through the present internal state that they create. There are three "routes" that input variables might traverse on their way to influencing the aggression process. They may influence the cognitive state of the person, such as by increasing the accessibility of aggressive thoughts, scripts, or related knowledge structures. They might influence the affective state, such as by increasing feelings of state hostility or anger. They might influence the state of arousal, such as by increasing heart rate.

A given input variable may have most of its impact via any or all of the three routes listed for present internal state. For example, some of our research suggests that the weapons effect has its impact primarily through the cognitive route (Anderson, Anderson, & Deuser, 1996; Anderson, Benjamin, & Bartholow, 1998). Other input variables may influence more than one route. A strong provocation may increase aggressive thoughts, anger, and heart rate. It is also important to recognize that these three internal states are themselves interlinked with each other, such that an input variable may directly influence one state and indirectly influence the others. For instance, being reminded of a past insult may directly increase aggressive thoughts, which in turn increase the present state of anger.

The focus on the episode and the present internal state does not mean that either the past or the future are irrelevant. To the contrary, develop-

mental issues are crucial to any general model, including this one. The past is represented by what people bring with them to the present episode, in terms of beliefs, expectations, general affective state, personality traits or styles, and so on. Similarly, future plans and expectations are brought to the present by people's construal of what is possible, likely, desirable, and so on.

### C. APPRAISALS

The third focus, on appraisals, includes several complex information processes, ranging from the relatively automatic to the heavily controlled (Lindsay & Anderson, in press). Automatic appraisals (called "immediate appraisal" in earlier versions of our model) are evaluations of the present environment and internal state that are made on-line, very quickly, with little or no awareness. When slapped in the face people will automatically "judge" that the present environment is threatening and that they are angry and/or scared-what is commonly referred to as the emotional part of the "fight or flight" response (e.g., Berkowitz, 1984, 1993, in press). Berkowitz's Cognitive Neoassociationist (CNA) model also posits that such automatic appraisals include the behavioral aspects of fight or flight, a notion that is entirely consistent with our model.

Controlled reappraisals are somewhat slower and require more cognitive resources than the automatic appraisals. In some situations, where there is little time for reappraisal, for instance, a relevant behavior is chosen and performed before reappraisal can take place. However, reappraisal does often occur, as when one carefully considers why a provoking individual behaved in a particular way before deciding how to respond. Although we've presented appraisal and reappraisal as a dichotomy, in keeping with recent thinking in cognitive psychology it would be more accurate to view appraisal processes as existing along a continuum with completely automatic and completely controlled as the endpoints (e.g., Bargh, 1994).

### D. OUTCOMES

Whether an aggressive behavior is emitted depends upon what behavioral scripts have been activated by the various input variables and the appraisal processes. Well-learned scripts come to mind relatively easily and quickly and can be emitted fairly automatically. Therefore, people who score high on aggressive personality have a relatively well developed and easily accessible array of aggression scripts which are easily activated by minimal provocation

(e.g., Anderson et al., 1998). Of more relevance to the present chapter are situational factors that can increase the accessibility of aggression-related thoughts, feelings, and behavior scripts or motor programs. Provocations of various kinds can do this (e.g., insults, physical attacks), as can various background factors that are aversive, such as temperature.

## **E. TEMPERATURE EFFECTS ON PRESENT INTERNAL STATE**

Laboratory studies have shown that hot temperatures can influence all three categories of internal states (Anderson & Anderson, 1998). Several types of cognitive effects have been reported. Hot temperatures increase self-reported hostile attitudes (e.g., Anderson, Deuser, & DeNeve, 1995); hot people are more likely to agree with the following item: "It is all right for a partner to slap the other's face if challenged." Hot temperatures also impair performance on a number of cognition-related tasks, including visual and auditory vigilance tasks, rifle marksmanship, arithmetic tasks, and short-term memory tasks (e.g., Johnson & Kobrick, 1988 as cited in Kobrick & Johnson, 1991; Kobrick & Fine, 1983; Mortagy & Ramsey, 1973; Pepler, 1958; Poulton, Edwards, & Colquhoun, 1974; Ramsey, Dayal, & Ghahramani, 1975; Wing & Touchstone, 1965, as cited in Kobrick & Johnson, 1991).

Hot temperatures also increase the specific affect of state hostility (anger) as well as more general affects such as feeling upset, uncomfortable, and distressed (e.g., Anderson, Deuser, & DeNeve, 1995; Anderson, Anderson, & Deuser, 1996). Finally, hot temperatures have two somewhat paradoxical effects on arousal (e.g., Anderson, Deuser, & DeNeve, 1995; Anderson, Anderson, & Deuser, 1996). Hot temperatures increase heart rate, but decrease perceptions of arousal. Physiological arousal (as measured by heart rate) is increased by excessive heat, whereas psychological arousal is decreased (e.g., feeling lethargic, not energized).

Whether these heat effects on cognition, affect, and arousal are direct or indirect is unclear. There is some reason to believe that being uncomfortably hot directly affects emotion and arousal and that the cognitive effects are indirect, most likely the result of affective priming (e.g., Anderson, Deuser, & DeNeve, 1995; Anderson, Anderson, & Deuser, 1996). Considerably more research is needed before firm conclusions can be drawn, however.

The effects of uncomfortably cold temperatures have received little empirical study (see Anderson & Anderson, 1998, for a review). However, what little evidence exists suggests that cold temperatures should increase aggressive affect and cognition in much the same way as does excessive heat. Behavioral increases in aggression due to cold are expected in lab settings, where the researcher can prevent people from compensating for

the cold. Cold effects are less likely to occur in the natural environment, because people can usually compensate fairly easily by adding clothing.

#### IV. Lab Inconsistencies and Curvilinear Models of Heat Effects

A major controversy surrounding laboratory research on the heat hypothesis concerns inconsistencies among laboratory studies themselves. The basic problem has been that hot temperatures sometimes increase and sometimes decrease aggressive behavior in laboratory settings. An interesting theoretical approach to dealing with these inconsistencies is the Negative Affect Escape Model (NAE), an early version of which was proposed by Baron and Bell (1975). Later writings on the NAE model (Anderson, 1989; Anderson & DeNeve, 1992; Baron, 1979) have clarified the basic assumptions and postulates. The main difference between NAE and a Simple Negative Affect model (SNA) is that in SNA, aggressive motivation and aggression are both assumed to be a direct function of negative affect, whereas NAE adds a number of assumptions about the competing role of escape motivation. It is important to note that the NAE position on the role of escape motives is wholly compatible with Berkowitz's CNA model and our own General Affective Aggression Model (GAAM). Though GAAM and NAE have occasionally been portrayed as in opposition, there is nothing in GAAM ruling out the possibility of multiple motives simultaneously existing and competing.

Figure 8 displays the main features of NAE. As can be seen in Fig. 8A, aggressive motives and escape motives are increased by increases in negative affect, but at different rates.

A variety of factors may influence the overall level of negative affect. For instance, uncomfortable temperatures, personal insults, pain, and other aversive stimuli can increase negative affect. At low overall levels of negative affect, aggressive motives are assumed to dominate escape motives, at least in some settings. However, the slope relating negative affect to escape motivation is assumed to be steeper than the corresponding slope relating negative affect to aggression motivation (Fig. 8A). Thus, when the overall level of negative affect is low, increases in temperature (from comfortable to uncomfortably warm) should increase aggressive behavior (Fig. 8B). But, when the overall level of negative affect is moderate, increasingly uncomfortable temperatures should make the escape motive dominant and should therefore decrease aggressive behavior. Note that this reverse heat effect on aggression should occur **only** when escape behavior is incompatible with aggressive behavior.

The NAE explanation of past laboratory inconsistencies relies on an assumption that the overall level of negative affect has varied systematically

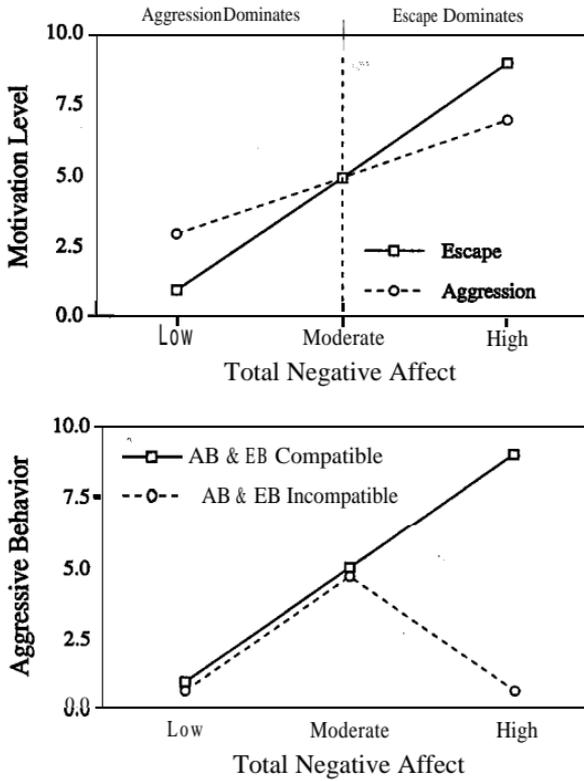


Fig. 8. The Negative Affect Escape model. (A) Motivation levels as a function of total negative affect. (B) Aggressive behavior as a function of total negative affect and compatibility of aggression and escape behaviors.

with the obtained findings of either a standard heat effect or the reverse heat effect. Several contextual factors have been used in prior research to vary the overall negative affect, such as attitudinal similarity, a cooling drink, and anger manipulations. According to the NAE explanation, the standard heat effect should occur when the context is relatively neutral, whereas the reverse heat effect should occur when the context is negative.

There are two problems with the NAE explanation of laboratory inconsistencies. First, most laboratory studies of the heat effect do not include any real escape option for participants. Thus, escape behaviors cannot interfere with aggressive behaviors and therefore none of these conditions should produce a decrease in aggression at hotter temperatures. The second problem is that the studies still appear to show considerable inconsistency even when categorized in terms of overall (context) level of negative affect (Anderson, 1989). To more objectively test the heat hypothesis in lab

settings, we conducted a meta-analysis (reported briefly in Anderson & Anderson, 1998), which is reported next.

## A. META-ANALYSIS OF LAB HEAT EFFECTS

All research reports which presented results of laboratory experiments that included both (a) a temperature manipulation and (b) a measure of aggressive behavior were included in the meta-analysis. First, all experiments referenced in the Anderson (1989) review were obtained. Second, the computer reference database *Psycinfo* was also searched from January, 1974 through December, 1995 crossing the words "temperature," "heat," and "climate" with all permutations of the words "aggress" and "violent." Third, the reference sections of the resulting articles were combed for additional relevant articles. A total of 10 articles were found; they reported a total of 11 experiments.

### *1. Effect Size Calculation and Categorization*

In order to assess the interactive effects of temperature and various affect-inducing manipulations on aggressive behavior, *d* indexes representing the difference between hot (90.0°-99.1°F) and comfortable (68.0°-75.2°F) temperatures on aggressive behavior were calculated for each nontemperature manipulation condition. We had to estimate means from reported graphs of the means and the mean square error (MSe) from the estimated means and reported *F*s for five experiments. For five other experiments, the MSe was estimated from reported *F*s and the *d* indexes were derived from the estimated MSe and the reported means. For the remaining experiment (Baron & Lawton, 1972), the reported Mann-Whitney *U* statistics were converted to *z* scores from which *d* indexes were calculated. One experiment (Baron, 1972) reported the results of two dependent variables, so the *d* indexes were averaged for this experiment. We calculated *d* indexes for one dependent variable in each of the remaining 10 experiments. A total of 28 effect sizes of the heat-aggression relation were derived. All *d* indexes were weighted by sample size (see Shadish & Haddock, 1994).

In order to test the effects of the nontemperature variables, we adopted a simple rule of assigning +1 to factors which may increase positive affect or reduce negative affect (e.g., a cooling drink) and -1 to those which may decrease positive affect or increase negative affect (e.g., an insult, or having dissimilar attitudes to a confederate). Conditions in which the net value of the nontemperature contextual factors were either positive or zero were assigned to a "neutral context" category. Those in which the net value was negative were placed in an "extranegative context" category. Table II lists

TABLE II  
TEMPERATURE AND AGGRESSION EFFECT SIZES BY AFFECT-INDUCING CONTEXT FACTORS<sup>a</sup>

86	Report	Dependent variable	<i>n</i>	Context factors		Net valence of context factors	<i>d</i>
				1	2		
	Baron (1972)	Shock intensity and duration	20	Anger (-)		-1	<b>- .58</b>
			20			0	<b>-.64</b>
	Baron and Bell (1975)	Shock intensity X duration	16	Anger (-)	Aggressive model (-)	-2	<b>-.21</b>
			16	Aggressive model (-)		-1	<b>.52</b>
			16	Anger (-)		-1	<b>-1.35</b>
			16			0	<b>1.10</b>
	Baron and Bell (1976)						
	Experiment 1	Shock intensity X duration	11.7	Anger (-)		-1	<b>-.87</b>
			11.7			0	<b>.43</b>
	Experiment 2	Shock intensity X duration	16	Anger (-)	Cooling drink (+)	0	<b>-.51</b>
			16	Cooling drink (+)		+1	<b>.19</b>
			16	Anger (-)		-1	<b>-.79</b>
			16			0	<b>.79</b>
	Baron and Lawton (1972)	Shock intensity	20	Anger (-)	Aggressive model (-)	-2	<b>.14</b>
			20	Anger (-)		-1	<b>-.46</b>
	Bell (1980)	Rating of E's reappointment	18	Anger (-)		-1	<b>1.19</b>
			18			0	<b>-.36</b>
	Bell and Baron (1976)	Shock intensity X duration	16	Anger (-)	Dissimilar attitudes (-)	-2	<b>-.83</b>
			16	Dissimilar attitudes (-)		-1	<b>.07</b>
			16	Anger (-)	Similar attitudes (+)	0	<b>.16</b>
			16	Similar attitudes (+)		+1	<b>1.43</b>
	Bell and Baron (1977)	Shock duration	18	Anger (-)		-1	<b>-.84</b>
			18			0	<b>.75</b>
	Palamarek and Rule (1979)	Choice of aggressive task	24	Anger (-)		-1	<b>-.23</b>
			24			0	<b>.38</b>
	van Goozen, Frijda, Kindt, and van de Poll (1994)	Withheld money from E.	30	Anger (-)	High anger disposition (-)	-2	<b>0.0</b>
			30	Anger (-)	Low anger disposition (0)	-1	<b>.14</b>
87	Boyanowski, Calvert-Boyanowski, Young, and Brideau (1975)	Shock intensity	10	Anger (-)		-1	<b>1.28</b>
			10			0	<b>.23</b>

<sup>a</sup> From Anderson and Anderson (1998).

<sup>b</sup> Shock intensity and duration effects were averaged for this experiment.

the types of affect manipulations and their presumed net effects on the participants' affective states as well as the *d* indexes of the effects of temperature on aggression.

## 2. Main Results

Across all 28 effects, there was no consistent effect of temperature on aggression. The average weighted *d* index was close to zero,  $d+ = .060$ , and the 95% confidence interval included zero  $[-.114 \text{ and } .234]$ . The 28 effect sizes were heterogeneous [ $\chi^2(27, N = 28) = 56.29, p < .001$ ]. Therefore, we tested the effect of the context factors (extranegative versus neutral) as a potential moderator of the temperature-aggression relation. The neutral contexts yielded significantly higher effect sizes of the temperature-aggression relation than the extranegative context conditions [ $\chi^2(1, N = 28) = 4.19, p < .05$ ]. As expected by virtually all theoretical models, the mean weighted *d* index for the neutral conditions was positive,  $d+ = .264$ , but it was barely significant, 95% confidence interval =  $[.001, .526]$ . The extranegative conditions revealed a nonsignificant negative relation between temperature and aggression,  $d+ = -.101$ , 95% confidence interval =  $[-.333, .132]$ .

## 3. Supplementary Results

One experiment which appears to support NAE at the behavioral level actually opposes it in other ways (Palamarek & Rule, 1979). Consistent with the NAE, aggressive behavior decreased more in the hot angry conditions than in the other conditions in this study. This experiment also included measures of escape motives and attributions about the causes of the participants' moods. Two interpretation problems arise from consideration of the results from these additional dependent variables. First, no temperature effects were found for desire to escape. Thus, this finding contradicts the NAE prediction that escape motives cause a decrease in aggression at uncomfortable temperatures. Second, more participants attributed their moods to the situation in the hot angry and cool nonangry conditions than in the other two conditions. These attributions match the decreases in aggression in these two conditions, suggesting that attributions rather than escape motives constituted the key mediational factor. Because of these concerns, we conducted a second meta-analysis with the two effect sizes from this experiment removed. The effect sizes remained heterogeneous [ $\chi^2(25, N = 26) = 55.18, p < .001$ ]. The difference between the neutral and extranegative context conditions became nonsignificant [ $\chi^2(1, N = 26) = 3.28, p > .05$ ], because the mean effect size for each context condition

became closer to zero. The neutral context condition effect of temperature became nonsignificant,  $d+ = .250$ , 95% confidence interval =  $[-.028, .528]$  and the extranegative condition moved even closer to zero,  $d+ = -.089$ , 95% confidence interval =  $[-.332, .154]$ .

#### *4. Summary*

Overall these results confirm earlier claims that the laboratory results of temperature-aggression studies are inconsistent. There is some support for the NAE predicted pattern of behavior, but little support for NAE itself. The Palamarek and Rule (1979) findings are particularly inconsistent with the NAE model.

## B. OTHER POSSIBLE CAUSES OF CURVILINEAR FUNCTIONS

Other factors may also create a curvilinear relation between level of negative affect and aggressive behavior. Four seem particularly relevant to the analyses of conflicting heat effects.

### *1. Attention Deficits*

Attentional deficits may occur as temperatures become increasingly uncomfortable (e.g., Hancock, 1986; Razmjou & Kjellberg, 1992; Shanazarov, Makhnovskii & Kuzyuta, 1989). At high temperatures, for instance, attention may be sufficiently diverted so as to interfere with the person's ability to notice or to fully process other provocation cues in their environment, such as a personal insult. Similarly, such attentional deficits may interfere with attempts to carry out an intended aggressive act. In both cases, a curvilinear relation between negative affect and aggression could be obtained. A modified version of the NAE model would also fit within this attention approach. If escape motives are distracting they may decrease aggression even in situations where escape behavior plays no direct interfering role. Figure 9 displays the perception of insult version of the attentional effects.

### *2. Social Justice*

Social justice concerns (e.g., Tedeschi & Felson, 1994) may prevent a linear negative-affect-aggression pattern in some paradigms. For instance, a hot temperature may prompt an initial aggressive outburst against a provocateur, followed by a lowering of aggression on later trials because

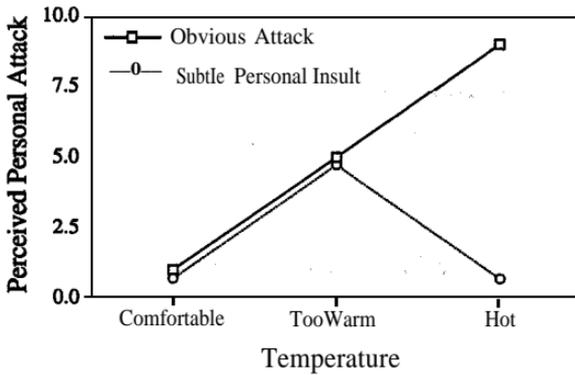


Fig. 9. Attention-deficit model of linear and curvilinear temperature effects.

the provocateur has been “sufficiently” punished (see Fig. 10). Those in a moderate negative-affect condition (e.g., in ‘moderately uncomfortable temperatures) may not be sufficiently upset by the initial provocation to succumb to the desire to deliver an initial aggressive outburst. Consequently, on later trials they may not feel that sufficient punishment has been delivered and therefore may not choose to decrease their aggression level. If the dependent measure of aggression fails to capture the initial outburst, or averages across multiple trials, then a curvilinear relation between negative affect and aggression may be observed. (Note that though this sequence may accurately capture the curvilinear aspect it may also miss or average out the initial outburst effect.)

In the standard Taylor Competitive Reaction Time (TCRT) paradigm, for instance, participants believe they are participating in a series of reaction

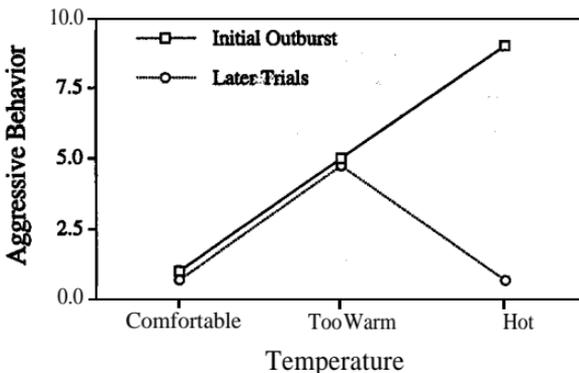


Fig. 10. Social Justice model of linear and curvilinear temperature effects.

time contests against an opponent (Taylor, 1967). The participants believe that the loser of each trial receives a punishment (usually electric shock), the intensity of which has been set by their opponent. Before each trial, the participant “sets” the punishment level that their opponent will receive if the opponent loses that trial.

In the TCRT paradigm, the participants actually receive wins, losses, and punishments on a predetermined schedule. In many real-world settings, of course, an initial aggressive outburst (either behavioral or verbal) is likely to produce immediate retaliative consequences which may, in turn, provoke even more highly aggressive responses. Thus, even if this social justice process is real, the curvilinear “he’s suffered enough” social justice effect may not come into play at all in many natural settings. Nonetheless, this model is particularly interesting because it is the only one that predicts both an initial outburst and a later diminution of aggression at high levels of negative affect.

### *3. Negative Affect Correction*

When a person’s self-perceived negative state of mind is obviously related to some stimulus other than a social provocation, there may be some attempt to “correct” one’s perceptions or treatment of other people. In other words, in unbearably hot conditions the realization that the heat might affect their reactions to other people in a negative way may lead to an attempt to correct for this negative bias by being nicer than what the situation seems to call for. When combined with the Simple Negative Affect process, this correction process may also produce interesting curvilinear effects on aggressive behavior and rated perceptions of others. Specifically, this would produce the same inverted “U” function between negative affect and aggressive behavior as in the NAE model when aggressive and escape behaviors are incompatible (Fig. 8), the Attention Deficit model when the insult is subtle (Fig. 9), and the Social Justice model for later aggressive trials (Fig. 10). What distinguishes the Negative Affect Correction model from the others is that it is the only one that predicts an inverted “U” function for judgments about the hostility (or kindness) of other people’s behaviors. This would most likely occur in situations in which the meaning of others’ behaviors is at least somewhat ambiguous.

### *4. Lab Setting Artifacts*

One frequent criticism of laboratory research on aggression in general is that aggression in the lab is fundamentally different than “real” aggression—that it lacks external validity. But a number of analyses have shown

that standard laboratory measures of aggression have considerable external validity (Anderson & Bushman, 1997; Anderson, Lindsay, & Bushman, 1999; Carlson, Marcus-Newhall, & Miller, 1989; Giancola, & Zeichner, 1995). For example, Anderson and Bushman (1997) found considerable correspondence between the effect sizes of key independent variables on aggression in lab and real-world settings.

The inconsistencies in laboratory research on temperature may be the result of laboratory artifacts. The possibility of participant suspicion is theoretically uninteresting, but could account for some inconsistent results in early studies in the temperature-aggression domain (Anderson, 1989; Rule & Nesdale, 1976). In many studies participants in the hotter conditions had a kerosene heater in the same room with them while performing the aggression task. If people in our society do have intuitive theories relating hot temperatures to aggressive behavior, then the obviousness of the temperature manipulation might well produce unusual behavior. To date, however, there has been no systematic assessment of people's beliefs about the likely effects of hot temperatures on aggressive behavior. Our Experiment 1 (to be described in a later section) provides such an assessment.

A more interesting lab-setting problem concerns paradigms that have used a series of trials, such as the TCRT procedure described earlier. This procedure can mask true linear or curvilinear relations between negative affect and aggression in two distinct ways. The apparent interactive nature of the serial contests may well make participants use their punishment settings to try to control what their opponent will set for them on future trials. In other words, the goal of controlling one's opponent may well override aggressive and/or social justice goals in ways that distort the aggressive behavior results (Baron, 1973; Gaebelin, 1978). Second, averaging early trial measures of aggression with later ones may hide true linear, curvilinear, or both types of relations between temperature and aggression. Our Experiment 5 (described in a later section) includes a modification to the TCRT procedure that eliminates the goal of controlling one's opponent and thus provides a better opportunity for the pattern displayed in Fig. 10 to occur. In both Experiments 4 and 5 we analyze the aggressive responses generated by participants on the first trial separately from their later aggression opportunities to allow for the detection of an outburst effect.

### C. HOT AND COLD EFFECTS

All models that involve negative affect or discomfort must deal with yet another inconsistency. This concerns a lack of symmetry between heat and cold effects in the field data as well as in the laboratory tests. The major

models of temperature effects on aggression rely on negative affect in one way or another (Anderson, 1989; Anderson, Anderson, & Deuser, 1996; Baron, 1979; Berkowitz, 1993). But cold temperatures might increase negative affect in much the same way as hot temperatures do. Therefore, we might expect to see increased aggression as a function of cold discomfort paralleling the hot discomfort effects. However, there is little evidence of a cold effect in field settings and there are few tests of it in laboratory settings (Anderson & Anderson, 1998).

There is one simple explanation for the lack of parallel cold-induced aggression in naturalistic settings. People and societies are generally better at reducing cold discomfort (via clothing, heating) than they are at reducing heat discomfort. There may well be evolutionary reasons for this, but such speculation takes us well beyond the scope of this chapter. Given that the temperature discomfort effect itself is a relatively fragile one, it is not too surprising that cold-induced increases in violent crime rates (for instance) are not obvious. If one eliminates this real-world asymmetry in ability to compensate for excessive cold vs heat, as one can do in lab settings, then similar hot and cold effects on aggressive behavior may well occur. In all five experiments reported in this chapter, we assess the effects of both hot and cold temperatures on a variety of dependent variables.

Figure 11 displays the Social Justice model of Fig. 10 extended to uncomfortably cold temperatures. Under some circumstances, such as when neither provocation nor strategic control motives overwhelm temperature effects, provoked people may be especially punitive in hot and cold conditions at the first retaliation opportunity—the initial outburst effect. Across the entire temperature range, then, the initial outburst would show up as a quadratic temperature effect on aggression in the initial trial—a “U”-shaped function.

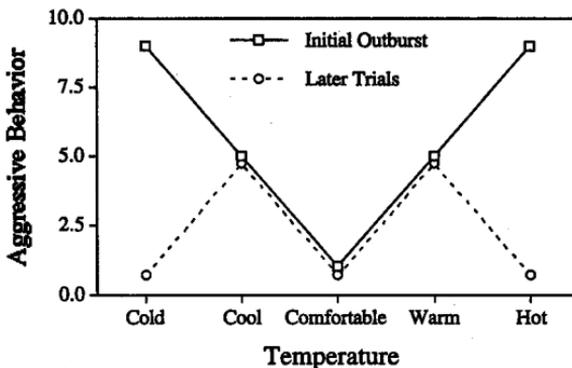


Fig. 11. Social Justice model applied to cold and hot temperature effects on aggression.

Having justly punished their provocateur on this initial trial, these same people may then become relatively less punitive on later trials. Those in extreme hot and cold temperatures may also be more likely to assume that their opponent is highly uncomfortable and is therefore less deserving of subsequent punishment. Across the entire temperature range, this would show up as a quartic temperature effect—an “M”-shaped function (i.e., two adjacent inverted “U”-shaped functions).

## **V. Experimental Studies of the Temperature-Aggression Hypothesis**

### **A. SUMMARY AND OVERVIEW**

As described earlier, results of laboratory experiments on temperature and aggression have been inconsistent and confusing. The results of the following five experiments and the theoretical explanations provided may shed light on the issues involved in the inconsistencies. There are several theoretical reasons for expecting curvilinear relations between temperature discomfort and aggressive behavior. The five experiments reported in this section were designed to address the following questions. First, what beliefs do people hold about the likely effects of uncomfortably hot and cold temperatures on affect and behavior (Expt. 1)? Second, what are the effects of temperature variations (from cold through comfortable to hot) on affect, physiological arousal, and perceived arousal (Expt. 2)? Third, what are the effects of temperature variations on hostile perceptions and on attention to hostility cues (Expt. 3)? Fourth, what are the effects of temperature variations on escape motives (Expts. 4 and 5)? Fifth, what are the effects of temperature variations and provocation on aggressive behavior in a standard Taylor Competitive Reaction Time paradigm (Expt. 4)? Sixth, what are the effects of temperature variations and ambiguous provocation on initial aggressive outbursts and on subsequent aggressive behavior trials when the goal of controlling one's provocateur is eliminated (Experiment 5)?

### **B. EXPERIMENT 1: SOCIAL THEORIES OF TEMPERATURE EFFECTS**

The goal of Experiment 1 was to assess the social theories of our participant population concerning the relation of temperature to the several variables of interest in this domain: affect, arousal, and aggression. A **question-**

naire was developed to measure participants' social theories concerning the relation of both hot and cold temperatures to these variables.

### 1. Method

**a. Procedures.** Fifteen female and seven male undergraduates at a large midwestern university participated in this experiment. Participants were given the two-page questionnaire, which was titled "Beliefs about temperature, emotions, and behavior." They were instructed to "Indicate your beliefs by circling a number for each item below." After completing the questionnaire, participants were thoroughly debriefed and thanked for their assistance.

**b. Temperature Questionnaire.** Participants' beliefs about the effects of hot and cold temperatures, compared to normal temperatures, were assessed on three dimensions: "alertness and energy level," "feelings of hostility and anger," and "aggression and violent behaviors." Each question was answered on a 5-point rating scale, with "-2" indicating a belief that the temperature (hot or cold) would decrease the target variable (i.e., alertness, hostility, or aggression), "0" indicating a belief in no temperature effect, and "+2" indicating a belief that the temperature would increase the target variable. The three questions concerning effects of hot temperatures were presented on one page. The corresponding three cold temperature questions were on another page. Participants were randomly assigned to completing the hot or the cold page first. This order manipulation allowed examination of the possibility that thinking about one type of temperature effect (e.g., hot) would influence participants' responses on the other (e.g., cold).

### 2. Results and Discussion

The six items and results are presented in Fig. 12. There were no reliable effects of task order or of sex ( $ps > .05$ ) so subsequent tests ignored these factors.<sup>3</sup> A *t* test was performed on each item mean to see whether it differed reliably from the scale midpoint of 0, which corresponded to a belief in no effect of temperature. As can be seen, hot temperatures were expected to have a very large impact on all three target variables. Compared to normal temperatures, hot temperatures were expected to produce a significant decrease in alertness and energy level [ $M = -1.50$ ,  $t(21) =$

<sup>3</sup> A larger study ( $N = 55$ ) was also conducted using these same procedures and items. However, the order of hot versus cold questions was not varied. The result was a practically identical set of means, each of which differed significantly from the scale midpoint of "No Effect."

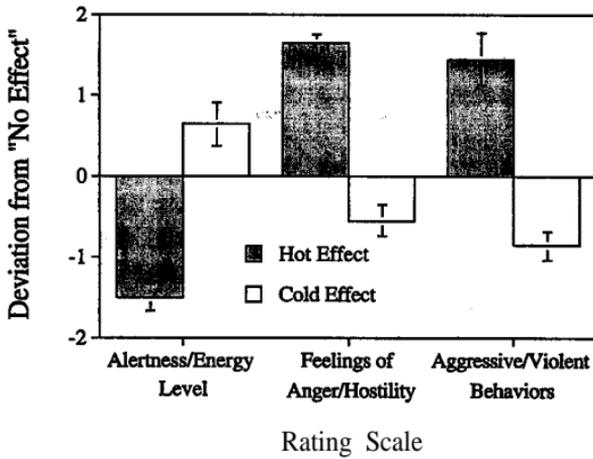


Fig. 12. Participants' beliefs about the effects of hot and cold temperatures. Negative scores indicate a belief that the temperature would decrease the target variable, whereas positive scores indicate a belief that the temperature would increase the target variable. Adapted from Anderson and Anderson (1998).

-8.77,  $p < .001$ ], a significant increase in anger and hostility [ $M = 1.64$ ,  $t(21) = 13.24$ ,  $p < .001$ ], and a significant increase in aggressive and violent behavior [ $M = 1.45$ ,  $t(21) = 10.14$ ,  $p < .001$ ].

Cold temperatures also were expected to have systematic effects on the target variables, but the size was much smaller. Also note that in every case the direction of the expected cold temperature effect was opposite of the expected hot temperature effect. Compared to normal temperatures, cold temperatures were expected to produce a significant increase in alertness and energy level [ $M = 0.64$ ,  $t(21) = 2.32$ ,  $p < .05$ ], a significant decrease in anger and hostility [ $M = -.55$ ,  $t(21) = -2.83$ ,  $p < .01$ ], and a significant decrease in aggressive and violent behavior [ $M = -.86$ ,  $t(21) = -4.84$ ,  $p < .001$ ].

Overall, these results confirm that people do have social theories relating temperature to a host of aggression-related variables. Past inconsistencies in laboratory research may be due, in part, to artifactual participant reactions based on these social theories. Future research may benefit from these findings by designing experiments that reduce participant suspicions and by including assessments of suspicion. The finding of opposite social theories for the effects of uncomfortably cold temperatures may also prove useful in future research on the effects of temperature on aggression. Specifically, when theory predicts similar behavioral responses to comparably uncomfortable cold and hot temperatures, if the results are similar for cold and

hot temperatures then a participant-suspicion alternative explanation based on underlying social theories is effectively ruled out.

### C. EXPERIMENT 2: HOT AND COLD EFFECTS ON COMFORT AND AROUSAL

In order to accurately test for the effects of both hot and cold discomfort on other dependent variables such as aggressive behavior, it is necessary to know with some precision what hot temperatures are equivalently uncomfortable to what cold temperatures. Obviously, thermal comfort depends not only on temperature but also on clothing and type of physical activity. Our current laboratory experiments involve minimal physical activity, so this factor is essentially controlled. In addition, to control for clothing factors all participants in our temperature studies are required to wear long pants and a short-sleeved shirt. Under these conditions, we sought in Experiment 2 to discover equivalently uncomfortable "hot" and "cold" temperatures.

In addition, Experiment 2 assessed the effects of differing temperatures on both physiological and perceived arousal. Prior work on heat effects suggests that we should expect perceived arousal to be negatively related to temperature, heart rate to be positively related to temperature, and blood pressure to be unrelated to temperature (Anderson, Deuser, & DeNeve, 1995). However, because that work did not include cold temperatures, we included blood pressure measures even though we did not expect large temperature effects on them.

Experiment 2 also provided a test of effects of hot and cold temperatures on general positive and negative affect. There are theoretical reasons for expecting uncomfortable temperatures to increase negative affect, though it is not clear whether such effects should occur on general negative affect measures or only on more specific ones related to annoyance, anger, and hostility. Thus, we had no strong prediction about the relation between temperature and general negative affect.

Prior work is also silent on the effects of discomfort on positive affect. Because positive affect is often uncorrelated with negative affect (Watson, Clark, & Tellegen, 1988), we had no firm expectations or predictions for temperature effects on positive affect; it was included for purely exploratory purposes.

#### *1. Method*

*a. Participants.* One hundred seventy-two students from a large mid-western university participated in the experiment. Sample size in reported

analyses varies slightly because of occasional missing values. Participants wore short-sleeved shirts and long pants in order to minimize the effects of clothing differences on the effectiveness of the temperature manipulation. Participants were run in pairs, with the first participant arriving 15 min before the second participant. Each received credit for course requirements in introductory psychology classes. The procedure took approximately 45 min to complete.

**b. Design and Apparatus.** The experiment employed five target temperature conditions (55°, 65°, 75°, 85°, and 95°F). Participants were assigned to one of two identical temperature rooms, where a Macintosh **IIcx** computer was set up to run a nonaggressive video game (called "Tetrix"). One temperature room was randomly set at a target temperature, while the other room was yoked. Specifically, the cold air outlet of a heat pump was ducted into the "cold" room; the hot air outlet was ducted into the "hot" room. In this way, if one room was randomly set to be 85°F, the other temperature room was yoked to be approximately 65°F.

The main dependent measures were perceived arousal, assessed by the Perceived Arousal Scale (PAS; Anderson et al, 1995); perceived comfort, assessed by the Perceived Comfort Scale (PCS; Anderson et al., 1996); and heart rate, blood pressure, and positive and negative affect, assessed by the Positive and Negative Affect Scales (PANAS; Watson et al, 1988).

The Perceived Arousal Scale was presented to participants as the "Current Feelings and Emotions" scale. Participants rated 23 adjectives on a scale of 1 (very slightly or not at all) to 5 (extremely) to indicate "the extent you feel this way right now, that is, at the present moment." Ten of the items indicate arousal (e.g., energetic), whereas 13 items indicate a lack of arousal (e.g., sleepy).<sup>4</sup>

The Perceived Comfort Scale (PCS) consists of 10 adjectives rated on a 1 (very slightly or not at all) to 5 (extremely) scale to indicate "the extent you feel each word describes the room right now, that is, at the present moment." Six items indicated comfort (e.g., comfortable), whereas the remaining four indicated discomfort (e.g., uncomfortable).

Heart rate and blood pressure were assessed by an oscillometric automatic constant-air-release blood pressure meter with a digital display (A & D Engineering, Model UA-701). Participants were not allowed to see their physiological measures until after the experiment was completed.

The PANAS consists of 10 general positive and 10 negative affect adjectives. Each is rated on a 5-point scale ranging from 1 (very slightly or not at all) to 5 (extremely) to indicate "... the extent you feel this way right now. . . ."

<sup>4</sup>The Perceived Arousal Scale has 24 items. One item (weary) was inadvertently omitted.

Several additional variables were recorded to see if their inclusion in the statistical analyses made any difference. These were sex, humidity, and the outside temperature. Because the latter two variables had no important effects in preliminary analyses, they are not discussed further.

c. **Procedures.** The experiment began in a room set at a comfortable temperature (approximately 72-75°F). Participants were led to believe that the research involved the effects of temperature on physiological arousal as related to video game performance. After participants signed consent forms, their heart rate and blood pressure were measured.

Participants were then led to one of two temperature rooms. The participant who arrived first was randomly assigned to either the target or the yoked temperature room. The second participant was assigned to the remaining temperature room. Participants then played the nonaggressive video game "Tetrix", writing down their score after each game. After 30 min heart rate and blood pressure were assessed a second time. Then participants completed the PAS, the PANAS, and the PCS.

## 2. Results from Preliminary Analyses

a. **Temperature Control.** Actual temperatures varied somewhat from the target temperatures, especially in the yoked room. For this reason, regression analyses were performed with temperature used as a continuous factor, and all figures are based on the slopes derived from these regressions. The actual range was from 58° to 96°F. Two statistical advantages to utilizing temperature as a continuous variable are that regression analyses make full use of the temperature IV and that predicted curvilinear effects (e.g., the "U"-shaped function) can be easily tested with polynomial terms (e.g., a quadratic temperature term).

b. **Perceived Comfort Scale.** The "comfortable" and "uncomfortable" subscales of the PCS were strongly correlated ( $r = -.60$ ). Thus, they were combined into one overall Perceived Comfort score after reverse scoring the negative items. The internal reliability was quite high (coefficient  $\alpha = .90$ ).

c. **Perceived Arousal Scale.** The "aroused" and "unaroused" subscales were strongly correlated ( $r = -.51$ ). Therefore, they were combined (after appropriate reverse scoring of the "unaroused" items) to form one overall Perceived Arousal score. The internal reliability for the PAS was also quite high (coefficient  $\alpha = .93$ ).

d. **PANAS.** As expected, the positive and negative affect scales were only slightly correlated ( $r = .16$ ). Thus, they were analyzed separately. The internal reliability was sufficient for both scales (coefficient  $\alpha = .89$  and  $.78$ , respectively).

### 3. Results from Main Analyses

Regression analyses were conducted with sex, linear temperature, and curvilinear temperature effects as the independent variables. Temperature was first centered (i.e., converted to deviation score form) by subtracting the mean temperature, which was 76.7°F. Curvilinear temperature effects were assessed by inclusion of a quadratic temperature term. For all regression models, an alpha level of .05 was used for the effects of the theoretically relevant temperature tests. Because of the large number of theoretically irrelevant effects that were tested in this analysis, a Bonferroni correction was used for these irrelevant effects to protect against possible Type I errors.

**a. Physiological Arousal.** To examine the effects of temperature on physiological arousal, heart rate and blood pressure measures taken immediately after the signing of consent, forms (Time 1) were compared to the measures taken after 30 min in the temperature room (Time 2). Specifically, we analyzed the change scores (T2-T1) to assess whether changes in the physiological measures were associated with the temperature manipulation.

As expected, heart rate changes were positively related to temperature [ $F(1, 158) = 7.27, p < .01$ ]. The regression line relating temperature to heart rate change revealed that hotter temperatures led to a relative increase in heart rate ( $b = .23, a = -2.67$ ). On this measure, then, hot temperatures increased physiological arousal, whereas cold temperatures decreased it. None of the sex or curvilinear temperature effects approached significance.

Interestingly, changes in diastolic blood pressure were negatively related to temperature [ $F(1, 163) = 7.17, p < .01$ ]. As temperature increased diastolic blood pressure decreased ( $b = -.13, a = -3.48$ ). Presumably, this was a result of vasodilation in hot temperatures and vasoconstriction in cold temperatures as a thermoregulatory mechanism. The change in systolic pressure analysis did not produce any significant effects.

**b. Perceived Arousal.** As anticipated, the main effect for linear temperature was significant [ $F(1, 166) = 15.55, p < .0001$ ]. Perceived arousal decreased as temperature increased ( $b = -.20, a = 3.14$ ). No other effects approached significance.

**c. Perceived Comfort.** We expected that participants in the extremely cold and extremely hot conditions would be the least comfortable. Therefore, we expected a curvilinear relation between temperature and comfort. This was confirmed, as both the linear and the quadratic temperature terms were significant [ $F_s(1, 165) = 9.71$  and  $51.90, p_s < .01$  and  $.0001$ , respectively]. No other effects were significant. The regression line relating linear and quadratic temperature terms to comfort indicated that temperatures in the mid to high 70s were most comfortable, ( $b_{lin} = .0135, b_{quad} = -.0037, a = 3.21$ ). These results are similar to Anderson et al.'s (1996),

but are shifted a few degrees toward the hot end. Similarly, temperatures in the low 60s were about as uncomfortable as was 96°F. Figure 13 displays the best fitting regression line. As can be seen, the coldest temperatures were slightly more uncomfortable than the hottest ones.

*d. Positive and Negative Affect.* The temperature manipulation had no reliable effects on either positive or negative affect. It is not clear from this result whether temperature effects on affect are limited to comfort, whether more specific types of negative affect are influenced by extreme temperatures, or whether more power is needed to reliably detect a true effect of temperature on general affect.

#### 4. Discussion

Experiment 2 yielded several interesting findings. The perceived comfort results showed that the PCS reliably measures comfort and that given the clothing restrictions and low level of activity typical of laboratory research, temperatures in the low 60s (°F) are as uncomfortable as temperatures in the mid-90s. This is important because it instructs researchers on the range of temperatures to use in future studies involving both hot and cold discomfort.

The arousal results of Experiment 2 are also valuable in directing future research. The heart rate results suggest that hot temperatures are somewhat arousing but that cold temperatures are not. However, the blood pressure results were considerably more complex. Certainly, additional research is needed.

The perceived arousal results were quite strong in showing decreases at hot temperatures and increases at cold ones. Taken together with the heart

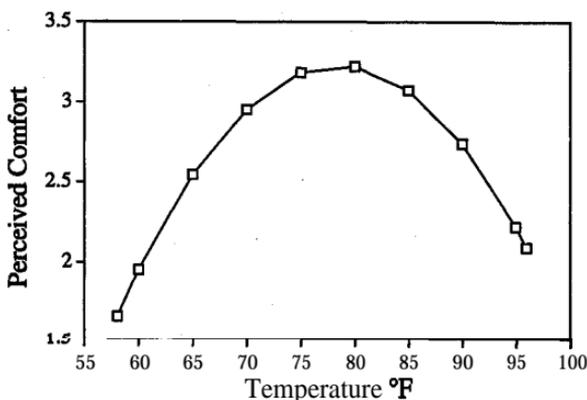


Fig. 13. Perceived comfort as a function of temperature.

rate findings, these results suggest that hot temperatures may produce optimal conditions for increased aggression. Specifically, in accord with Zillmann's excitation transfer theory (e.g., 1983a, 1983b), people in hot conditions may experience increased arousal without being aware that they are in fact aroused. If a salient anger-producing event or person were present, then the heat-based increase in arousal may be transferred (misattributed), increasing the experienced anger. If this pattern holds up in further research, then we may see excitation-transfer-based increases in aggressive behavior primarily in hot temperatures rather than cold ones. Additional research is needed to confirm these preliminary arousal findings, as well as to more clearly explicate the roles of physiological versus perceived arousal.

Finally, the general affect results were instructive. We thought that general negative affect might increase in both hot and cold temperatures. It may well be that negative affect, as measured by PANAS, is too general in this context.

#### D. EXPERIMENT 3: TEMPERATURE EFFECTS ON PERCEPTIONS OF HOSTILITY

This experiment was designed to examine two factors related to the various models of temperature effects, rated perceptions of hostility and attention to hostility-related cues. Participants watched four brief video tapes, each of which showed a different couple interacting. The interactions varied in amount of aggressive content. After each tape, participants rated the couples on a large number of items, 10 of which were related to perceptions of hostility.

##### *1. Method*

*a. Participants.* Sixty-one males and 88 females were recruited from undergraduate general psychology courses via sign-up sheets. They received extra credit for their participation.

*b. Procedures.* Participants were always scheduled to be run in groups of between two and four in each of two temperature-controlled lab rooms. Participants were greeted by an experimenter and were told that they were participating in a study concerned with the effects of lighting and temperature on several different cognitive tasks. Participants were informed that they would be randomly assigned to one of five temperature conditions (cold, cool, comfortable, warm, or hot). After being randomly assigned to a temperature room, participants were seated at a desk or cubicle that had

a consent form and four envelopes containing the stimulus materials for the various tasks. All of the seats were arranged so that participants would be facing a television monitor approximately 7 feet away from them. Each of the temperature rooms were preset to a randomly determined temperature for a particular session. Each temperature room had its own digital thermostat allowing it to be set to one of the five target temperatures. The targeted room temperature (in Fahrenheit degrees) was 57° for the cold condition, 65° for the cool condition, 75° for the comfortable condition, 85° for the warm condition, and 97° for the hot condition. The actual temperature was recorded at the end of each session by the experimenter and recorded on a data sheet.

After obtaining informed consent, the experimenter went to an adjacent control room and gave tape-recorded instructions by way of an intercom system. Participants understood that both audio and video from their room was being monitored and that they could ask questions (by raising their hand and addressing the experimenter) at any time during the experiment. The first task was a word-scanning filler task. This task was included for two different reasons: (1) to start the study with an attention-demanding task to assist with the cover story and (2) to allow participants to experience the temperature of the room for 10 min before completing the main tasks of interest. The instructions for the filler task asked participants to:

Carefully read the three-page article about fresh-baked bread. As you carefully read the article, count the number of times the word "flour" and the word "baked" appear as text anywhere on the three page article and write the correct answers on the appropriate line of the small sheet of paper. Please do not make any marks anywhere on the article. Accuracy is the primary concern for this task. This is a timed task, and you will have 10 minutes to complete the task. When the time is up, place the article and the word count form back in envelope "A."

After the 10 min had elapsed, recorded instructions announced that time was up and that the materials should be placed back into envelop "A."

The second task was a video interpretation task previously used and reported in Dill, Anderson, Anderson, and Deuser (1997). Participants watched four different video scenarios. The videos each contained one male and one female having a conversation. The male and female "actors" in the videos were actually psychology graduate students acting out rehearsed scenarios. Each scenario contained a different pair of actors. One of the videos, a neutral video, was always shown first and was used as a practice video. The remaining three videos were shown in random counter-balanced orders (three different orders were used). These three videos varied with respect to ambiguity of their aggressive content. The "neutral" video contained virtually no aggressive content. The "ambiguous" video

contained a moderately small amount of aggressive content. The “aggressive” video contained more clearly aggressive content (verbal).

The task of participants was to view each video and then to rate both the male and the female in the video on 28 adjectives using a 7-point Likert-type rating scale. Participants were given 4 min to rate each video. Ten of the items were aggression related (e.g., bitter, hostile, aggressive). For details on the creation, selection, and content of the video interpretation task see Dill et al. (1997). Finally, all participants were debriefed and any questions that participants had were addressed by the experimenter.

## 2. Results

**a. Data Preparation and Preliminary Analyses.** The main dependent variable of interest was perceived hostility, based on participants' ratings of the two actors in each of the three video tapes on 10 aggression-related adjectives. As in Dill et al. (1997), for each adjective we averaged each pair of ratings within each video taped dyadic interaction and then averaged these across the 10 adjectives to get each participant's hostile perception score for each of the three video tapes. Thus, from each participant we obtained three hostility scores, one for each of the three video interactions. These scales proved to be internally consistent; coefficient alphas were .87, .90, and .92 for the neutral, ambiguous, and aggressive videos, respectively.

Recall that participants were randomly assigned to one of five temperature conditions: cold, cool, comfortable, warm, and hot. We also recorded the exact temperature at which each person actually participated, which often varied from the assigned temperature by 1° to 3°. There was no overlap in actual temperature between the five assigned temperature conditions.

For all analyses the actual temperature was used as a continuous independent variable rather than the assigned temperature. Temperature was first centered. Then, three additional temperature terms were created to allow a test of the hypothesis that the relation between temperature and hostile perceptions would be “M” shaped. Specifically, quadratic, cubic, and quartic temperature terms were created from the temperature z scores. By centering temperature before creating the three curvilinear terms, we reduced the artifactual multicollinearity between these four predictors. It should be noted that one misconception held by some scholars in this area is that centering eliminates the multicollinearity problem. However, the linear term and the cubic term will still be very highly correlated, as will the quadratic and the quartic terms. In the present study the linear and cubic terms still correlated at .94; the quadratic and quartic terms correlated at .97. Because the underlying distribution of temperatures was not perfectly symmetric, remaining possible pairs of temperature terms were also corre-

lated; they ranged from .26 to .44. Therefore, the proper method for testing for the effects of these temperature predictors is to do so hierarchically. In other words, each temperature term is tested with all lower order terms but none of the higher order terms in the statistical model.

A repeated-measures regression analysis was performed, with type of video (neutral, ambiguous, aggressive) as the repeated variable, the four temperature terms as continuous predictors, and order-of-videotape presentation as a categorical variable.

Preliminary analyses revealed no sex differences in hostile perceptions. Therefore, this variable was dropped in subsequent analyses. **Order-of-videotape** presentation yielded a significant (and uninteresting) main effect,  $F(2, 142) = 3.81, p < .03$ . However, order-of-videotape presentation did not interact with the temperature variables, so these interaction terms were dropped from the final model. There was also a significant main effect of video tape on hostile perceptions [ $F(2, 284) = 219.36, p < .001$ ]. As expected, participants perceived the least hostility in the neutral video ( $M = 1.35$ ), the most in the aggressive video ( $M = 5.09$ ), and a moderate amount in the ambiguous video ( $M = 3.20$ ).

*b. Temperature and Hostile Perceptions.* Overall, only the quartic temperature term yielded a significant effect on perceptions of hostility [ $F(1, 142) = 4.27, p < .05$ ]. As predicted by the Negative Affect Correction model, hostility ratings were lowest at comfortable temperatures, highest at uncomfortably warm and cool temperatures, and slightly elevated at hot and cold temperatures. Figure 14 displays these results. None of the other temperature effects were significant ( $ps > .5$ ).

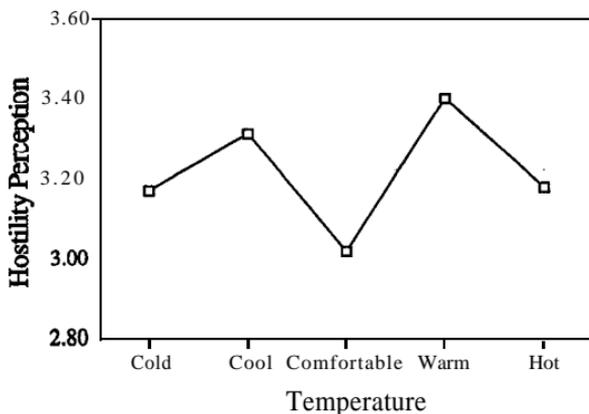


Fig. 14. Mean perception of hostility in three dyadic interactions as a function of temperature.

The video tape  $\times$  quartic temperature term was not significant ( $p > .4$ ), suggesting that this temperature effect did not reliably differ for the neutral, ambiguous, and aggressive videos. However, we expected that the temperature effects on hostile perceptions would be most pronounced on the ambiguous video. Supplementary analyses of temperature effects on each video separately revealed that the quartic effect was individually significant for the ambiguous video [ $F(1, 142) = 5.10, p < .03$ ], but not for either of the other two videos ( $ps > .2$ ).

It is also interesting to note that the magnitude of the video tape effect on hostile perception did not differ in the different temperature conditions. The attention-deficit model predicts that participants in the more extreme temperature conditions would have more difficulty attending to the video tapes and thus would be less likely to notice differences in the aggressiveness of the three tapes. But, this quadratic temperature  $\times$  video tape interaction was not significant, suggesting that the attention explanation does not apply in this context.

#### E. EXPERIMENT 4: PROVOCATION AND TEMPERATURE EFFECTS IN THE TAYLOR COMPETITIVE REACTION-TIME PARADIGM

In this experiment college students participated in a competitive **reaction-time** task modeled after Taylor's paradigm. Specifically, participants were led to believe that they were competing against another person on a reaction-time task. Supposedly as a means of motivating everyone to do their best, the contestants received punishment after each reaction-time trial that they lost. The punishment consisted of white noise delivered via headphones (see Bushman & Geen, 1990). The level of punishment was to be set by each contestant's opponent prior to each trial. The level of punishment for each trial that the participant set for his or her opponent was the indicator of aggressive behavior. Several theoretically meaningful affect measures were also assessed.

##### *1. Method*

*a. Participants and Design.* Two hundred thirty-three undergraduates enrolled in introductory psychology courses participated. To control for possible effects of sex of the opponent, participants were run in same-sex dyads. A second experimenter of the same sex as the participants acted as a confederate when only one participant arrived. Participants were not allowed to sign up or participate with an acquaintance or friend. Participants

wore short-sleeve shirts and long pants so that the temperature manipulation would be similarly experienced.

The design may be conceptualized as a 2 X 2 X 5 factorial with **between-participant** factors of sex of participant, provocation (high versus low), and temperature (55°, 65°, 75°, 85°, and 95°F). As in Experiment 2, half of the participants were randomly assigned to an experimental room that was set at one of the five target temperatures. The other half were assigned to a room that was yoked to the experimental room.

*b. Apparatus.* The two temperature-controlled rooms were identical. Each contained a Macintosh IIcx computer, monitor, keyboard, and mouse. A third room was used to give initial instructions and to take the initial measures of physiological arousal. Ambient temperature in a hallway that led from this "Start" room to the two temperature rooms was maintained between 68° and 70°F by window-unit air conditioners and space heaters. White noise was generated by the Macintosh computers and was amplified through two Sony SRS-5 Speakers to two pairs of Labtec LT101 stereo headphones. Heart rate and blood pressure readings were obtained by a Takeda medical UA-701 blood pressure meter.

*c. Competitive Reaction-Time Task.* At the beginning of each of 25 trials a green square on the computer screen signaled the participant to set the noise level for his or her opponent. A yellow square then appeared to alert the participant for the upcoming tone. The tone (approximately 65 db) signaled for the participant to press the mouse button as quickly as possible.

Once a trial was completed, the participant saw the level of noise feedback that the opponent had supposedly set for them. This feedback was presented in a bar graph on the computer screen. The participant also received the noise on 12 "lose" trials. If the participant took too long to respond (greater than 500 ms), that trial became a "lose" trial even if the computer had originally scheduled it to be a "win" trial. This was necessary to maintain the viability of the cover story because pretesting indicated that some participants would intentionally wait for several seconds on a few trials just to see if they were truly playing against another person.

*d. Provocation Manipulation.* The provocation manipulation took place during the reaction time task. The 10 levels of noise intensity ranged between 60 and 105 dB (in 5-dB increments). The duration of experienced noise blasts ranged from .25 to 2.50 s.

In the High Provocation condition, noise intensity increased from level 4 (75 dB) to level 10 (105 dB) across the three blocks of trials (eight trials in each block). The first block average intensity was level 6 (85 dB), the second block averaged level 7 (90 dB), and the third averaged level 8 (95 dB). Duration of the noise, also supposedly set by the opponent, in-

creased from an average of 1.5 s on the first block to 1.75 s in the second and 2.00 s in the third.

Noise feedback in the Low Provocation condition ranged between the three lowest intensity levels (60, 65, and 70 dB) and the three lowest durations (.25, .50 and .75 s) across all of the trials. The order in which the levels and durations were presented across trials were randomized for each participant within each of the three blocks of trials.

*e. Dependent Variables.* One set of dependent variables consisted of the punishment intensity levels set by participants for their opponents. Several affect measures, some filler items consistent with the cover story, and a belief questionnaire were administered after completion of the competitive reaction-time task. Of most theoretical interest were the state hostility and the escape motives scales. State hostility was measured with a 35-item scale labeled "Current Mood" (Anderson et al., 1995). Statements such as "I feel angry" were rated on Likert-type scales anchored at "strongly disagree" (1), "disagree" (2), "neither agree nor disagree" (3), "agree" (4), and "strongly agree" (5). Eleven items were reverse scored so that high scores on each item indicate higher levels of state hostility. A composite score of state hostility was obtained by summing across items.

Escape motives were assessed by a newly developed "Current Motives Scale." This measure lists 19 escape-related verbs such as "exit" and "retreat" and four unrelated words. The instructions asked participants to indicate on a 5-point scales-anchored at "very slightly or not at all" (1) and "extremely" (5)-to what extent they felt like performing the behaviors that the words suggest (see the Appendix).

Perceived arousal was once again measured with the Perceived Arousal Scale (Anderson et al., 1995). One item (passive) was added to the original 24 items in this scale.

Physiological arousal was measured by obtaining the participants' heart rate and blood pressure both before they entered the temperature room and after completion of the competitive reaction time task. Heart rate and blood pressure were measured twice at each time period to ensure accurate readings.

*5 Assessment of Suspicion.* After all of the dependent measures were collected, a structured interview was conducted with each participant individually. The experimenter asked a series of questions about the participant's reaction to the procedures. The first questions were general in nature such as, "Did you know anything about what the experiment was about before you came in to participate today?" The questions gradually increased in specificity about the independent and dependent variables. The goals of this interview were to (a) determine if the participant suspected that the purpose of the task was to measure aggressive behavior, (b) assess whether

the participant believed that he/she was actually setting noise levels for and receiving noise from the other participant, and (c) lead into the debriefing in such a way that the participant eventually "guessed" the hypothesis. "Discovering" the hypothesis has been shown to be a particularly effective way to alleviate negative effects produced by deception in experiments (Aronson, Ellsworth, Carlsmith, & Gonzales, 1990).

g. **Procedure.** Two participants could sign up for each experimental session. The experimenter randomly assigned participants to either the temperature-controlled room or to the yoked-temperature room. Each participant was also randomly assigned to either the high- or low-provocation condition. When one participant failed to attend, a confederate was used.

Upon arrival, two same-sex participants were led to the "Start" room, which was kept at a comfortable temperature (between 70° and 72°F). The participants were told that the experiment was on the effects of environmental stressors on performance on a reaction-time task. Temperature and noise were described as the environmental stressors under current investigation.

After completion of the consent procedures, the experimenter measured participants' heart rates and blood pressures and then led them to their proper temperature rooms. Two experimenters separately described the competitive reaction-time task to the two participants. These instructions included all necessary details about how to set their opponent's punishment levels and a reminder that their opponent would be doing the same for them. In addition, sound levels 1, 3, 5, 7, and 9 were demonstrated. When participants indicated that they understood the task, the experimenters told participants that subsequent instructions would be given over an intercom system. The experimenters then left the rooms and used the intercom to instruct participants to begin.

At the end of the reaction-time task the computer instructed participants to signal the experimenters via an intercom system. At this point in time, the affect questionnaires were brought to both participants and were completed in the temperature rooms. After participants completed the questionnaires, their heart rate and blood pressures were again measured, this time in the temperature rooms rather than in the "Start" room.

Finally, participants were led into separate comfortable temperature rooms by two different experimenters. Their suspicion of the experiment was assessed by a structured interview and they were thoroughly debriefed. If a confederate was used because one of the participants did not arrive, the purpose of the confederate was fully explained. Care was taken to ensure that the participant did not leave the experiment feeling upset. Table III summarizes the sequence of events.

TABLE III  
PROCEDURAL SUMMARY OF EXPERIMENT 4

- 
1. Start room (70°-72°F)
    - Cover story
    - Consent procedure
    - Baseline heart rate and blood pressure measurement
  2. Temperature rooms (56°-98°F)
    - Competitive reaction-time task explained and conducted
    - State hostility, perceived arousal, and escape motives questionnaires completed
    - Posttask heart rate and blood pressure measurements
  3. Start room
    - Suspicion assessment (orally administered)
    - Oral and written debriefing
- 

### 3. Results

Participants' suspicions about the noise intensities they received and about the temperature-aggression relation were assessed during the debriefing interview. Notes made during the interview were later examined by the chief experimenter, who then assigned a rating between 0 (no suspicion) and 4 (highly suspicious) for each participant. Only 12 participants were highly suspicious; they were evenly distributed across the temperatures. Preliminary analyses performed both with and without these participants' data yielded no major differences. These suspicious participants were not included in the final analyses. Thus, the final sample contained 221 participants, 115 males and 106 females. Occasional missing values on some of the questionnaires resulted in a slightly smaller sample for some dependent variables.

*a. Analysis Strategy.* Five target temperatures (55°, 65°, 75°, 85°, and 95°F) were sought in both of the experimental rooms. As anticipated, the actual temperatures deviated somewhat from the target temperatures, especially in the yoked room. Actual temperatures ranged from 56° to 99°F. Due to the dispersal of temperatures within this range, temperature was treated as a continuous variable. Temperatures were first centered (i.e., converted to deviation scores). Linear, quadratic, cubic, and quartic temperature terms were created from these scores.

Hierarchical regression analyses were conducted on all of the dependent variables with linear, quadratic, cubic, and quartic temperature terms, provocation level, sex of participant, and all possible interactions as predictor variables. Sex was dropped from the analyses whenever it had no reliable impact. The intensity-of-noise-level setting for Trial 1 was analyzed separately, both because it is the first opportunity for the participant to aggress

and because it occurred before the high- or low-provocation manipulations began. Intensity-of-noise settings for the remaining 24 trials were grouped into 3 blocks of 8 trials. These three blocks were treated as a repeated-measures factor in the regression ANOVAs on intensity.

State hostility, escape motives, perceived arousal, heart rate, and blood pressure change were also tested for effects of temperature, provocation, and sex. For all regression models, an alpha level of .05 was used for the effects of the theoretically relevant provocation and temperature manipulations. A Bonferroni correction was performed on all nonpredicted tests to protect against possible Type I errors.

The questionnaire measures were taken after completion of the TCRT task. We therefore predicted a main effect of the provocation manipulation and a quadratic effect of the temperature manipulation on the main affective measures of state hostility and escape motives. Finally, we predicted a linear temperature effect on perceived arousal, with higher scores in the colder temperatures.

*b. State Hostility.* This 35-item scale was highly internally reliable (coefficient  $\alpha = .95$ ). As expected, participants in the high-provocation condition reported higher levels of state hostility (adjusted  $M = 2.19$ ) than those in the low-provocation condition (adjusted  $M = 1.91$ ) [ $F(1, 212) = 15.21, p < .0001$ ].

Also as expected, there was a "U"-shaped relation between temperature and state hostility, as shown by the significant main effect of the quadratic temperature term [ $F(1, 212) = 7.00, p < .01$ ]. Hot and cold temperatures created increases in state hostility as can be seen in Fig. 15. None of the provocation  $\times$  temperature interactions, sex effects, or effects of the linear temperature term approached significance.

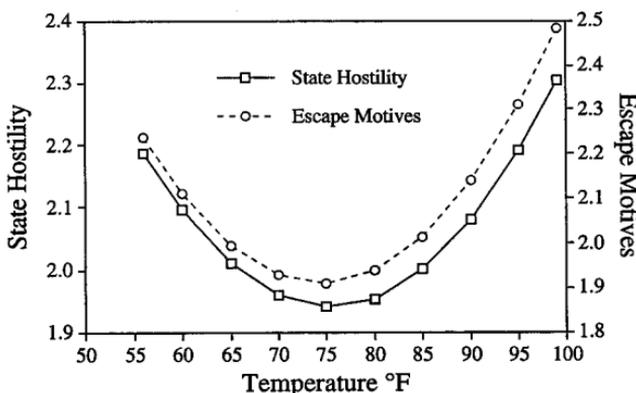


Fig. 15. State hostility and escape motives as a function of temperature.

These results demonstrate that both cold and hot temperatures can increase feelings of state hostility. Note that other temperature effects (linear, cubic, quartic) were not expected to be significant on this measure, and they were not.

*c. Escape Motives.* Internal reliability of this newly created 19-item scale was high (coefficient  $\alpha = .95$ ). As predicted, the quadratic temperature term was significantly related to escape motives [ $F(1, 219) = 5.65, p < .02$ ]. Desire to escape increased at uncomfortable ambient temperatures. None of the other effects approached significance. Figure 15 also displays these results.

*d. Perceived Arousal.* This 25-item scale had high internal reliability (coefficient  $\alpha = .92$ ). Perceived arousal was influenced by uncomfortable temperatures. Main effects were revealed for both the linear temperature term [ $F(1, 214) = 13.77, p < .001$ ], and for the quadratic temperature term [ $F(1, 214) = 8.87, p < .005$ ]. As Fig. 16 illustrates, participants who were in the colder temperatures reported that they felt more aroused than those in hotter temperatures. The linear effect was expected (see Anderson et al., 1996). However, the modest downturn in perceived arousal at the coldest temperatures was unanticipated (and unreplicated in our other work). None of the other effects approached significance.

*e. Heart Rate and Blood Pressure.* As in Experiment 2, change in heart rate was positively linearly related to temperature [ $b_{lin} = .141, a = -.643, F(1, 202) = 5.98, p < .02$ ]. None of the other effects approached significance. In addition, none of the effects on blood pressure reached significance by the Bonferroni-corrected criterion.

*f. Aggressive Behavior on Trial 1.* Only the sex main effect on the noise-intensity punishment level set by participants for the first competitive

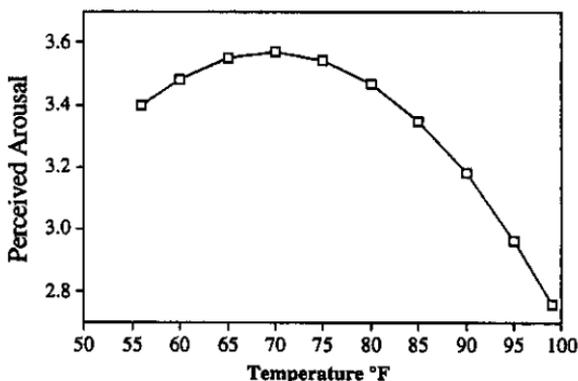


Fig. 16. Perceived arousal as a function of temperature.

reaction-time trial was significant [ $F(1, 217) = 8.92, p < .005$ ]. Males set a higher punishment level than did females,  $M_s = 4.44$  and  $3.67$ , respectively. Of course, in the standard TCRT paradigm used in this experiment no provocation occurs until after Trial 1, so the lack of provocation effects are not surprising.

*g. Aggressive Behavior on Later Trials.* Repeated-measures regression ANOVAs were performed on the average noise intensity settings of the three blocks, with eight trials in each block. The main effects of block [ $F(2, 434) = 10.21, p < .0001$ ] and provocation [ $F(1, 217) = 184.42, p < .0001$ ] were both highly significant. Intensity settings increased across blocks and were greater in the high-provocation than in low-provocation conditions. In addition, the block  $\times$  provocation interaction was also significant [ $F(2, 434) = 57.37, p < .0001$ ]. Intensity settings increased across the blocks in the high-provocation condition and decreased slightly across blocks in the low-provocation condition (see Fig. 17). No other effects were significant.

#### 4. Discussion

These results show that this noise version of the TCRT paradigm was sensitive to provocation. Thus, the lack of temperature effects cannot be attributed to this modification (i.e., from shock to noise punishment). In addition, the significant quadratic effects of temperature on state hostility and escape motives demonstrate that at least some of the underlying conditions necessary for temperature effects on aggression were met.

As discussed earlier, though, there are at least two reasons for expecting the relatively fragile effects of uncomfortable temperatures on aggressive behavior to be overwhelmed or hidden in this paradigm. First, because the

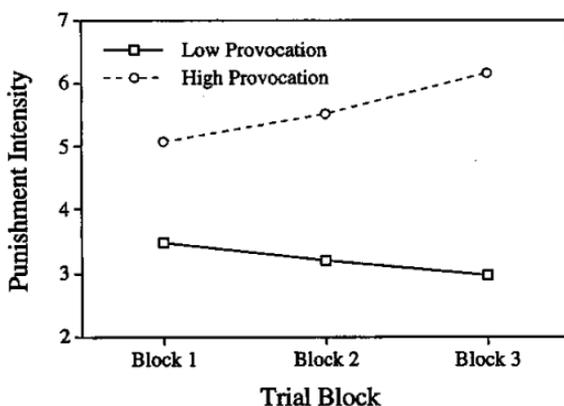


Fig. 17. Punishment level as a function of trial block and provocation.

participants believe that both they and their opponent will continue to set punishments for each other on subsequent trials they may be more concerned with controlling the opponent's behavior than with aggressive retaliation. Second, the high and low provocation conditions are so clear to participants and exert so powerful an effect that there is little room left for the relatively smaller effects of uncomfortable temperatures.

#### F. EXPERIMENT 5: TEMPERATURE EFFECTS IN A REVISED COMPETITIVE REACTION-TIME PARADIGM

Experiment 5 was designed to circumvent both of these potential problems with the TCRT paradigm of aggressive behavior. The first problem-concern with controlling the opponent's punishing behavior on subsequent trials-was handled by changing the competitive reaction time task itself. Specifically, the Revised Competitive Reaction Time paradigm (RCRT) split the trials into two phases. In the first phase, participants were to receive punishment set by their opponents on "lose" trials, but the opponents were not to receive punishment for their "lose" trials. In the second phase, the roles were reversed: Participants set the punishment levels that the opponents were to receive on "lose" trials, but were no longer to receive punishments themselves. Thus, the punishment levels set by participants could not be seen as an attempt to control the punishing behavior of their opponents.

The second problem-the clarity of the opponent's intentions in the standard high- and low-provocation conditions-was handled by replacing the low-provocation condition with a different type of high-provocation condition. This *ambiguous-provocation* condition had exactly the same intensities and durations of opponent-set punishments delivered to the participant during phase one as the high-provocation condition of Experiment 4. However, whereas the high-provocation condition in Experiment 4 consisted of a systematic increase in punishment levels across 25 trials, the ambiguous-provocation condition in Experiment 5 delivered the punishments in an apparently random fashion. Thus, the opponent's intentions were less clear in the ambiguous condition. The *clear-provocation* condition in Experiment 5 also used the RCRT paradigm, but differed from the ambiguous-provocation condition in that the high-provocation pattern of punishments from Experiment 4 were used in phase one.

If the change to the RCRT two-phase paradigm is sufficient, then we should see temperature effects on aggressive behavior in both the ambiguous- and the clear-provocation conditions. However, we expected temperature effects would be most pronounced in the ambiguous condition. Further-

more, the Social Justice model predicts a "U"-shaped function relating temperature to aggression on Trial 1 and an "M"-shaped function on later trials.

### *1. Method*

*a. Participants.* Sixty-seven female and 65 male college students participated in the experiment in exchange for partial course credit. As in Experiment 4, participants were run in same-sex dyads and acquainted participants were not allowed in the same sessions. Each participant wore a short-sleeve shirt and long pants. When only one participant came to the session, a confederate of the same sex was waiting as the alleged other participant. If the confederate was not needed, he/she served as a second experimenter to explain the task.

*b. Procedure.* The same laboratory, cover story, and temperature-manipulation procedures were used as in Experiment 4. After informed consent was obtained, blood pressure and heart rate were obtained. Physiological readings were taken twice in succession, and responses were averaged to provide more reliable measures.

Participants were next led to separate temperature-controlled rooms, each containing a computer. Experimenters explained the modified competitive reaction-time task. It was explained that there would be two phases of the reaction-time task and that for the first phase, the participant was "randomly assigned" to receiving white noise punishment if they lost (i.e., responded slower to the tone than their opponent). They were further informed that the length and intensity level of the noise would be set by their opponent prior to each trial. It was explained that for the second phase their roles would be reversed. They were told that they would be setting the length and intensity of noise that their opponent would hear if he/she lost and that they (the participant) would no longer be receiving any noise punishment. All participants were given sample noise blasts of levels "1" (60 dB), "3" (70 dB), "5" (80 dB), "7" (90 dB), and "9" (100 dB). Finally, it was explained that during the task there would be a square in the middle of the screen that would turn yellow as a warning that a tone would soon sound. As soon as participants heard the tone, they were to click on the mouse button as quickly as possible. If they won, they would not hear any noise, but if they lost, they would hear a noise of the length and level that their opponent set for them. They would also see the level of noise that was set for them by their opponent for each trial, whether they won or lost. After answering questions, the Experimenter left the room and told participants (over the intercom) when to begin. Participants then completed the 25 trials of phase one.

After participants completed several filler questionnaires, the second phase was explained to them once again. They were shown how to set the noise punishment level for each of the 25 trials to follow. After answering questions, the Experimenter left the room and again told participants (over the intercom) when to begin.

Upon completion of phase two, heart rate and blood pressure were reassessed. Finally, as in Experiment 4, participants completed some filler items consistent with the cover story and an expanded version of the escape motives scale used in Experiment 4.

*c. Provocation Manipulation.* To manipulate provocation we varied the noise-intensity levels and duration, supposedly set by the opponent. There were two conditions: clear provocation and ambiguous provocation. In both conditions, the participant lost the first trial and received a noise-level 1 punishment for the minimum duration of .25 s. In each of the remaining three blocks of eight trials, the participants won four and lost four in a random pattern. The noise intensities (displayed on each trial, delivered on "lose" trials) and durations (delivered on "lose" trials) varied by provocation condition.

The first block (not counting trial 1) in the clear-provocation condition consisted of noise-intensity levels of 2, 3, and 4 with durations of .5, .75, and 1.0 s. The second block consisted of intensity levels 4, 5, 6, and 7 at durations of 1.0, 1.25, and 1.5 s. The third block consisted of intensity levels 7, 8, and 9 at durations of 1.5 and 1.75 s.

The ambiguous-provocation condition consisted of exactly the same intensities and durations as the clear-provocation condition. Instead of systematically increasing across block, however, the pattern was random.

*d. Dependent Measures.* Noise-intensity levels set for opponents during phase two served as the measure of aggressive behavior. Trial 1 intensity settings were analyzed separately because of our interest in the potential temperature-induced outburst effect. The remaining intensity settings were averaged within each of the three blocks and analyzed in a repeated-measures regression ANOVA. The escape motives scale contained 28 items (plus 4 fillers), 9 more than the version used in Experiment 4. The Appendix lists these additional items.

## 2. Results

*a. Aggressive Behavior on Trial 1.* The effects of temperature and provocation on aggressive behavior were assessed by hierarchical-regression ANOVAs, as in Experiment 4. Quadratic (U-shaped), cubic, and quartic (M-shaped) effects of temperature on aggression were assessed. Preliminary

analyses yielded no reliable effects of sex of participant, so it was dropped from all subsequent analyses.

To examine punishment set by participants on their first retaliation opportunity (Trial 1), a series of multiple-regression analyses were conducted. None of the cubic or quartic effects approached significance. However, the quadratic temperature X provocation interaction was statistically significant [ $F(1, 126) = 7.29, p < .01$ ]. This indicates that the quadratic temperature effect differed in the two provocation conditions.

To explore this interaction we examined the linear and quadratic temperature effects within each provocation condition separately. The quadratic effect of temperature was statistically reliable in the ambiguous-provocation condition only [ $F_{amb}(1, 63) = 5.45, p < .02$ ;  $F_{clear}(1, 63) = 2.23, p > .10$ ]. The linear temperature effect was nonsignificant in each of these analyses ( $p_s > .25$ ).

The continuous line with squares in Fig. 18 displays the best fit line for Trial 1 intensity settings in the ambiguous-provocation condition, with linear and quadratic terms in the model. What we see is the predicted "U"-shaped function, with more aggression occurring at the hot and cold temperatures. This curve is slightly tipped because of higher aggression at the 55° temperature than at 95°F. This fits well the findings from Experiment 2 that 60° is about as uncomfortable as is 95° in our particular laboratory context. Figure 18 shows that the aggression levels displayed by participants in the ambiguous provocation condition was about the same at these two temperatures.

**b. Aggressive Behavior on Later Trials.** To test temperature effects on aggressive behavior in later trials, we conducted repeated-measures

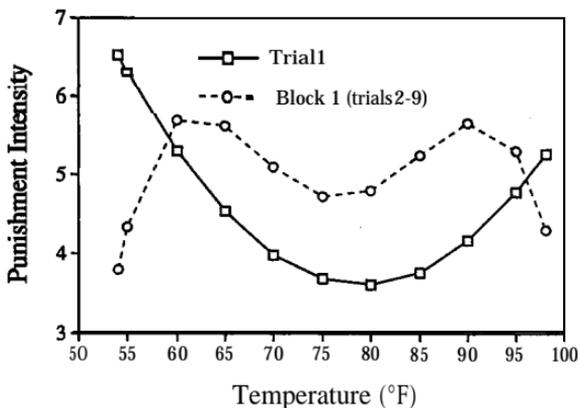


Fig. 18. Punishment levels set by ambiguous provocation participants on Trial 1 and Block 1 as a function of temperature.

ANOVAs with the punishment intensities from trials 2 to 25 divided into 3 blocks of 8 each. Thus, there was a 3-level repeated factor (Block); the provocation manipulation; the four temperature terms; and the various block, provocation, and temperature interactions as predictors in the various regression models.

We were most interested in the possibility of obtaining an "M"-shaped quartic effect of temperature on intensity settings, either as a main effect or as an interaction with block or provocation. We believed that this downturn in aggression at the most uncomfortable temperatures was most likely to occur in the ambiguous-provocation condition in the first or second block of trials.

The Block  $\times$  Quartic temperature effect was significant [ $F(2, 252) = 3.12, p < .05$ ]. To further examine this interaction we analyzed the quartic effect for each block separately. Block 1 yielded a significant quartic effect [ $F(1, 126) = 4.70, p < .03$ ]. Further analyses of each separate provocation condition revealed that the quartic effect was significant for ambiguous provocation [ $F(1, 61) = 4.95, p < .05$ ], but not for clear provocation [ $F(1, 61) < 1$ ]. The Block 1 temperature effects on punishment intensities set by participants who had been ambiguously provoked are displayed in Fig. 18, along with the Trial 1 effects discussed previously.

In Block 2 the quartic effect was considerably weaker (nonsignificant) [ $F(1, 126) = 2.16, .10 < p < .15$ ]. However, as in Block 1 the "M"-shaped quartic temperature effect was significant for ambiguous provocation [ $F(1, 61) = 4.00, p < .05$ ], but not for clear provocation [ $F(1, 61) < 1$ ]. By Block 3 the quartic temperature effect had disappeared from both provocation conditions ( $ps > .2$ ).

*c. Aggressive Behavior Summary.* The combination of a "U"- (Trial 1) and an "M"- (Blocks 1 and 2) shaped function relating temperature to aggression in the ambiguous condition best fits the Social Justice model discussed earlier. Participants in the most extreme temperature conditions tended to "get even" with their provocateurs on Trial 1 and then reduced their retaliation on subsequent trials (Blocks 1 and 2). The "M" function is also consistent with the Negative affect Correction model as well as the attention-deficit model.

*d. Escape Motives.* There was a reliable quadratic effect of temperature on escape motives [ $F(1, 128) = 4.74, p < .04$ ]. As predicted, escape motives increased in the most extreme hot and cold temperatures. No other effects approached significance,  $F_s < 1$ .

*e. Physiological Arousal.* We assessed the effects of temperature, provocation, and their interactions on heart rate, systolic blood pressure, and diastolic blood pressure separately. As in previous research, change scores were created by subtracting the pretest readings (taken before entering the

temperature-controlled room) from the posttest readings (taken at end of second CRT session).

Temperature had a linear effect on heart rate [ $F(1, 127) = 8.51, p < .005$ ], such that hotter temperatures produced a higher heart rate than did cold temperatures. None of the remaining effects on heart rate approached significance ( $F_s < 1$ ). As in Experiment 4, none of the blood pressure effects were significant.

## G. DISCUSSION OF THE FIVE EXPERIMENTS

The five experiments presented in this chapter yielded several major findings. First, we verified that people do have “social theories” about temperature effects on arousal, affect, and behavior. Specifically, people believe that hot temperatures (relative to comfortable ones) increase feelings of anger and hostility, decrease alertness and energy, and increase aggression and violence. In addition, people believe that cold temperatures have exactly the opposite effects. These findings highlight the utility of examining cold temperature effects as well as hot temperature effects in a lab setting. If hot and cold temperatures produce similar effects on aggression, then a simple “demand characteristic” interpretation becomes implausible.

Second, the actual effects of uncomfortable temperatures on arousal varied depending upon whether physiological or psychological measures of arousal were used. The heart rate indicator of arousal was positively related to temperature across studies and experimental contexts. Hot temperatures increased heart rates, whereas cold temperatures decreased heart rates. Subjective perceptions of arousal generally showed the opposite relation. This complex pattern of results suggests that excitation-transfer effects may occur under some circumstances. However, if excitation transfer is the dominant process underlying the temperature-aggression relation, then hot and cold temperatures that are equally uncomfortable should produce very different patterns of aggressive behavior. But, Experiment 5 yielded essentially the same aggression pattern in hot and cold conditions. Thus, in the present laboratory context excitation transfer apparently was not operative. Nonetheless, we believe that such effects may occur in other temperature related contexts, especially those in which temperature is not so salient a feature.

Third, we found that uncomfortable temperatures, both hot and cold, increase hostile feelings and a desire to escape the situation. This supports the affective underpinnings of the Negative Affect Escape model of the temperature-aggression relation (e.g., Anderson & DeNeve, 1992; Baron,

1979) and suggests that escape motives might play a role in decreasing aggression in those contexts where escape behavior is both possible and incongruent with aggressive behavior. These affect results also support aspects of the major cognitive models of affective aggression in that they all assume that negative affect either primes aggressive inclinations, energizes aggressive behavior, or removes inhibition to aggression (e.g., Anderson et al., 1996; Berkowitz, 1993; Geen 1990). However, it is important to keep in mind that escape was not possible in our two experiments on aggressive behavior and that Experiment 5 yielded two very different patterns of aggression depending upon whether it was on the first trial (an outburst effect) or on later trials. Thus, the behavioral results of our experiments provide no support for the NAE model.

Fourth, as predicted by the Negative Affect Correction model, hostile perceptions were related to temperature in an "M"-shaped function. As temperatures deviated from the most comfortable, perception of hostility in the videotape interactions first increased and then decreased.

Fifth, our Social Justice analysis of temperature effects was supported by the initial temperature-aided outburst of aggression and the subsequent decline in further aggression in the ambiguous provocation condition of Experiment 5. Participants who had received an ambiguous pattern of provocation and who were in the hot or cold temperature conditions gave the highest punishments to their antagonist on Trial 1. The outburst was shortlived, however, suggesting that once the "injustice" had been punished, participants were willing to cease further delivery of heightened punishments.

These five experiments, along with the naturalistic studies of the temperature-aggression hypothesis, strongly support the conclusion that hot temperatures can and do increase aggression in many contexts. An important practical issue arising from these findings concerns the likely impact of global warming on violent crime rates. Anderson, Bushman, and Groom (1997) recently showed that hotter years in the United States yield higher assault and murder rates (summed) than cooler years. This result held true even when a variety of statistical and social control variables were added to the model. We recently added more data to that data set; the following section provides adjusted estimates of the likely effects of global warming on violent crime.

## **VI. Global Warming and Violent Crime**

### **A. HOT YEARS AND HIGH VIOLENCE RATES**

Anderson, Bushman, and Groom (1997) reported two studies on how hotness of year affects violent crime. Study 1 used time-series regre

procedures to test the effects of yearly average temperature and age distribution on violent crime in the United States from 1950 to 1995. As expected, a significant ( $p < .05$ ) positive relation between temperature and violent crime rate was observed, even after time series, age, and linear year-to-year trend effects were statistically controlled. Study 2 examined the effects of number of hot days ( $> 90^{\circ}\text{F}$ ) on the usual summer increase in violence. As expected, years with more hot days produced a bigger summer increase in violent crime than years with fewer hot days. Nonviolent crime was unaffected by number of hot days. Before updating those two studies, we present a look at changes in the U.S. murder/assault rate over the years 1950-1997 and changes in the average temperature during this same period.

The murder/assault rate data in Fig. 19 reveal a dramatic increase from the mid-1960s to the early 1990s, with a brief hiatus in the early 1980s and a small decline in the last few years. The temperature data in Fig. 20 are much less consistent, but there is evidence of an upward trend, consistent with the global warming trends we have all read so much about in recent years.

## B. HOT SUMMER EFFECT

The summer effect is the oft-replicated finding that violent crime rates are higher in the summer than in any other quarter of the year (Anderson, 1989; Anderson & Anderson, 1998). If the summer effect is in fact a result of more hot days, rather than an artifact of school schedules or vacation days or other seasonal activities, then hotter summers (i.e., those with more hot days than typical) should produce a larger summer effect. In this updated study, we examined the relation between the hotness of summers

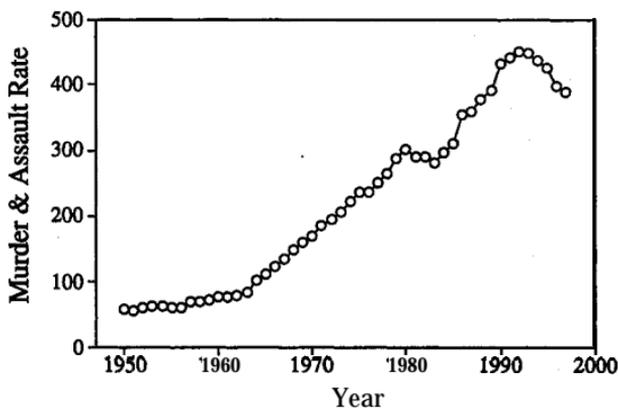


Fig. 19. Murder and assault rates in the United States (1950-1997).

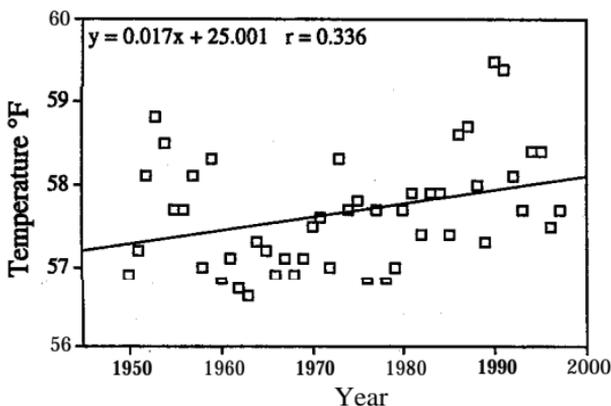


Fig. 20. Average temperature in the United States (1950-1997).

and the magnitude of the summer effect for the combined murder/assault rates in the United States from 1950 to 1997. Hotness of summer was measured by averaging the number of hot days (i.e., days which reached at least 90°F) experienced in 50 of the largest U.S. cities. The summer effect for murder/assault was computed as the proportion of all U.S. murders and assaults committed during the year that occurred during July, August, and September minus the averaged proportion for the other three quarters of that year, adjusted to equate quarters for number of days. Thus, if the summer proportion for a given year is the same as in the other quarters (i.e., is exactly 25%) then the summer effect is zero. If the summer proportion of murders/assault is greater than the average of the other quarters, the summer effect is greater than zero. If relatively fewer murders/assaults occurred in the summer, the summer effect would be less than zero. Over this 48-year period the summer effect was quite robust [ $M = 2.55$ ,  $d = 2.41$ ,  $t(47) = 16.71$ ,  $p < .001$ ].

To further test the heat hypothesis, we ran a number of regression analyses. The main finding, as predicted, was that hotter summers produced larger summer effects than cooler ones [ $b = .071$ ,  $r = .39$ ,  $t(47) = 2.88$ ,  $p < .01$ ]. In other words, hot summers produce a disproportionate amount of murders and assaults. Figure 21 displays this result.

### C. HOT YEAR EFFECT

The average annual temperatures of the same set of 50 U.S. cities were used to estimate how hot each year was during this same 48-year period of time. The overall U.S. murder/assault rate for each year constituted the

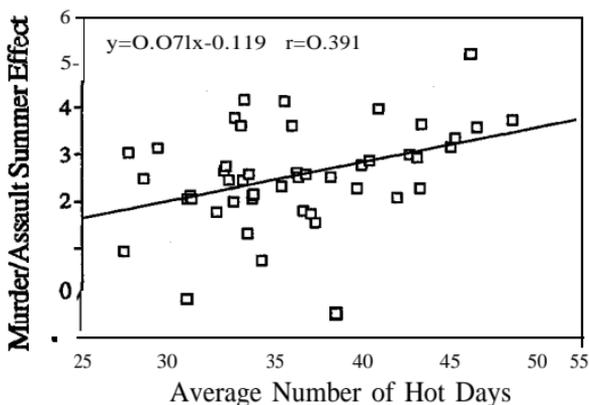


Fig. 21. The summer effect for murder and assault as a function of average number of hot days.

dependent variable. A set of time-series regressions were run to test whether temperature was a significant predictor of this type of violent crime and, if so, to estimate the magnitude of the hot year effect. As in our previous hot year study, three autoregressive parameters were needed to deal with autocorrelations in the residuals. Year was also included as a predictor variable to help control for systematic shifts in violent crime rates across time. We also tested for possible effects of shifts in age distribution (proportion of the U.S. population in the 15- to 29-year age range) and in prison population (proportion of the U.S. population in prison). These latter two variables had no appreciable impact on the murder/assault rate when year and autoregressive parameters were in the statistical model, so they were dropped from the final analysis.

As in our earlier study, hotness of year was significantly related to murder/assault rate, but with a slightly steeper slope ( $b = 4.58$ ,  $t = 3.03$ ,  $p < .01$ ). The slope reveals that for each  $1^{\circ}\text{F}$  increase in average temperature, the United States experienced 4.58 additional murder/assault crimes per 100,000 population.

#### D. GLOBAL WARMING EFFECT

One reason we so carefully reexamined the Minneapolis studies earlier in this chapter is that if the initially published conclusions were accurate (i.e., that violence decreases at hot temperatures), the implications of global warming on violent crime might not be so serious. But all of the evidence, including the Minneapolis data (when analyzed more appropriately), points

to the same conclusion—increasing temperatures will increase violence. The hot year effect gives us a means of predicting just how much of an increase in murder and assault we can expect given a particular increase in average temperature from global warming. Figure 22 displays these estimates for four global warming estimates, three estimates of the true causal impact of temperature on murder and assault, and assuming a population of 270 million (which the United States will reach in a few years).

The left vertical axis displays the results in terms of the rate per 100,000 population, whereas the right vertical axis displays the same results in terms of absolute numbers of murders and assaults based on an overall U.S. population of 270 million. Global warming predictions for the next 50 to 100 years vary considerably, so we've chosen some typical figures to display in Fig. 22. Using the best slope estimate from the earlier time-series regression analysis (i.e., 4.58), we see that a 2°F increase in average temperature predicts an increase of about 9 more murders/assaults per 100,000 people, or over 24,000 additional murders/assaults per year in a population of 270 million. If global warming is as high as 8°F, we get a predicted increase in murder/assault totals of almost 100,000 per year in a population of 270 million.

Of course, the true slope may be somewhat greater or smaller than 4.58, so Fig. 22 includes prediction lines for other estimates. It should be kept in mind that the 4.58 slope estimate may well be too small because of the conservative nature of the time-series regression analyses used to generate it.

It is also important to keep in mind that if significant global warming does occur, then the many other serious consequences to the physical

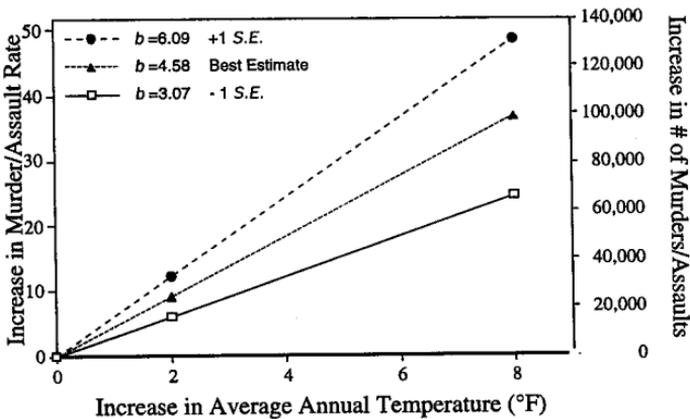


Fig. 22. Global Warming Effect on murders and assaults per year in the United States, based on a population of 270 million.

environment will also dramatically alter our social environments. These estimates of increases in violent crime due solely to the effects of hot temperatures are just one additional factor to consider when contemplating the seriousness of global warming.

## VII. General Discussion

Overall, the results of recent studies of the temperature-aggression hypothesis have produced considerable insight into the age-old phenomenon of high temperatures being associated with increased rates of violence. The Negative Affect Escape model of Baron and colleagues has not fared very well in terms of empirical tests. The predicted decrease in aggression at hot temperatures has been elusive in the lab and nonexistent in naturalistic settings. Those few lab studies that have obtained a decrease under some conditions have, in other ways, yielded data that contradict the NAE model (e.g., Palamarek Rule, 1979). Nonetheless, that pioneering work has successfully accomplished one of the most important goals of any **theory**—stimulating additional research and theory and leading to a better understanding of the phenomenon.

Of course, there remain a number of unanswered questions in this domain. A few reasoned speculations may point the way to further advances.

### A. DYNAMIC INTERPERSONAL PROCESSES

We believe that discomfort in general can produce short-lived aggressive outbursts in a variety of settings, much like the one displayed on the noise-intensity settings in Experiment 5. A question of obvious importance concerns how a short-lived outburst induced by hot or cold temperatures (which apparently lasted for only one trial) could influence violent behavior in real-world settings. The answer lies in a difference between most laboratory paradigms of aggression and dyadic interactions in the real world. In most laboratory paradigms there is no real dyadic interaction. That is, aggressive behavior by a participant is not actually received by another real participant. When people aggress against someone in the real world, that person receives our provocation and reacts to it. Any factor that increases the perceived “provocativeness” of an act will also increase the target’s anger and the likely aggressiveness of the behavioral response. This cycle of escalating provocations is exactly what happens in most arguments and fights leading to assault and murder. Thus, even short-lived increases in

aggression may translate into substantial increases in violence in naturalistic settings. We believe that this is why hot temperatures are monotonically associated with increased violence across a wide range of studies. We also believe that modifying standard laboratory aggression paradigms to include this dynamic interpersonal process would allow better examination of a variety of aggression and violence phenomena under controlled conditions.

## B. HOT AND COLD REVISITED

This dynamic explanation of temperature effects also raises another question concerning the effects of cold temperatures. If the same discomfort-outburst process is at work in both hot and cold temperatures, why don't the field studies on violent crime yield comparable increases in aggression in cold temperatures? As noted earlier in this chapter, the simplest explanation is that people are better able to protect themselves from cold discomfort (e.g., more layers of clothes, heated buildings) than they are from the heat. Thus, people are seldom uncomfortably cold long enough for a cold-induced increase in real-world violence to appear. As use of modern air conditioning expands, this difference in ability to escape hot versus cold temperatures may be greatly reduced and may eventually reduce the magnitude of the heat effect in field studies of aggression (cf., Harries & Stadler, 1988). Indeed, this possibility suggests that we may be able to substantially reduce aggression in some contexts by providing better temperature control. Prisons, factories, and schools are all environments where violence is a problem and where air conditioning might realistically be capable of reducing the violence problem.

## C. NEW DIRECTIONS FOR TEMPERATURE EFFECTS

Although the studies examined in this chapter answer a number of important questions about aggression processes in general and the temperature-aggression relation in particular, we should also point out a number of remaining issues. Research has shown that thermal stress can have significant effects on attention and judgment (e.g., Hancock, 1986; Shanazarov, Makhnovskii, & Kuzyuta, 1989; Razmjou & Kjellberg, 1992). For example, attentional capabilities decline under heat-stress conditions, as do quality of judgments. One of our "filler" items given just prior to debriefing in Experiments 4 and 5 asked participants to indicate "How easy was it to concentrate in the room you were in?" Analysis of responses to this item

yielded a strong quadratic temperature effect in both experiments [ $F(1, 217) = 32.12$  in Experiment 4;  $F(1, 128) = 11.91$ , in Experiment 5,  $ps < .001$ ]. This “U”-shaped effect was the same as we have seen for state hostility and escape motives in several studies. Participants in the extreme temperatures (hot or cold) found it harder to concentrate than did those in more moderate temperature conditions, thus replicating the more cognitive work in this area. Further work on this attention deficit effect seems warranted, particularly in terms of social perceptions, social action, and aggression.

It is also worth noting that participants in the hostile perception experiment (Experiment 3) were sensitive to the differences in amount of interpersonal aggression built into the three different videotapes, arguing against an attention deficit process in that particular study. Perhaps in other contexts, with more subtle aggression cues being varied, the cognitive deficits created by extremely uncomfortable temperatures would influence hostile perceptions.

How would such effects influence the aggression processes? Attentional deficits of any kind may increase, decrease, or have no impact on aggressive behavior depending upon the situation. For example, reducing an annoyed person's attentional abilities may well reduce his or her ability to suppress aggressive inclinations and thus increase aggressive behavior. Or, it may reduce the ability to perceive and take into account mitigating circumstances, thereby increasing aggression. In other contexts, reduced attentional capacity may result in a person not fully perceiving or understanding a personal insult. In this circumstance, the attentional deficit would reduce aggression by decreasing the perceived provocation. Finally, aggression-enhancing and aggression-inhibiting processes may well cancel each other out in yet other circumstances.

Other fruitful directions for future work on the temperature-aggression hypothesis involve pitting various motives against each other. What happens when escape and aggressive motives can be satisfied only by engaging in mutually exclusive behaviors? At what point do escape motives dominate? Similarly, what happens when these two motives can be satisfied by the same behavior? Do we see heightened aggression in these latter circumstances? We believe that additional research along these lines will improve our understanding of affective aggression in general while providing cleaner tests of NAE.

The present set of studies raises additional questions about processes underlying temperature effects. The aggression results in Experiment 5 most clearly support the Social Justice model. The NAE model is contradicted by the Trial 1 quadratic effect in that study. However, the hostile perception results of Experiment 3 best fit the Negative Affect Correction

model. As negative affect increased (in uncomfortably cool and warm conditions) so did reported hostile perceptions. But when temperatures became even more extreme the salience of the temperature effect on mood may have led Experiment 3 participants to try to correct their social judgments for this potentially biasing factor. The Social Justice model is contradicted by this quartic temperature effect on hostile perceptions. It is possible, of course, that all of these processes are operative, either across participants or within the same participant but at different times in the aggression cycle. Clearly, additional work is needed to identify when (and in which people) these various processes are most likely to operate.

Finally, the temperature effects on physiological and psychological indicators of arousal invite use of temperature manipulations to explore key questions in excitation transfer theory. Generally, manipulations that increase indicators of sympathetic arousal such as heart rate also increase psychological feelings of arousal. For example, exercise increases heart rate and perceived arousal. The paradoxical effects of hot and cold temperatures on heart rate and perceived arousal would seem ideal for further tests of the limits of excitation transfer phenomena in a variety of contexts, including aggression.

## Appendix

### ESCAPE MOTIVES SCALE

The following are several verbs. Please indicate to what extent you feel like doing what they suggest right now. Although some may be impossible actions for you to do right now, please mark how much you feel like performing them.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely
<input type="checkbox"/> abandon		<input type="checkbox"/> avert		<input type="checkbox"/> avoid
<input type="checkbox"/> begin <sup>b</sup>		<input type="checkbox"/> depart		<input type="checkbox"/> desert
<input type="checkbox"/> disappear		<input type="checkbox"/> escape		<input type="checkbox"/> evacuate
<input type="checkbox"/> evade		<input type="checkbox"/> exit		<input type="checkbox"/> forsake
<input type="checkbox"/> improve <sup>b</sup>		<input type="checkbox"/> listen <sup>b</sup>		<input type="checkbox"/> leave
<input type="checkbox"/> move		<input type="checkbox"/> quit		<input type="checkbox"/> release
<input type="checkbox"/> relax <sup>b</sup>		<input type="checkbox"/> resign		<input type="checkbox"/> retreat

___ vanish	___ withdraw	—continue <sup>c</sup>
___ extend <sup>c</sup>	___ persist <sup>c</sup>	—prolong <sup>c</sup>
___ approach <sup>c</sup>	___ confront <sup>c</sup>	___ delay <sup>c</sup>
___ explore <sup>c</sup>	___ pursue <sup>c</sup>	

<sup>a</sup> The scale is labeled “Current Motives Scale” when given to research participants. The authors retain the copyrights to both versions of the Escape Motives scale. We grant permission to researchers to use either version of the Escape Motives scale for research purposes.

<sup>b</sup> Indicates a filler item not scored as part of the Escape Motives Scale.

<sup>c</sup> Items added for Experiment 5. All nine of these newer items were reverse scored.

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