Assault as a function of time and temperature: A moderator-variable time-series analysis

Article *in* Journal of Personality and Social Psychology · June 1997

DOI: 10.1037/0022-3514.72.6.1322

Ellen G. Cohn
Florida International University

Assault as a Function of Time and Temperature: A Moderator-Variable Time-Series Analysis

Ellen G. Cohn and James Rotton
Florida International University

The authors hypothesized that relations between temperature and assaults are stronger during evening hours than during other hours of the day and tested this hypothesis by obtaining 3-hr measures of assaults, temperature, and other weather variables for a 2-year interval. The hypothesis was confirmed by autoregression analyses that controlled for secular trends, seasonal differences, other weather variables, holidays, and other calendar events. In addition, as predicted by the negative affect escape model, assaults declined after reaching a peak at moderately high temperatures. The inverted U-shaped relation survived tests that controlled for secular trends, seasonality, autocorrelation, outliers, and heteroscedasticity. In addition, consistent with routine activity theory, moderator-variable regression analyses indicated that relations were strongest during evening hours and on weekends.

It is widely believed that uncomfortably hot temperatures facilitate the occurrence of human aggression (Pennebaker, Rimé, & Blankenship, 1996). This belief is supported by results from many studies (for reviews of the literature, see Anderson, 1989; Bell, Fisher, Baum, & Greene, 1996). With one exception (Lab & Hirschel, 1988), however, field studies on temperature and violent crime have been based on daily averages. Lab and Hirschel obtained 6-hr averages for weather variables and assaults in Charlotte, NC. Their analyses indicated that assaults and temperature were positively correlated during daytime and nighttime hours. Unfortunately, as LeBeau (1988) pointed out, their report contained a number of serious flaws. In particular, Lab and Hirschel did not report the significance of variance estimates (i.e., multiple correlations), and did not control for secular and seasonal trends that may have been responsible for apparent relations between temperature and assaults.

The present study was originally undertaken as part of a program whose aim is to develop a practical model for forecasting criminal behavior (Cohn, 1993, 1996). Consequently, the analyses are based on 3- rather than 24-hr averages and totals. We anticipated that time of day would moderate relations between temperature and violence (e.g., the relationship between temperature and violence would be stronger in the evening because of factors such as alcohol consumption). On the basis of Anderson's (1989) comprehensive review of the literature, we expected that only monotonic or linear relations would be observed. However, while checking for outliers, we noticed what appeared to be curvilinear trends in our residual plots (Belsley, Kuh, & Welsch, 1980). Thus, although our aims were originally applied, the results of this investigation are relevant to issues raised in a recent exchange (Anderson & DeNeve, 1992; Bell, 1992) about the shape of the relationship between temperature and aggression.

Questions about relationships between temperature and aggression can be traced to a series of laboratory studies on heat and aggression conducted by Baron and colleagues (e.g., Baron, 1972; Baron & Bell, 1976). These studies uncovered a surprising diversity of relations between heat and aggression. As Bell (1992) observed, heat sometimes led to higher levels of aggression; at other times, it led to lower levels of aggression; and at still other times, heat had no effect on aggression. Bell and Baron (1976) advanced what is now called the *negative affect escape (NAE) model* to reconcile these inconsistent results. According to the NAE model, relationships between heat and aggression are mediated by negative affect, which exerts one of two effects on behavior. Initially, moderately high levels of heat tend to increase the probability of aggression. However, as negative affect increases, individuals become more interested in escaping, which conflicts with and reduces aggressive tendencies.

The idea that individuals respond with fight-and-flight reactions to aversive stimuli is not new (Cannon, 1932). The NAE model suggests that these responses are incompatible; that is, individuals choose to fight *or* flee. Thus, escape may be regarded as one of several responses that are incompatible with and reduce aggression; other responses are humor, mild sexual arousal,

Ellen G. Cohn, School of Policy and Management, Florida International University; James Rotton, Department of Psychology, Florida International University.

We thank Steve White for comments on an earlier version of this article.

Correspondence concerning this article should be addressed to Ellen G. Cohn, School of Policy and Management, Florida International University, North Miami, Florida 33181-3600. Electronic mail may be sent via the Internet to cohne@servax.fiu.edu.

Journal of Personality and Social Psychology, 1997, Vol. 72, No. 6, 1322–1334

and distraction (Baron, 1983). Very different predictions can be derived from a precursor of Berkowitz's (1993) cognitive–neoassociationist conception of anger and aggression. Berkowitz (1993) has, on more than one occasion, asserted that "negative affect generates *both* fight *and* flight reactions, not one or the other" (p. 58; see also Berkowitz, 1983, p. 1135). Furthermore, whereas the NAE model predicts that extreme discomfort reduces aggression, Berkowitz (1993) argued that "the stronger the felt displeasure, the stronger will be the resulting instigation to aggression" (p. 56). As a theory based on results from laboratory studies, which typically use an invented stressor (the cold pressor task) and paper-and-pencil measures of hostility, its ability to predict criminal assault in real-world settings has yet to be tested.

Much of the exchange between Anderson (1989) and Bell (1992) dealt with how results from laboratory experiments should be interpreted. In extra-laboratory settings, aggression appears to be a monotonic (perhaps linear) function of temperature; as Anderson (1989) observed, "the original negative affect escape model received no support, because the predicted inverted-U-shaped function never occurred" (p. 89). Anderson advanced several possible reasons why nonlinear relationships did not attain significance. In particular, he observed that a downturn in aggression may have been masked by the fact that the analyses were based on 24-hr periods of time: "during most hot days there is a cooler period of time that may be on the high-aggression side of the inflection point" (p. 89).

Bell (1992) defended the NAE model by pointing out that the results of field studies were not as consistent as Anderson (1989) suggested. In particular, Bell and Fusco (1986, 1989) uncovered curvilinear as well as linear relations when they reanalyzed data from previously published studies. Their reanalyses revealed a fanlike pattern when violence was plotted against temperature; that is, relations between temperature and violence were more variable at high than at moderately warm temperatures. Such a pattern could mask a curvilinear relationship (see Figure 6-8 in Bell et al., 1996, p. 206). In addition, Bell et al. (1996) suggested several other factors that could inhibit escape tendencies in field studies, including air conditioning, alcohol consumption, and time of day: "Averaging temperatures across time intervals will inevitably distort the impact of the highest temperatures (and the lowest) because averaging causes a statistical loss of data points" (p. 343).

As reasonable as these suggestions may be, they have not been tested. If one excludes Lab and Hirschel's (1988) study, research on concomitant relations between temperature and aggression has been based on observations aggregated over 24-hr intervals (e.g., Rotton, 1993). These analyses have ignored diurnal variations in criminal activity. It is a well-known fact that more assaults are reported during the late hours of the evening and early hours of the morning than at other times of the day (Falk, 1952; Harries, 1981–1982; Pokorny, 1965; Shepherd, 1990). There is also ample evidence that more assaults occur on weekends than on weekdays (Falk, 1952; Harries & Stadler, 1983, 1988; Pittman & Handy, 1964). Surprisingly, although it is widely believed that most crimes occur on Friday and Saturday nights, investigators have not examined the intersection of time of day with day of week.

Fairly straightforward predictions about when crimes occur can be derived from routine activity theory (L. E. Cohen & Felson, 1979). According to Felson (1987, p. 911), most crime requires the presence of a motivated offender, a suitable target, and the absence of guardians (e.g., police). Messner and Tardiff (1985) proposed that "the volume of criminal offenses will be related to the nature of normal, everyday patterns of interaction" (pp. 241–242). Such interactions are known as *routine activities;* they are events or behaviors that occur regularly and are a significant part of one's daily life. The time spent on routine activities, such as work and school (vs. time spent at leisure), may help to explain crime rates and patterns. For example, the amount of time spent outside the home is clearly related to the risk of both personal and property crime (Field, 1992). Cohn (1990a) extended routine activity theory to argue that certain types of criminal behavior are more prevalent when weather conditions (e.g., warm, pleasant days) lead individuals to depart from their usual schedule of routine activities.

On the basis of routine activity theory, we hypothesized that the relation between temperature and assaults would be stronger during evening hours than during afternoon or morning hours. We based this hypothesis on two assumptions. First, although the afternoon tends to be the hottest part of the day, we assumed that the routine activities of work and school would keep people indoors. This assumption is consistent with speculations by Harries and Stadler (1988) about the effects of air conditioning; they suggested that fewer people are exposed to high temperatures during working than during leisure hours. Second, we assumed that individuals might cope with high temperatures by imbibing more beverages (including alcohol) during evening than during other hours of the day.

In addition, although past studies have focused on a single weather variable (namely, temperature) and violence, we included humidity, wind speed, and a number of other weather variables in our analyses, because they have emerged as significant predictors of crime in previous studies (e.g., Rotton & Frey, 1984, 1985; for reviews of the literature, see Cohn, 1990a, 1990b). We did not expect that these variables would affect the shape of temperature–aggression relations, but omitting a known predictor biases regression coefficients and increases their standard errors.

Method

We obtained crime data from the police department in Minneapolis, MN (population = 356,840 in 1987). The data consisted of all nonduplicate calls for service relating to assaults that were received by the Minneapolis Police Department in 1987 and 1988 (see Cohn, 1996, for details of the procedures used for the collecting and processing of crime data). The police received 36,617 reports that were categorized as assaults. The category included calls classified as assaults, assaults in progress, fights, fights with a weapon, shootings, stabbings, threats, and kidnapping. Because of technical problems with the computer-aided dispatch system, assault data were not available on 19 days. Because the data were tallied eight times each day, missing data constituted 152 time periods (2.6% of the series).

Data on ambient temperature, relative humidity, wind speed, visibility, and percentage sky cover were obtained from the National Weather Service (NWS). Investigators doing research on heat have followed the lead of the NWS in reporting outdoor temperatures in degrees Fahrenheit. During the two years of this study, ambient temperatures ranged from a low of −18°F to a high of 104°F (M = 48.40; SD = 23.55).

Relative humidity ranged from 12% to 100% (M = 65.03; SD = 19.73). Wind speed was measured in knots, which is equivalent to 1.15 land miles per hour. Speeds ranged from 0 knots to 34 knots (M = 9.30; SD = 5.02). *Visibility* is defined by the NWS as the number of miles that can be seen at an elevation of 2 m above the ground. Visibilities between 0 and 25 miles (40.2 km; M = 14.15; SD = 5.56) were recorded during this study's period. *Sky cover* is the percentage of the sky (in tenths of the total sky) that is overcast or obscured by cloud layers. This variable ranged from a low of 0 to a high of 10 (M = 5.60; SD = 4.19). Data on three other meteorological variables were collected but were not included because they were collinear (in the case of precipitation), badly skewed (ceiling), or dichotomous (fog). The NWS takes standard meteorological observations at 3-hr intervals; the assault data were grouped into intervals (e.g., 12:00–2:59 a.m.) to correspond with these recording patterns.

Temporal Controls

A time-series plot disclosed seven segments of data on assaults, which were separated by six periods of missing observations. Accordingly, we created seven dummy variables by assigning a 1 to each segment and 0s elsewhere. By omitting the last dummy variable (for a 6-*df* test) we were able to determine if the series' level had changed after days on which observations were missing. We also used dummy variable coding to assess and control for temporal trends associated with 8 time periods, 7 days of the week, and 12 months of the year. Ones and 0s were used so that the constant (or intercept) term in our regression analyses could be used to estimate the mean for the last time period, day, and month in moderator-variable regression analyses (Aiken & West, 1991). We also created a dummy variable for the first of each month, which is the day on which checks from the government (e.g., welfare) are received. Similarly, we also used 1s and 0s to assess effects that could be attributed to major holidays and local festivals. Major holidays included New Year's Day, Memorial Day weekend (three days), Independence Day, Labor Day weekend (three days), Thanksgiving Day weekend (four days), Christmas Eve, Christmas Day, and New Year's Eve. Festivals were special events specific to the Minneapolis–St. Paul area. They included the Winter Carnival (late January to early February), the Aquatennial (mid-July), the Minnesota State Fair (late August to early September), and the dates of the 1987 World Series games, four of which were played in Minneapolis. Major holidays and festivals were considered to include the day of the holiday plus the first time period of the following day (i.e., until 2:59 a.m. the following morning). We also used a dummy variable to indicate days on which public high schools were closed for holidays, vacations, teacher in-service days, snow days, and so on. Finally, we created a sequence variable whose values ranged from 1 (at 12:00–2:59 a.m. on January 1, 1986) to 5,848 (at 9:00–11:59 p.m. on December 1, 1987) to assess and control for linear trend.

Analytic Strategies

We subjected our data to two types of analyses. First, we performed ordinary least squares (OLS) analyses to assess the amount of variance explained by clusters of related variables. Unlike generalized least squares (GLS) estimates, OLS allows one to take advantage of the omnibus tests that accompany the hierarchical entry of variables (e.g., day of week, time of day, and their interaction). Unfortunately, OLS procedures are biased when residuals are linked in an autoregressive fashion (Hibbs, 1974; West & Hepworth, 1991). Accordingly, for the second step of our analyses, we used an iterative algorithm to obtain Prais–Winsten estimates of regression coefficients and their standard errors (Johnston, 1984). Prais–Winsten estimates include data from the first observation in each series (Kmenta, 1986, p. 318). Thus they are more accurate than traditional procedures, such as Cochrane–Orcutt's method.

Results

Preliminary analyses uncovered what appeared to be a nonlinear trend when we plotted residuals against predicted values. However, our plots contained 5,696 points, making their interpretation difficult. Therefore, we divided temperatures into 12 intervals to produce the curve in Figure 1. Applying the formula for determining a curve's inflection, we found that assaults declined after reaching a maximum of 74.9°F.[1] Although comfort depends on several factors, such as humidity and wind speed (see below), it is worth noting that Rohles (1974) identified 74.4°F as the upper threshold for the comfort of a fully clothed individual (i.e., clo value of 1.0).

Temporal Variables

OLS regression analysis indicated that the 35 temporal controls explained 50.4% of the variance in assaults, $F(35, 5{,}667) = 164.27$, $p < .001$. This cluster included the variables for sequence and first day of the month, which attained significance in autoregressive analysis. The significant effect for the sequence variable indicated that there had been a linear decline in assaults over time ($b = -.002$, $\beta = -.51$), $t(5{,}618) = -2.28$, $p < .05$. A beta of .0327 indicated that significantly more assaults occurred on the first day than on other days of the month (adjusted *Ms* = 10.42 vs. 9.22), $t(5{,}618) = 3.65$, $p < .001$. Coefficients for festivals, major holidays, and school holidays fell short of statistical significance.

Seasonality. Several contrasts for months of the year attained significance in the GLS analysis. An omnibus test for months also attained significance in an OLS analysis, $F(11, 5{,}685) = 22.64$, $p < .001$ (see Figure 2).

Days and time periods. The seven contrasts for time periods explained 40.30% of the variance in OLS analyses that controlled for other temporal variables, $F(7, 5{,}661) = 657.02$, $p < .001$. Day of week also added a significant amount of variance when it was introduced after controlling for time periods and other temporal variables, $R^2 = .05$, $F(6, 5{,}661) = 95.85$, $p < .001$. Multiplying the dummy variables for day of week by time of day, we found that the resulting interaction explained an additional 15.1% of the variance in assaults, $F(42, 5{,}619) = 58.75$, $p < .001$.

Using Tukey's honestly significant difference (HSD) procedure and an alpha of .01, we found that more assaults were reported on weekends than on weekdays (see Table 1). Reports about assaults were also higher during evening and early morning hours (between 6:00 p.m. and 3:00 a.m.) than during other times of the day. Moreover, as we hypothesized, the two trends converged on weekends: The largest numbers of assaults were reported on Friday and Saturday nights.

Missing data. The variables used to control for missing data attained significance, $F(6, 5{,}661) = 2.97$, $p < .007$. They explained approximately 2% of the variance in analyses that controlled for the other temporal variables.

[1] The formula for the maximum or minimum of a curve is $m = -b_1/2b_2$, where m stands for maximum and b_1 and b_2 are the partial OLS regression coefficients for linear and quadratic trends, respectively (J. Cohen & Cohen, 1983).

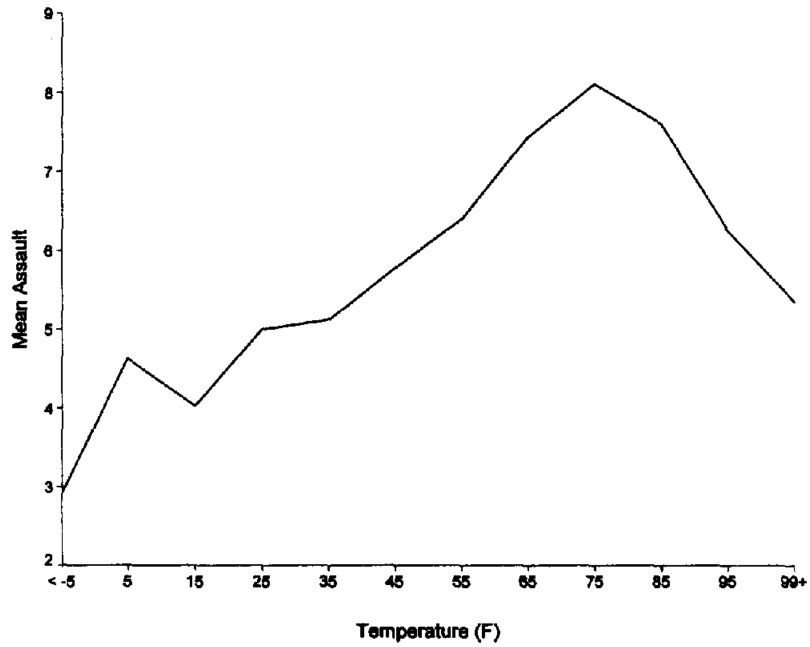

Figure 1. Assault as a function of temperature. F = degrees Fahrenheit.

Weather Variables

We evaluated the curve in Figure 1 by first centering our variables (i.e., subtracting the mean from each) and then performing moderator-variable regression analyses. Statistically, Anderson's (1989) general affect (GA) model predicts a significantly positive coefficient for temperature's linear trend component (b_1) and a nonsignificant coefficient (b_2) for temperature's quadratic component. The NAE model predicts that regardless of b_1's significance, b_2 will be negative and significant.

The 5 weather variables and the squared term for temperature's quadratic component explained less than 1% of total variance (R^2 = .008) in analyses that controlled for the previously described 77 temporal variables. Although small, this addition

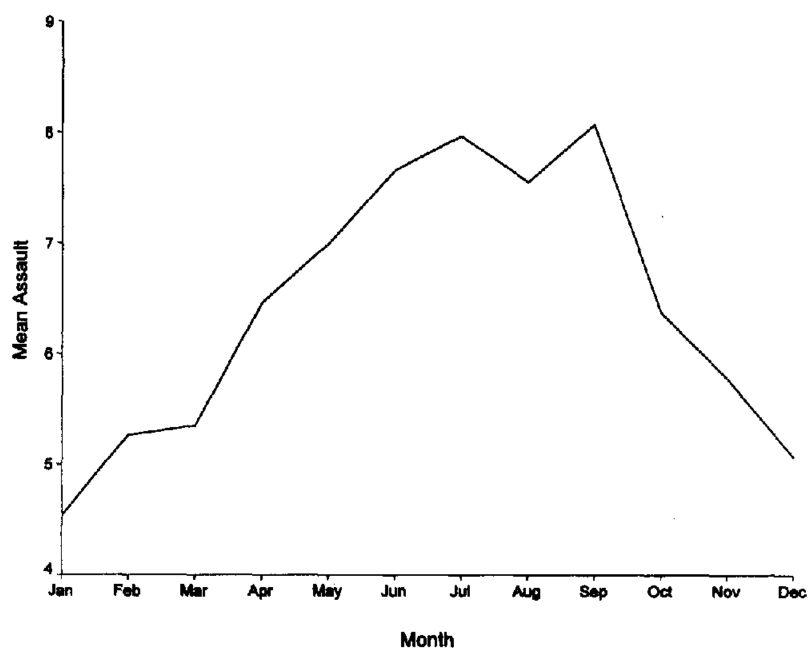

Figure 2. Assault as a function of month of the year.

Table 1
Mean Assaults for Time and Day of Week

	Day of week						
Time of day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
12:00 a.m.–2:59 a.m.	4.78_{A}	8.19_{B}	$8.44_{A,B}$	9.07_{A}	$9.25_{A,B}$	22.01	19.51
n	101	101	101	102	103	103	101
3:00 a.m.–5:59 a.m.	$1.06_{B,b}$	$1.85_{C,b}$	$2.04_{C,b}$	$2.23_{C,b}$	$2.22_{C,b}$	$7.92_{A,a}$	$7.70_{A,a}$
n	101	101	101	102	103	103	101
6:00 a.m.–8:59 a.m.	$1.12_{B,a}$	$1.29_{C,a}$	$1.31_{C,a}$	$1.67_{C,a}$	$1.53_{C,a}$	$2.62_{C,a}$	$2.15_{D,a}$
n	101	101	101	102	103	103	101
9:00 a.m.–11:59 a.m.	2.51_{a}	$2.38_{C,a}$	$2.52_{C,a}$	$2.56_{C,a}$	$2.78_{C,a}$	$3.54_{C,a}$	$2.78_{C,D,a}$
n	101	101	101	102	103	103	101
12:00 p.m.–2:59 p.m.	$4.76_{A,a}$	5.15_{a}	4.52_{a}	$5.20_{B,a}$	4.94_{a}	$5.72_{B,a}$	$4.49_{C,a}$
n	101	101	101	102	103	103	101
3:00 p.m.–5:59 p.m.	$5.99_{A,a,b}$	$7.18_{B,a}$	$7.00_{B,a,b}$	$6.68_{B,a}$	7.52_{D}	$7.08_{A,B,a}$	$5.30_{B,C,b}$
n	101	101	101	102	103	103	101
6:00 p.m.–8:59 p.m.	8.71_{b}	$8.90_{A,B,a}$	$9.13_{A,a}$	$9.16_{A,a}$	$9.61_{A,a,B}$	10.54_{a}	6.28_{B}
n	101	101	101	102	103	103	101
9:00 p.m.–11:59 p.m.	10.87_{b}	$10.11_{A,b}$	$9.94_{A,b}$	$10.77_{A,b}$	15.53_{a}	15.29_{a}	$6.69_{A,B}$
n	101	101	101	102	103	102	101

Note. Means sharing uppercase subscripts in each row do not differ by Tukey's honestly significant difference (HSD) test, $p < .01$. Means sharing lowercase subscripts in each column do not differ by Tukey's HSD test, $p < .01$.

was highly significant, $F(6, 5{,}613) = 22.58, p < .001$. Temperature's linear component was positive ($\beta = .15$) and highly significant, $t(5{,}613) = 7.04, p < .001$, when it was entered first into a GLS equation that contained the other 4 weather variables and 77 controls (35 temporal controls and 42 contrasts for the interaction between day of week and time of day). Consistent with the NAE model, the negative coefficient temperature's quadratic component also attained significance ($b = -.0006$, $\beta = -.06$), $t(5{,}612) = -5.25$, $p < .001$.[2] The significant coefficients for sky cover and wind speed in Table 2 indicate that more assaults occurred when sky cover and wind speed were low.

Heteroscedasticity: Variances Are Also an Inverted U-Shaped Function of Temperature

Recall that Bell and Fusco (1989) suggested that daily violence might be more variable at high temperatures than at moderate or low temperatures. To test this hypothesis, we divided temperature into 10 nearly equal categories (see Table 3). Bartlett's test disclosed an overall difference among the variances, $\chi^2(9, N = 5{,}697) = 171.71$, $p < .001$. We used a modified version of Levy's (1975) multiple range procedure to test for pairwise differences. Our modification was to use Tukey's HSD criterion and an alpha of .01. Doing so, we found that assaults were more variable on moderately warm than on cool or hot days.

Although Bartlett's test indicated that one assumption underlying the general linear model had been violated, we obtained substantially the same results after the data were transformed logarithmically. We decided to continue working with original rather than transformed scores, because the latter are more interpretable, and Monte Carlo studies indicate that tests of significance are robust to violations of homogeneity (J. Cohen & Cohen, 1983, p. 51).

Table 2
Generalized Least Squares Coefficients for Meteorological Variables (Controlling for 77 Temporal Variables)

Variable	b	β	r^a
Humidity	.0041	.01	.01
Sky cover	−.0373	−.02*	−.04
Wind speed	−.0302	−.03**	−.04
Visibility	.0052	.00	.01
Temperature (linear)	.0337	.12***	.07
Temperature (quadratic)	−.0006	−.06***	.07

Note. Degrees of freedom for linear and quadratic t values are 5,613 and 5,612, respectively.
[a] Derived from the generalized least squares t values with 5,612 *df*, using Equation 2a in Rosnow and Rosenthal (1996) for contrast correlations.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Moderating Effects of Time and Day

Time of day. To assess the generality of the results presented thus far, we first centered and then multiplied the terms for temperature's linear and quadratic components by indicator variables to estimate interactions with time of day. The interaction attained significance, $F(14, 5{,}567) = 44.43$, $p < .001$, and explained 3.3% of the variance in an OLS analysis that included the 77 other temporal and meteorological variables. We evaluated this interaction by running moderator-variable regression

[2] Citing results from a Monte Carlo study, a reviewer suggested that temperature's quadratic trend stemmed from our having controlled for months of the year. However, we obtained almost identical results when we dropped the 11 contrasts for months of the year. Obtained values for linear and quadratic trends were $b = .054$, $\beta = .19$, $t(5{,}624) = 15.42$, $p < .001$, and $b = -.0005$, $\beta = -.05$, $t(5{,}623) = -5.10$, respectively.

Table 3
Assault Variability as a Function of Temperature

Temperature (°F)	n	SD^2
<19	580	20.66_a
20–29	648	17.35
30–34	500	22.15_a
35–40	582	23.83_b
41–49	600	33.84_c
50–57	531	33.21_c
58–64	547	46.93_d
65–71	608	47.89_d
72–78	533	43.48_d
≥79	568	$22.57_{a,b}$

Note. Variances sharing common subscripts do not differ ($p < .01$) by Tukey's honestly significant difference procedure.

analyses for each day of the week (Aiken & West, 1991, pp. 89–92). The coefficients in Table 4 indicate that assaults were a linear function of temperature during four periods of the day (specifically, from 3:00 a.m. to 5:59 a.m., 12:00 p.m. to 2:59 p.m., and after 6:00 p.m.). Adding temperature's quadratic trend to the regression equations, we found that nonlinear components attained significance during two other periods. First, as the positive coefficient for temperature's quadratic component indicates, assaults were an accelerated function of temperature between the hours of 12:00 a.m. and 3:00 a.m. It should be noted that temperatures did not exceed 90°F during these hours. Second, assaults were an inverted U-shaped function of temperature during the late afternoon hours between 3:00 p.m. and 6:00 p.m., as indicated by the significantly negative coefficient for temperature's quadratic component.

We obtained almost identical results when we expanded our equations to include temperature's interaction with day of week. Once again, temperature's linear component attained significance for the periods from 12:00 a.m. to 6:00 a.m. and from 3:00 p.m. to 12:00 a.m. However, the previously significant linear component for the period between 12:00 p.m. and 3:00 p.m. shrank to nonsignificance ($b = .014$, $\beta = .05$), $t(5,600) = 1.59$. In contrast, the two quadratic effects in Table 3 retained their significance: A positive coefficient was obtained for the hours between 12:00 a.m. and 3:00 a.m. ($b = .002$, $\beta = .11$), $t(5,586) = 3.50$, $p < .001$, and a negative coefficient was obtained for the hours between 3:00 p.m. and 6:00 p.m. ($b = -.002$, $\beta = -.07$), $t(5,586) = -2.29$, $p < .02$.

Day of week. Temperature's linear and quadratic components also interacted with day of week, $F(12, 5,613) = 22.58$, $p < .001$. This interaction explained only 0.4% of the variance in assaults ($R^2 = .004$). An analysis of slopes indicated that the interaction stemmed from the fact that temperature's quadratic component attained significance ($ps < .05$) on every day of the week except Tuesday, $t(5,600) = -1.19$, $p > .20$. The interaction retained its significance after temperature's interaction with time of day was forced into the equation, $F(12, 5,587) = 4.92$, $p < .001$ ($R^2 = .003$). An analysis of slopes indicated that temperature's linear component attained significance on every day of the week (all $ps < .001$), but the quadratic component never did so (all $ps > .10$).

Temperature–assault relations as a function of time of day and day of week. The preceding results were complicated by a triple interaction among temperature, day of week, and time of day, $F(84, 5,503) = 2.29$, $p < .001$. This interaction explained a relatively small percentage of variance in assaults ($R^2 = .011$). Some care has to be exercised when interpreting this three-way interaction, because the relation between temperature and assaults during each time period was based on no more than 103 observations (see Table 1). Although this number would be sufficient under other circumstances, temperatures ranged from −18°F to 104°F (more than 1° per observation). As a consequence, the analyses suffered considerable restriction of range, especially for analyses of crimes during cooler (nighttime) hours of day. Thus, these analyses should be regarded as exploratory.

Consistent with the results we have presented thus far, the simple main effect tests in Table 5 indicate that temperature's linear component attained significance between 6:00 p.m. and 3:00 a.m. regardless of what day was examined. Furthermore, with two exceptions (on Saturdays), neither linear nor quadratic contrasts attained significance in the analyses of crimes reported between 6:00 a.m. and 2:59 p.m. These results suggest that the previously observed linear relationship for early afternoon hours (12:00 p.m.–2:59 p.m.) owed its significance to results obtained on one day of the week (namely, Saturday).

Table 4
Generalized Least Squares Regression Coefficients for Temperature (Linear and Quadratic) at Time of Day (Controlling for 77 Temporal and 4 Other Weather Variables)

	Linear			Quadratic		
Hours	b	β	r	b	β	r
12:00 a.m.–2:59 a.m.	.129	.47***	.22	.001	.10***	.06
3:00 a.m.–5:59 a.m.	.039	.14***	.07	.003	.03	.02
6:00 a.m.–8:59 a.m.	.007	.03	.01	.001	−.01	−.01
9:00 a.m.–11:59 a.m.	.008	.03	.02	−.001	−.01	−.01
12:00 p.m.–2:59 p.m.	.022	.08**	.04	.000	.00	.00
3:00 p.m.–5:59 p.m.	.036	.13***	.07	−.001	−.06**	−.04
6:00 p.m.–8:59 p.m.	.081	.30***	.14	.000	.01	.00
9:00 p.m.–11:59 p.m.	.131	.48*	.21	.000	.04	.06

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 5
Generalized Least Squares Estimates of Regression Coefficients for Temperature (Linear and Quadratic) for Time Periods and Days

	Linear			Quadratic		
Hours	b	β	r	b	β	r
12:00 a.m.–2:59 a.m.						
Monday	.0668	.25***	.06	.0014	.14*	.02
Tuesday	.1177	.44***	.09	.0017	.17**	.04
Wednesday	.0979	.36***	.08	.0011	.11	.03
Thursday	.0808	.30***	.07	.0002	.02	.00
Friday	.0849	.32***	.07	.0014	.15*	.03
Saturday	.2115	.79***	.19	.0005	.05	.01
Sunday	.2122	.79***	.18	.0017	.18**	.03
3:00 a.m.–5:59 a.m.						
Monday	.0028	.02	.00	.0000	−.01	.00
Tuesday	.0220	.08	.02	.0002	.02	.01
Wednesday	.0124	.05	.01	.0001	.01	.00
Thursday	.0051	.02	.00	.0000	.00	.00
Friday	.0265	.10	.02	−.0001	−.02	.00
Saturday	.1055	.39***	.09	.0004	.04	.01
Sunday	.0737	.25***	.07	.0021	.17*	.03
6:00 a.m.–8:59 a.m.						
Monday	−.0026	−.01	.00	−.0002	−.03	−.01
Tuesday	−.0001	−.00	.00	−.0003	−.03	.01
Wednesday	−.0002	−.01	.00	−.0001	−.01	.00
Thursday	.0060	.02	.01	−.0002	−.02	−.01
Friday	.0012	.00	.00	−.0004	−.04	−.01
Saturday	.0129	.05	.00	.0002	.02	.01
Sunday	.0104	.06	.01	.0001	.01	.00
9:00 a.m.–11:59 a.m.						
Monday	.0091	.03	.01	−.0002	−.02	−.01
Tuesday	.0089	.03	.01	−.0001	−.01	.00
Wednesday	.0080	.03	.01	−.0004	−.04	−.01
Thursday	−.0062	−.02	−.01	−.0005	−.06	−.01
Friday	.0032	.01	.00	.0003	.03	.00
Saturday	.0097	.04	.01	−.0001	−.01	.00
Sunday	.0088	.03	.01	−.0003	−.02	.01
12:00 p.m.–2:59 p.m.						
Monday	.0232	.09	.02	−.0001	−.02	.00
Tuesday	.0273	.10	.03	−.0002	−.02	−.01
Wednesday	.0113	.04	.01	.0001	.01	.00
Thursday	.0107	.04	.01	.0001	.01	.00
Friday	.0142	.05	.01	−.0003	−.03	−.01
Saturday	.0347	.13*	.04	.0002	.02	.01
Sunday	.0174	.06	.02	.0000	.00	.00
3:00 p.m.–5:59 p.m.						
Monday	.0247	.01	.02	−.0009	−.09	−.02
Tuesday	.0488	.18*	.05	−.0003	−.03	−.01
Wednesday	.0328	.12*	.03	−.0004	−.04	−.01
Thursday	.0400	.15*	.04	−.0014	−.14*	−.04
Friday	.0356	.12*	.03	−.0005	−.06	−.02
Saturday	.0346	.13***	.04	.0000	.00	.00
Sunday	.0251	.09	.02	−.0011	−.11*	−.03
6:00 p.m.–8:59 p.m.						
Monday	.0851	.31***	.07	.0004	.05	.01
Tuesday	.0851	.31***	.09	−.0002	−.02	−.01
Wednesday	.0705	.26***	.06	−.0006	−.06	−.02
Thursday	.0844	.31***	.08	.0004	.04	.01
Friday	.0162	.24***	.06	−.0009	−.07	−.02
Saturday	.1162	.43***	.11	−.0001	−.01	.00
Sunday	.0577	.21**	.06	.0005	.05	.01
9:00 p.m.–11:59 p.m.						
Monday	.1752	.65***	.14	.0008	.07	.02
Tuesday	.1091	.41***	.09	.0019	.19***	.05
Wednesday	.1070	.40***	.09	.0019	.20***	.01
Thursday	.1120	.42***	.10	−.0002	−.02	−.01
Friday	.1461	.54***	.13	−.0023	−.24***	−.05
Saturday	.1735	.65***	.15	.0012	.12	.03
Sunday	.0787	.29***	.07	.0086	.09	.02

Note. Degrees of freedom for linear and quadratic tests are 5,558 and 5,502, respectively.
* $p < .05$. ** $p < .01$. *** $p < .001$.

In contrast, the quadratic trend for assaults between 12:00 a.m. and 2:59 a.m. attained significance on four out of seven days of the week. Similarly, although every day of the week showed a quadratic effect for temperature between 3:00 p.m. and 5:59 a.m., the relationship attained significance only on Mondays and Sundays.

Daily Averages: The Attenuating Effects of Aggregation

One of this study's most interesting, and methodologically important, findings was obtained when we aggregated our data over 24-hr intervals. We accomplished this by computing a total for assaults and daily averages for the five meteorological variables. Controlling for 35 temporal variables, the regression coefficient for temperature's linear component attained significance ($b = .44$, $\beta = .51$), $t(686) = 7.85$, $p < .001$. This finding is consistent with past studies in which 24-hr averages have been used. Also consistent with past studies, the coefficient corresponding to temperature's quadratic component ($b = .0006$, $\beta = .018$) fell short of statistical significance, $t(866) = 0.59$. These findings suggest that past failures to uncover nonlinear relations were due, at least in part, to attenuation that accompanies aggregation.

Subsidiary Analyses

Other trends and interactions. We undertook subsidiary analyses to identify higher trends and examine one of several possible interactions between weather variables. We added cubic and quartic trends to the equation, because one stopping strategy when performing a trend analysis is to test until one obtains a nonsignificant result. We also examined temperature's interaction with humidity, because the two variables are frequently combined when creating discomfort indices (Kalkstein & Valimont, 1986) and models of thermal comfort (Rohles, 1974).

Significant results were obtained for temperature's cubic component, $t(5{,}608) = -3.99$, $p < .001$, but not its quartic component, $t(5{,}608) = -1.21$, $p > .20$. A plot of predicted values from these analyses indicated that the cubic result stemmed from a theoretically uninteresting dip in assaults when temperatures were in the teens. Temperature's interaction with humidity also attained significance, $t(5{,}608) = 4.11$, $p < .0001$. However, before too much is made of these results, we caution that the temperature's cubic component did not attain significance, $t(5{,}595) = -1.55$, $p > .10$, after temperature's interaction with time of day was added to the prediction equation. Temperature's interaction with humidity shrank to nonsignificance in the same analysis.

Missing data. The analyses we have presented thus far were based on a listwise deletion of missing cases. Subsidiary analyses indicated that very similar results would have been obtained if data on all days had been available. First, the block that contained the dummy variables for missing data did not attain significance after weather variables were added to the equation, $F(6, 5{,}661) = 1.83$, $p > .08$. Second, we obtained similar results when we used linear interpolation at each point to replace observations; that is, in no case did a significant effect for temperature's components fail to attain significance, and previously nonsignificant effects did not become significant. Third, we obtained almost identical results when we used maximum likelihood procedures and a Kalman filter to estimate missing observations (Harvey, 1989).[3]

Discussion

As hypothesized, relations between temperature and assaults were stronger during the evening than during other hours of the day. Thus, this study's analyses confirmed our original hypotheses, which were derived from routine activity theory (Cohn, 1993, 1996). In addition, they revealed that relations between temperature and aggression are considerably more complex than existing theories suggest. In particular, it appears that heat and cold exert very different effects on aggression in extra-laboratory settings.

Heat and Aggression

It is only by combining several theories of aggression that we can begin to make sense of how the relationship between heat and aggression varies over time. First, as Anderson, Anderson, and Deuser's (1996) GA model suggests, there was an overall linear relation between temperature and assaults. Furthermore, only linear relations emerged early in the morning (3:00 a.m.–5:59 a.m.) and during evening hours (6:00 p.m.–11:59 p.m.). However, as the NAE model suggests, there was also a curvilinear relation between temperature and assaults when all periods were analyzed. Quadratic trends attained significance on all but one day of the week, although this relationship shrank to nonsignificance when the analysis was expanded to temperature's two-way interaction with time of day. Thus, the nonlinear relationship can be traced to results that were obtained during late afternoon and early evening hours (3:00 p.m.–5:59 p.m.), which are typically the warmest hours of the day.

Although the downturn in assaults during late afternoon hours is consistent with predictions derived from the NAE model, we can think of several other reasons why assaults declined during afternoon hours. First, high temperatures are particularly salient early in the day, especially when one has been working in an air-conditioned office. As Anderson and Anderson (1984) suggested, individuals may be more prone to attribute discomfort to heat (rather than to the actions of others) when high tempera-

[3] A reviewer suggested that an analysis of lagged scores might indicate that the quadratic trend during evening hours was due to residual levels of arousal. We obtained a significant coefficient when we lagged temperatures across one time period ($b = .111$, $\beta = .40$), $t(5{,}611) = 8.51$, $p < .001$. Although this result is consistent with Zillmann's (1994) excitation-transfer model, it is suspect because a negative coefficient for temperature's same-time (lag 0) component was obtained in the same analysis ($b = -.067$, $\beta = -.24$), $t(5{,}611) = -5.03$, $p < .0001$. This undoubtedly stemmed from the fact that successive measures of temperature were so highly correlated as to produce problems associated with multicollinearity even in autoregression analyses. We tried to address this problem by prewhitening the predictor; unfortunately, every time we removed serial dependencies from the predictor (Rotton, 1985; Rotton & Frey, 1985) we obtained a concurrent correlation between prewhitened temperatures and time-adjusted assaults that was negative as well as significant.

tures are obvious. One might be more likely to make a conscious effort to inhibit aggressive impulses if one knows that heat caused one's discomfort. ("It's hot, so maybe I'm feeling angry because of the heat and not the SOB who insulted me.") Later, in the evening, when equally high temperatures may not be as noticeable or obvious, individuals may be more likely to attribute heat-induced arousal to another person's action (the insult). Second, the downturn might be due to the shared stress of enduring high temperatures during early hours of the day. It is reasonable to suppose that individuals are more likely to interact with people they know during afternoon hours than during evening hours of the day. This admittedly post hoc explanation is consistent with results obtained in an unpublished study by Berkowitz and Dunard (cited in Berkowitz, 1982). They found that women placed in an uncomfortably hot room expressed less hostility when they thought that the target of aggression also was enduring unpleasant temperatures. This reaction is similar to behavior observed in laboratory studies on malodorous air pollution (Rotton, Barry, Frey, & Soler, 1978).

Alcohol consumption probably accounts not only for the fact that assaults were a positive function of temperature, but also that the curve relating assaults to temperature was positively accelerated (Bell, 1992; Harries & Stadler, 1983). There is ample evidence linking alcohol to violence in field settings (e.g., Gerson & Preston, 1979) and aggression in laboratory experiments (e.g., Leonard, 1989; Richardson, 1981; Taylor & Leonard, 1983). Past studies have suggested that alcohol consumption might act as a moderator of heat–aggression relations because of "thirsts produced by the dehydration of summer" (Harries & Stadler, 1988, p. 131). Routine activity suggests another path linking heat, alcohol consumption, and aggression. People are more likely to frequent settings where alcohol is served (e.g., taverns and bars) on warm than on cool days. A previous analysis of assaults in Minneapolis found that 46% of them were located within 0.1 m (0.2 km) of places where liquor was sold (Frisbie, Fishbone, Hintz, Joelson, & Nutter, 1977). It is worth noting that moderator-variable regression time-series analysis could be used to test the hypothesis that relations between temperature and violence are stronger in alcohol-related settings (e.g., bars and parking lots) than in other parts of a city.

There are several other results that psychological theories of aggression do not explain. First, violence is not more variable at high temperatures, as Bell and Fusco (1989) asserted. Second, relations between temperature and violence are not as ubiquitous as Anderson's (1989) review suggested. There were times (6:00 a.m.–11:59 a.m. on all days except Saturday) when there was no relation between assaults and temperature. In addition, Anderson's GA model does not explain why assaults were a positively accelerated (J-shaped) function of temperature during early morning hours (12:00 a.m.–2:59 a.m.). Paradoxically, relations between temperature and aggression were strongest during the coolest hours of the day. This raises questions about one of the assumptions underlying Anderson's theory, namely, that negative affect is responsible for the relationship between temperature and aggression. It is of course possible that afternoon temperatures initiated angry feelings and thoughts that were not expressed until later hours. Although this post hoc explanation is consistent with Zillmann's (1994) excitation-transfer hypothesis, there are two reasons why we doubt that individuals were giving vent to emotions and thoughts provoked earlier in the day. First, this study's periods of time are considerably longer than the relatively short (usually 10-min) periods observed in laboratory studies; second, there is ample evidence that externally generated arousal dissipates after about 15 min (Glass & Singer, 1972).[4] However, Berkowitz's (1993) cognitive–neo-associationism theory of aggression raises the possibility that heat primes hostile cognitions, which produce higher levels of aggression at a later point in time.

Cold and Aggression

Psychological explanations. Although research and theorizing have centered on the effects of high temperature on behavior, the NAE model also makes predictions about the effects of low temperatures. According to the NAE model and results from a laboratory experiment (Bell & Baron, 1977), there should be a secondary peak in assaults at moderately low temperatures (i.e., 60–70°F). Statistically, this would imply cubic and quartic trends. However, as we noted, the cubic trend we uncovered was due to a dip in assaults around 10°F, and it disappeared when we controlled for time of day. In contrast, according to Berkowitz's (1993) theory, heat and cold should exert similar effects on behavior. However, as Anderson et al. (1996) pointed out, it has consistently been found that fewer violent acts are reported to police on cold days than on temperate or comfortably warm days (Cohn, 1996; Dexter, 1904; Rotton & Frey, 1985). Anderson et al. (1996) suggested that these findings stem from the fact that individuals "can better compensate for cold temperatures (with clothing, heating) than for hot ones" (p. 375). This is similar to an explanation advanced by P. A. Bell (personal communication, August 27, 1982). However, as reasonable as this explanation may be, it is not based on results from an empirical investigation. This hypothesis would obviously be easier to test in a laboratory than in a field setting. All of the theories we have cited lead to the prediction that low temperatures facilitate aggression when individuals are lightly clothed, but the relationship should vanish when individuals are heavily clothed.

Social explanations. One could argue that the results of this study, especially the fact that fewer offenses occur at low temperatures than at comfortable temperatures, can be more parsimoniously explained in terms of theories that emphasize social rather than psychological factors. In particular, social contact theory accounts for the overall relation between temperature and aggression. According to this theory (Sommers & Moos, 1976), people are more likely to interact with others on warm than on cool days, which increases the probability that some encounters will result in aggression. Consistent with this theory's predictions, we found that relations between temperature and assault were strongest during evening hours. These are the

[4] One might object that Zillmann (1994, p. 49) hypothesized that adrenocortical activity "may persist for hours and days after termination of stressful stimulation." However, as Zillmann pointed out, there are formidable difficulties in conducting research on persistent effects of prolonged stress; as a consequence, "controlled experiments do not exist, and theoretical proposals remain just that" (p. 54).

times when strangers are most likely to come into contact with each other. Unfortunately, social contact theory does not explain the absence of reliable relations between temperature and aggression during the warmest part of the day (namely, between 9:00 a.m. and 3:00 p.m.). A model that does so is routine activity theory.

As L. E. Cohen and Felson's (1979) theory predicts, fewer assaults were reported to the police during working hours than during other hours of the day simply because most people were engaged in other activities (in particular, the routine activity of earning a living). Working, attending school, and commuting fall under the heading of what theorists in this area term *obligatory activities*. These are usually contrasted with *discretionary activities* (e.g., relaxing, socializing, sports). According to routine activity theory, people are more likely to come into contact with motivated offenders while engaged in discretionary rather than obligatory activities. As the theory predicts, we found that people in this city were much more likely to report that they had been assaulted when most individuals are engaged in discretionary activities: during evening hours, on weekends, and during summer months.

In addition, routine activity theory reminds us that crime depends on the presence of suitable targets and the absence of capable guardians as well as the presence of motivated offenders. All too frequently, the offender's target is a family member or acquaintance; for example, 49% of all people victimized by assault in 1994 knew their assailants (Perkins & Klaus, 1996). Consistent with research on domestic violence, our findings indicate that most assaults occurred when discretionary activities brought offenders and acquaintances into close proximity (namely, during evening hours, on weekends, and during summer months).

One might object that family members are more likely to come into contact with each other (i.e., the juxtaposition of offenders and targets) on cold nights than on warm nights because fewer people venture outdoors during inclement weather. This objection ignores the role that capable guardians play in preventing and controlling violence. Felson (1994) defined the concept of *guardians* broadly to include coworkers, supervisors, and parents as well as people paid to assume the role (e.g., police and security officers). There are two mechanisms by which informal guardians may reduce violence during discretionary periods. First, they may do so directly by intervening (e.g., stepping between an offender and target). One reason why fewer assaults are reported to police during working hours (9:00 a.m.–3:00 p.m.) may be that they are resolved by supervisors and coworkers; in addition, we suspect that the guardians in this setting (i.e., supervisors) take steps to keep less serious violence from entering official records. Second, colleagues, supervisors, and other family members are potential witnesses. Routine activity theory goes beyond its main competitor (namely, social contact theory) in pointing out that the presence of other people can reduce as well as increase the probability of violence if the other persons know the offender and act as potential witnesses. This fact may explain why, contrary to what social contact theory would predict, domestic violence is less prevalent on cold days than on warm days (Rotton & Frey, 1985).

Other Weather Variables

Although this study was primarily concerned with the shape of the temperature–violence relations, several other weather variables emerged as concomitants of assaults. One of them was sky cover: Fewer assaults were reported to police on cloudy than on clear days. This finding makes sense if one assumes that cloudy days are darker, as darkness releases normally inhibited behavior effects (Page & Moss, 1976). However, pending replication, we suggest that this finding and our interpretation should be regarded as tentative. In contrast, Rotton and Frey (1985) also uncovered a reliable correlation between wind speed and assaults, which they attributed to the ability of wind to disperse pollutants. We can think of other reasons why high winds might be associated with fewer activities reported to the police. For example, high winds precede and accompany turbulent weather (e.g., storms), which would reduce crime by inhibiting social interaction (Cohn, 1993). However, this suggestion should also be regarded as speculative until additional data (e.g., on pollution levels, actual interaction levels) have been obtained.

Practical Implications

Although our discussion has emphasized theoretical issues, we would be remiss if we did not point out this study's practical implications. Perhaps the most important is that temporal variables explain nearly two thirds of the variance in reports of assaults. Consistent with past research in this area, more crimes occurred on weekends and during evening hours. In addition, we found that most assaults occurred during late evening and early morning hours on Fridays and Saturdays. Although these findings are consistent with common beliefs, we believe that they are important because they place the forecasting of criminal activities on a firm, empirical footing.

At first glance it might appear that weather variables do not add much to the prediction of violence. Some people may be inclined to dismiss a variable that explains less than 1% of the variance in criminal offenses. However, Rosenthal (1990) showed that very small effect sizes can be persuasive when one's criterion is important (e.g., a heart attack). In our view, assaults are as important (and may be as deadly) as heart attacks. Of greater importance is that focusing on the overall variances ignores the fact that the relation between temperature and assault depends on time of day. Temperature's correlation with assaults may be small during morning and afternoon hours (rs = .01 and .04); however, correlations of .21 and .22 were obtained during late evening and early morning hours. These values correspond to what J. Cohen (1992) termed *medium* effect sizes.

Limitations

We are not surprised that temperature interacted with day of week as well as time of day, because people often engage in different activities on Friday and Saturday nights than they do on other nights of the week. This is precisely what routine activity theory predicts. However, it would be a mistake to place too much emphasis on any one of the tests summarized in Table 5, because the omnibus test for this interaction was based on a large number of degrees of freedom. Furthermore, the study's triple interaction explained a small (1%) amount of variance. Moreover, as we noted, the tests in Table 5 were based on slightly more than 100 observations. Because temperatures ranged from −18°F to 104°F, the analyses suffered from the disattenuating effects associated with restriction of range. Of equal concern, Aiken and West (1991) cautioned against placing too much weight on results from tests probing three-way interactions. As they point out, such tests simultaneously increase the probability of Type I errors and reduce the power of individual tests.

An even more serious limitation to this study's findings stems from the fact that they are based on results obtained in one northern city. It is possible that individuals living in southern cities, such as Dallas or Houston, have acclimated to higher and possibly less extreme variations in temperature (Frisancho, 1979; Tromp, 1980). Behavioral adjustments also distinguish individuals living in northern and southern cities. For example, unlike individuals living in a warm city, such as Dallas, residents of Minneapolis have to split their funds between cooling and heating their residences. Obviously, follow-up studies are needed to determine if similar relations are obtained in other cities and geographical regions.

It might be noted that our prose has suffered at times as we have tried to avoid words that imply causation (e.g., "temperature effects"). Although it is tempting to conclude that temperature is responsible for the relations we have uncovered, especially when they vary as a function of time of day and day of week, we can do no more than suggest that there appears to be a reliable correlation between temperature and assaults. We could have drawn definitive conclusions from correlations between assaults and lagged temperatures; however, as we noted (see footnote 3), we were not successful in removing serial dependencies from the time series for presumed cause (namely, temperature).

Finally, we recognize that missing data constitute a serious problem in time-series analyses, because autoregressive coefficients depend on relations within the series which, in turn, depend on observations at every time period (Cook, Dintzer, & Mark, 1980). However, three facts lessen our concern over this problem. First, missing observations were fairly evenly distributed across the series (i.e., were not in one cluster). Second, as we reported, dummy variables for segments did not attain significance after weather variables were included as predictors. Third, we obtained similar results when we used a Kalman filter to handle missing values (Harvey, 1989).

Conclusions

Despite its limitations, we believe that this study contributes to the literature on temperature and violence in three ways. First, from a methodological standpoint, we have shown that investigators who rely on daily counts and averages have committed the ecological fallacy of ignoring variables (e.g., time of day) that determine the size and shape of relations between temperature and violence. This finding may come as a surprise, because aggregation is frequently promoted as a means of increasing a measure's reliability and, consequently, the probability of obtaining significant results. However, information is lost when one aggregates, especially when adjacent observations in a time series are combined (Orcutt, Watts, & Edwards, 1968). Second, at a more substantive level, this study's results suggest that the primary moderator of temperature–aggression relations is time of day. Finally, it should be apparent from our discussion that no single theory accounts for varied relations between temperature and assaults over time and across days of the week and seasons of the year. The challenge facing future investigators will be to combine social psychological theories of affect-based aggression with theories from other disciplines (e.g., sociology and criminology) that emphasize changing patterns of routine activities over time.

References

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions.* Newbury Park, CA: Sage.

Anderson, C. A. (1989). Temperature and aggression: Ubiquitous effects of heat on occurrence of human violence. *Psychological Bulletin, 106,* 74–96.

Anderson, C. A., & Anderson, D. C. (1984). Ambient temperature and violent crime: Test of the linear and curvilinear hypotheses. *Journal of Personality and Social Psychology, 46,* 91–97.

Anderson, C. A., Anderson, K. B., & Deuser, W. E. (1996). Examining an affective aggression framework: Weapon and temperature effects on aggressive thoughts, affect, and attitudes. *Personality and Social Psychology Bulletin, 22,* 366–376.

Anderson, C. A., & DeNeve, K. M. (1992). Temperature, aggression, and the negative affect escape model. *Psychological Bulletin, 111,* 347–351.

Baron, R. A. (1972). Aggression as a function of ambient temperature and prior anger arousal. *Journal of Personality and Social Psychology, 21,* 183–189.

Baron, R. A. (1983). The control of human aggression: A strategy based on incompatible responses. In R. G. Geen & E. Donnerstein (Eds.), *Aggression: Theoretical and empirical reviews* (pp. 173–190). New York: Academic Press.

Baron, R. A., & Bell, P. A. (1976). Aggression and heat: The influence of ambient temperature, negative affect, and a cooling drink on physical aggression. *Journal of Personality and Social Psychology, 33,* 245–255.

Bell, P. A. (1992). In defense of the negative affect escape model of heat and aggression. *Psychological Bulletin, 111,* 342–346.

Bell, P. A., & Baron, R. A. (1976). Aggression and heat: The mediating role of negative affect. *Journal of Applied Social Psychology, 6,* 18–30.

Bell, P. A., & Baron, R. A. (1977). Aggression and ambient temperature: The facilitating and inhibiting effects of hot and cold environments. *Bulletin of the Psychonomic Society, 9,* 443–445.

Bell, P. A., Fisher, J. D., Baum, A., & Greene, T. E. (1996). *Environmental psychology* (4th ed.). New York: Holt, Rinehart & Winston.

Bell, P. A., & Fusco, M. E. (1986). Linear and curvilinear relationships between temperature, affect, and violence: Reply to Cotton. *Journal of Applied Social Psychology, 16,* 802–807.

Bell, P. A., & Fusco, M. E. (1989). Heat and violence in the Dallas field data: Linearity, curvilinearity, and heteroscedasticity. *Journal of Applied Social Psychology, 19,* 1479–1482.

Belsley, D. A., Kuh, E., & Welsch, R. E. (1980). *Regression diagnostics: Identifying influential data and sources of colinearity.* New York: Wiley.

Berkowitz, L. (1982). Aversive conditions as stimuli to aggression. In L. Berkowitz (Ed.), *Advances in experimental social psychology* (Vol. 15, pp. 249–288). New York: Academic Press.

Berkowitz, L. (1983). Aversively stimulated aggression: Some parallels and differences in research in animals and humans. *American Psychologist, 38,* 1135–1144.

Berkowitz, L. (1993). *Aggression: Its causes, consequences, and control.* Philadelphia: Temple University Press.

Cannon, W. B. (1932). *The wisdom of the body.* New York: W. W. Norton.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112,* 155–159.

Cohen, J., & Cohen, P. (1983). *Applied multiple regression/correlation analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: A routine activity approach. *American Sociological Review, 44,* 588–608.

Cohn, E. G. (1990a). Weather and crime. *British Journal of Criminology, 30,* 51–64.

Cohn, E. G. (1990b). Weather and violent crime: A reply to Perry and Simpson, 1987. *Environment and Behavior, 22,* 280–294.

Cohn, E. G. (1993). The prediction of police calls for service: The influence of weather and temporal variables on rape and domestic violence. *Journal of Environmental Psychology, 13,* 71–83.

Cohn, E. G. (1996). The effect of weather and temporal variables on calls for police service. *American Journal of Police, 15,* 23–43.

Cook, T. D., Dintzer, L., & Mark, M. M. (1980). The causal analysis of concomitant time series. In L. Bickman (Ed.), *Applied social psychology annual* (Vol. 1, pp. 93–135). Beverly Hills, CA: Sage.

Dexter, E. G. (1904). *Weather influences.* New York: Macmillan.

Falk, G. J. (1952). The influence of the seasons on the crime rate. *Journal of Criminal Law and Criminal Police Science, 43,* 199–213.

Felson, M. (1987). Routine activities and crime prevention in the developing metropolis. *Criminology, 25,* 911–931.

Felson, M. (1994). *Crime and everyday life: Insight and implications for society.* Thousand Oaks, CA: Pine Forge.

Field, S. (1992). The effect of temperature on crime. *British Journal of Criminology, 32,* 340–351.

Frisancho, A. R. (1979). *Human adaptation: A function interpretation.* St. Louis, MO: Mosby.

Frisbie, D. W., Fishbone, G., Hintz, R., Joelson, M., & Nutter, J. B. (1977). *Crime in Minneapolis: Proposals for prevention.* St. Paul, MN: Governor's Commission on Crime Prevention and Control.

Gerson, L. W., & Preston, D. A. (1979). Alcohol consumption and the incidence of violent crime. *Journal of Studies of Alcohol, 40,* 307–312.

Glass, D. C., & Singer, J. E. (1972). *Urban stress.* Hillsdale, NJ: Erlbaum.

Harries, K. D. (1981–1982). Crime rates and environmental denominators. *Journal of Environmental Systems, 11,* 3–15.

Harries, K. D., & Stadler, S. J. (1983). Determinism revisited: Assault and heat stress in Dallas, 1980. *Environment and Behavior, 15,* 235–256.

Harries, K. D., & Stadler, S. J. (1988). Heat and violence: New findings from Dallas field data, 1980–1981. *Journal of Applied Social Psychology, 18,* 129–138.

Harvey, A. C. (1989). *Forecasting, structural time series models and the Kalman filter.* New York: Cambridge University Press.

Hibbs, D. (1974). Problems of statistical estimation and causal inference in dynamic time series models. In H. Costner (Ed.), *Sociological Methodology 1973/1974* (pp. 252–308). San Francisco: Jossey-Bass.

Johnston, J. (1984). *Econometric methods* (2nd ed.). New York: McGraw-Hill.

Kalkstein, L. S., & Valimont, K. M. (1986). An evaluation of summer discomfort in the United States using a relative climatological index. *Bulletin of the American Meteorological Society, 67,* 842–848.

Kmenta, J. (1986). *Elements of econometrics* (2nd ed.). New York: Macmillan.

Lab, S. P., & Hirschel, J. D. (1988). Climatological conditions and crime: The forecast is . . . ? *Justice Quarterly, 5,* 281–299.

LeBeau, J. L. (1988). Comment—Weather and crime: Trying to make social sense of a physical process. *Justice Quarterly, 5,* 301–309.

Leonard, K. E. (1989). The impact of explicit aggressive and implicit nonaggressive cues on aggression in intoxicated and sober males. *Personality and Social Psychology Bulletin, 16,* 390–400.

Levy, K. J. (1975). Large-sample pair-wise comparisons involving correlations, proportions, or variances. *Psychological Bulletin, 82,* 174–176.

Messner, S. F., & Tardiff, K. (1985). The social ecology of urban homicide: An application of the "routine activities" approach. *Criminology, 23,* 241–268.

Orcutt, G. H., Watts, H. W., & Edwards, J. B. (1968). Data aggregation and information loss. *American Economic Review, 58,* 773–787.

Page, R. A., & Moss, M. K. (1976). Environmental influences on aggression: The effects of darkness and proximity of victim. *Journal of Applied Social Psychology, 6,* 126–133.

Pennebaker, J. W., Rimé, B., & Blankenship, V. E. (1996). Stereotypes of emotional expressiveness of northerners and southerners: A cross-cultural test of Montesquieu's hypothesis. *Journal of Personality and Social Psychology, 70,* 372–380.

Perkins, C., & Klaus, P. (1996). *Criminal victimization 1994.* Washington, DC: Bureau of Justice Statistics.

Pittman, D. J., & Handy, W. (1964). Patterns in criminal aggravated assault. *Journal of Criminal Law, Criminology, and Police Science, 55,* 462–470.

Pokorny, A. D. (1965). Human violence: A comparison of homicide, aggravated assault, suicide, and attempted suicide. *Journal of Criminal Law, Criminology, and Police Science, 56,* 488–497.

Richardson, D. (1981). The effects of alcohol on male violence toward female targets. *Motivation and Emotion, 5,* 333–344.

Rohles, F. K. H. (1974). The modal comfort envelop and its use in current standards. *Human Factors, 16,* 311–322.

Rosenthal, R. (1990). How are we doing in soft psychology? *American Psychologist, 45,* 775–777.

Rosnow, R. L., & Rosenthal, R. (1996). Computing contrasts, effect sizes, and counternulls on other people's published data: General procedures for research consumers. *Psychological Methods, 1,* 331–340.

Rotton, J. (1985). Time-series analysis: A tool for environmental psychologists. *Population and Environmental Psychology Newsletter, 12*(1), 15–19.

Rotton, J. (1993). Atmospheric and temporal correlates of sex crimes: Endogenous variables do not explain seasonal differences in rape. *Environment and Behavior, 25,* 625–642.

Rotton, J., Barry, T., Frey, J., & Soler, E. (1978). Air pollution and interpersonal attraction. *Journal of Applied Social Psychology, 8,* 57–71.

Rotton, J., & Frey, J. (1984). Psychological costs of air pollution: Atmospheric conditions, seasonal trends, and psychiatric emergencies. *Population and Environment, 7,* 3–16.

Rotton, J., & Frey, J. (1985). Air pollution, weather, and violent crimes: Concomitant time-series analysis of archival data. *Journal of Personality and Social Psychology, 49,* 1207–1220.

Shepherd, J. (1990). Violent crime in Bristol: An accident and emergency room perspective. *British Journal of Criminology, 30,* 289–305.

Sommers, P., & Moos, R. H. (1976). The weather and human behavior. In R. H. Moos (Ed.), *The human context: Environmental determinants of behavior* (pp. 73–107). New York: Wiley.

Taylor, S. P., & Leonard, K. E. (1983). Alcohol and human physical aggression. In R. G. Geen & E. I. Donnerstein (Eds.), *Aggression: Theoretical and empirical reviews* (Vol. 2, pp. 77–101). New York: Academic.

Tromp, S. W. (1980). *Biometeorology: The impact of the weather and climate on humans and their environment.* London: Heydon.

West, S. G., & Hepworth, J. T. (1991). Statistical issues in the study of temporal data: Daily experiences. *Journal of Personality, 59,* 609–662.

Zillmann, D. (1994). Cognition–excitation interdependencies and the escalation of anger and angry aggression. In M. Potegal & J. F. Knutson (Eds.), *The dynamics of aggression* (pp. 43–71). Hillsdale, NJ: Erlbaum.

Received June 27, 1996
Revision received January 28, 1997
Accepted January 30, 1997 ■