GLOBAL WARMING AND U.S. CRIME RATES
An Application of Routine Activity Theory

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ABSTRACT: Two archival analyses were performed to examine the association between annual temperatures and U.S. crime rates. The first was based on area-averaged temperatures in the United States as a whole for the years 1950 through 1999. Box-Jenkins time-series analyses indicated that annual temperatures were associated with assault but not murder rates in analyses that controlled for yearly population, ethnicity, and three economic variables. The second analysis was based on state-centered crime rates from 1960 through 1998 and included the same controls. Contrary to the general aggression model, cross-sectional time-series analyses indicated that annual temperatures were associated with rates for assault, rape, robbery, burglary, and larceny, but not murder or motor vehicle theft. The results are consistent with a routine activity theory interpretation of everyday and criminal behavior.

***Keywords**: temperature; crime; aggression; global warming; routine activities*

The Web site for the U.S. Environmental Protection Agency (2000) identifies several negative consequences of global warming: melting icecaps, rising oceans, changes in regional climate, reduced crop yields, deforestation, eutrophication of lakes and ocean, and increases in heat exhaustion, strokes,

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and traffic accidents (Bell, Greene, Baum, & Fisher, 2000; Murray, 2001; Oskamp, 2000). Even the Bush administration, which was initially skeptical, has acknowledged that global warming is a problem (Engel, 2002). This report focuses on changes in criminal behavior that may accompany increases in atmospheric temperature. It builds on a study (Anderson, Bushman, & Groom, 1997) that examined relationships between annual temperatures in the United States and six types of crime rates. Anderson and colleagues examined annual rates for deadly and serious assaults, rapes, robberies, and property crimes (the sum of burglaries and motor vehicle thefts). Using data that spanned the 46-year period from 1950 to 1995, they were successful in uncovering a highly significant correlation between annual temperatures and crime rates for serious and deadly assaults.

Anderson, Anderson, Dorr, DeNeve, and Flanagan (2000) subsequently interpreted results from their study of global warming as support for a general affective aggression model (GAAM). According to GAAM, temperature is one of several input variables that arouses negative affect, heightens physiological arousal, and primes aggressive thoughts. These variables are described as mediators that increase the probability of aggressive behavior including violent acts (e.g., assault and murder) that come to the attention of law enforcement. However, it has yet to be shown that relationships between temperature and aggression are mediated by affective states (Rotton & Cohn, 2002). It appears that Anderson and Bushman (2002) have responded to this criticism by dropping *affective* from their model's name, which they now term the general aggression model (GAM).[1] However, regardless of what the model is called, it is not the only one that predicts a positive relationship between temperature and aggression. Rotton and Cohn (1999) pointed out that the same prediction can be derived from routine activity (RA) theory. As originally formulated (Cohen & Felson, 1979), RA theory suggests that predatory crimes occur when circumstances bring potential victims into contact with motivated offenders in the absence of controllers (i.e., guardians, place managers, and intimate handlers such as parents, teachers, and employers). Cohn (1990) extended RA theory to research on weather and crime by identifying comfortable temperature as a factor that brings people together. RA theory also provides a parsimonious explanation for the fact that low levels of violence are recorded on cold days: People avoid outdoor settings on cold days thereby reducing the probability that they will come into contact

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with motivated offenders. In contrast, although there can be little doubt that low as well as high temperatures are aversive, the GAAM suggests that more rather than less violence should occur on cold than temperate or warm days. However, precisely the opposite pattern of results has been documented since Dexter's (1899) pioneering study: Fewer violent crimes occur on cold than temperate or warm days. For example, Rotton and Frey (1985) found that assault was a linear function of temperature during a period when daily temperatures never exceeded 79 °F. The GAAM also does not explain why fewer crimes are recorded during winter than spring or fall months of the year (Baumer & Wright, 1996), but Cohen and Felson (1979) identified seasonality as one of several temporal variables that determines the probability and intensity of routine activities.

Very different predictions about the effects of temperature on rates for murder and nonnegligent manslaughter can be derived from the GAAM and RA theory.[2] Anderson and colleagues (1997) used the term *lethal assault* to describe homicide, which suggests that this crime can be understood in terms of theories (specifically, the GAAM) used to explain relationships between temperature and assault. In contrast, RA theory suggests that temperature plays a smaller role in the etiology of homicides than assaults. In particular, there is no need to postulate factors that bring perpetrators and victims into contact, because the majority of homicides are committed by individuals known to the victim such as family members and close acquaintances (Harries, 1989). In contrast, the majority of aggravated (although not simple) assaults are committed by strangers (U.S. Department of Justice, 2001). Thus, higher temperatures may have little effect on the likelihood of contact between a murderer and a victim, but they are more likely to increase the probability of contact between an assailant and the victim of a serious assault.

There are some (e.g., Harries, 1989) who maintain that the only difference between assaults and homicides is the presence of a firearm, which may turn a violent encounter into a lethal event. However, the data on which Harries bases this conclusion reveal several other differences; for example, Harries found that homicides were much more likely to take place in residences, whereas assaults were more likely to occur in public settings. Rotton and Cohn (2002) recently found that temperature's correlation with assault rates was stronger for outdoor crimes than indoor crimes. Thus, we anticipated that a stronger relationship between temperature and violent crime would be found when the criminal event was an assault rather than when it ended in death.

There are three other reasons why we believe that data on annual temperatures and violent crimes are worthy of closer scrutiny. First, as a category, violent crime is usually assumed to be composed of murders, assaults, rapes, and sometimes robberies; however, although Anderson and colleagues (1997) reported separate analyses for rapes and robberies, they combined rates for murders and assaults into the single category of deadly and serious assaults. Commenting on this type of aggregation, an organization that specializes in interpreting scientific reports for journalists (Statistical Assessment Service [STATS], 2001, para. 5) pointed out that “homicides make up only a very small proportion” of serious and deadly assaults. For example, police received reports of 15,517 homicides and 910,744 assaults in 2000 (U.S. Federal Bureau of Investigation, 2002). These figures imply that homicides comprised only 1.7% of the deadly and serious assaults in that year. The STATS (2001) organization suggested that the results that Anderson and colleagues obtained were because of temperature’s correlation with assaults rather than to its relationship with the relatively small number of murders that had been committed.

Second, Rotton and Cohn (2002) recently located five studies that had examined relationships between temperature and homicide rates (Cheatwood, 1988; Feldman & Jarmon, 1979; Maes, de Meyer, Thompson, Peeters, & Cosyne, 1994; Valentine, Ebert, Oakey, & Ernst, 1975; Yan, 2000). Not one of these studies uncovered a significant relationship for temperature and homicide for smaller (e.g., daily and monthly) time periods. These null findings suggest that a more detailed analysis of annual temperatures and homicide rates might also fail to uncover a significant relationship for homicide.

Finally, Anderson and colleagues (1997) controlled for only two possible confounds in their study of deadly and serious assaults. One was an increase in crime over time (trend); the other was age (Felson, 2002). In this attempt to extend and explicate results from their study, we controlled for ethnicity and several economic variables. According to the frustration-aggression hypothesis (Berkowitz, 1989), unemployment and other economic variables should also be correlated with annual rates for criminal behavior. We realize that the frustration-aggression hypothesis has received mixed support from studies that have examined relationships between economic indexes and crime (Catalano, Novaco, & McConnell, 1997; Green, Glaser, & Rich, 1998; Hepworth & West, 1988; Landau, 1984). However, there is a considerable amount of data that links absolute and relative deprivation to criminal behavior; as Hsieh and Pugh (1993) observed, it is “an accepted tenet of criminology that economic conditions (unemployment rates, income inequality, poverty rates) are associated with crime rates” (p. 183). In addition to controlling for unemployment and income inequality, we considered the possibility of curvilinear relationships between temperature and violent crime rates (Cohn & Rotton, 1997). However, because the data in this study were aggregated over 365 (sometimes 366) 24-hour intervals, we were skeptical of uncovering anything other than a linear relationship. Rotton and Cohn (2000) showed that nonlinear relationships only emerge when relationships are assessed during short (3- and 6-hour) periods of time. Still, the possibility of uncovering a nonlinear relationship was worth considering in light of the fact that crime rates have declined during recent years (Johnson, 2001) whereas, during the same period of time, annual temperatures have increased.

STUDY 1: U.S. TOTALS

METHOD

Most of the data for this study were downloaded from government Web sites. Area- averaged temperatures for the years between 1950 and 1999 were obtained from an online data page on the National Climatic Data Center's (2002) Web site. Each year's average was based on data from between 121 and 750 weather stations covering 11 to 69% of the U.S. land mass. Data on homicide and assault rates between 1950 and 2000 were obtained from Web pages maintained by the Bureau of Justice Statistics (U.S. Department of Justice, 2002a). The file was expanded to include controls for trend (year), total U.S. population, percent unemployment, the consumer price index, and income inequality. Following convention (e.g., Land, McCall, & Cohen, 1990), a logarithmic transformation was applied to figures for estimated population, which were obtained from a Web site maintained by the U.S. Bureau of the Census (2002). The Bureau was also the primary source for the yearly Gini index of income inequality for the period from 1967 to 1998. Data for the period from 1950 to 1966 were obtained from an archive of historical tables.[3] The source for data on unemployment rates and the consumer price index was the U.S. Bureau of Labor Statistics (2002). Finally, the Census Bureau Web site was also the source for figures on the number of persons classified as White between 1995 and 2000; figures for previous years were obtained from printed volumes (U.S. Bureau of the Census, 1951-1994). Percent non-White was derived from these figures by dividing number of Whites by population size and subtracting the result from 1.

RESULTS

The positive correlation between year and temperature, which is listed above the diagonal in Table 1, is consistent with research that indicates that

TABLE 1
Correlation Matrix for Original and Difference Series

	1.	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*	*9.*
1. Year (trend)	—	.31*	.95**	.46**	.77**	.96**	.99**	.95**	.76**
2. Temperature	.07	.30*	.38**	–.03	.38**	.23	.27	.33*	.04
3. Consumer price	.69**	.02	.95**	.38*	.91**	.90**	.93**	.94**	.59**
4. Unemployment	–.06	–.07	.14	.76**	.22	.48*	.43*	.48*	.59**
5. Inequality	.31*	–.12	.21	.35*	.91**	.70**	.75**	.77**	.29*
6. Population (log)	–.83*	–.06	–.67**	.06	–.22	.93**	.98**	.92**	.78**
7. Non-White	–.09	–.16	–.23	–.26	–.06	.06	.92**	.94**	.75**
8. Assault rate	–.01	.37**	.06	.02	–.17	–.04	.03	.94**	.74**
9. Murder rate	–.26	.11	–.09	.21	–.04	.09	–.09	.28	.95**

NOTE: Original and differenced series are above and below the diagonal; entries on the main diagonal are autocorrelation coefficients. Degrees of freedom for entries above and below the diagonal are 47 and 46, respectively.
$^*p < .05$. $^{**}p < .01$.

the earth's atmosphere is heating up as is the first-order autocorrelation coefficient on the table's main diagonal. The latter was computed by lagging observations 1 year and then pairing lagged values with themselves (Gottman, 1981). The very high autocorrelations for homicide and assault rates are indicative of a random walk. This is a stochastic process that can be simulated by tossing a penny, adding its value every time the coin comes up heads, and taking away a penny every time it comes up tails (Malkai, 1990; Rotton, 1985). Random walks are typically handled by computing first-differences between current and previous observations in a time series ($z_t = y_t - y_{t-1}$). Referring to the entries below the main diagonal in Table 1, it can be seen that intercorrelations were greatly reduced after variables had been differenced; for example, the correlation between time (represented by an ordered array of numbers between 1 and 50) and percent non-White shrank to nonsignificance.

Homicide rates. Temperature was not correlated with annual homicide rates before the series was differenced (see Table 1), and a nonsignificant transfer function was also obtained after the series had been differenced and an autoregressive parameter was estimated (see Table 2). The model's residuals resembled white noise as evidenced by nonsignificant autocorrelations after they had been lagged two time periods (McCleary & Hay, 1980), and a nonsignificant value for Ljung and Box's (1978) *Q* statistic was obtained after residuals had been lagged 20 time periods. Following procedures described in Aiken and West (1991), we assessed temperature's quadratic component by first centering temperature (i.e., converting values into deviation scores) and then squaring the scores. The quadratic component did not attain significance, $t(45) = -0.65$, $p > .50$.

It might be objected that the failure to uncover a reliable relationship between temperature and murder rates was because of low statistical power. Although the data set included as many observations as Box, Jenkins, and Reinsel (1994) proposed are necessary for a time-series analysis, our tests had a power of only .71 of rejecting the null hypothesis of detecting what Cohen (1992) termed a medium effect size ($r = .30$). We addressed this limitation by locating a Web site that gave murder rates since 1900, which listed the National Center for Health Statistics as its source for rates before 1960.[4] Including these cases brought the sample's size up to 100. Although the power of our test (for a medium effect size) was .93, temperature's transfer function did not attain significance, $t(95) = 0.64$, *ns*, in an analysis that included an autoregressive parameter of 0.26, $t(95) = 2.58$, $p < .05$.

Assault rates. Temperature's linear component attained significance in an analysis that included five other predictors and a nonsignificant term for autocorrelation. The latter was added after diagnostic tests indicated that the residuals for the differenced series had a lag-one autocorrelation of –0.28, $p < .05$. Finally, for the model summarized in Table 2, temperature's quadratic component did not attain significance, $t(39) = 1.72$, $p > .09$.[5]

DISCUSSION

As hypothesized, the results of separate analyses of assaults and homicides indicated that temperature is correlated with serious but not deadly assaults (i.e., homicides). These results are consistent with our interpretation and extension of RA theory; as we have suggested, violence occurs when environmental conditions (e.g., warm temperatures) bring offenders and victims into close proximity. This study's findings bring research on annual temperatures in line with studies that have employed more frequent (e.g., hourly and daily) measures, which also indicate that temporal variations in temperature are associated with assaults (e.g., Rotton & Cohn, 2001a) but not homicides (e.g., Cheatwood, 1988; Maes et al., 1994).

The only relationship to attain significance in this study was a linear one. The data provided no evidence for a downturn in violence at high temperatures. There might be some who will interpret this nonsignificant result as a failure to confirm the negative affect-escape (NAE) model, but even critics of the NAE model (e.g., Anderson et al., 2000) concede that annual data do not provide a fair test of Baron and Bell's (1976) model. As Rotton and Cohn

TABLE 2
Summary of Autoregressive Integrated Moving Average (ARIMA) Models of Order (1, 1, 0)

Regressor	*Transfer Function*	t^{a}	r_1	r_2	$\chi^{2, b}$
Murder/manslaughter					
Autoregression	0.41	3.04**	–.04	.06	9.56
Temperature	0.15	1.27			
Intercept (trend)	0.01	0.08			
Assault					
Autoregression	–0.31	–1.96	.01	.10	15.22
Temperature	20.79	2.20*			
Consumer price index	1.16	0.53			
Unemployment	5.11	1.14			
Inequality	–874.98	–1.21			
Population (log)	–599.97	–0.16			
Percent non-White	1610.80	1.02			
Intercept (trend)	3.03	0.12			

a. df = 40 and 48 for murder/negligent manslaughter and assault, respectively.
b. df = 20.
*$p < .05$. **$p < .01$.

(2000) have shown, restriction of range makes it difficult to uncover nonlinear relationships when data are aggregated. The extent to which temperature's range was restricted in this study became apparent when we examined the distribution's highest and lowest scores: We found that the minimum and maximum values for temperature were separated by less than two degrees Celsius (10.93 to 12.92 °C), which is less than four degrees Fahrenheit (51.67 to 55.27 °F).

This study focused on assaults and homicides, but Anderson and colleagues (1997) also considered the possible effects of annual temperatures on rape, robberies, and property crime (the sum of rates for burglary and motor vehicle theft). Insufficient statistical power may explain why they failed to uncover significant relationships for these other crimes. Admittedly, there are theoretically interesting differences between assaults and rapes, as Anderson and colleagues observed, but past investigations (Cohn, 1993; Michael & Zumpe, 1983; Rotton, 1993a) have found that temperature is correlated with reports about rape. Cohn and Rotton (2000) recently found that temperature was also correlated with robberies, burglaries, and larceny/thefts in Minneapolis. The nonsignificant results in the study by Anderson and colleagues constitute something of a challenge for investigators who favor RA theory. Cohen and Felson (1979) originally formulated RA to predict predatory crimes, and early evidence for the theory (Cohen, Felson, & Land, 1980) was based on analyses of larcenies and burglaries. If crime occurs when high temperatures bring victims into contact with motivated offenders, as Cohn (1990) has suggested, then annual temperatures should predict property crimes as well as crimes against persons.

In addition to the problem of low power, it may be that the nonsignificant relationship between temperature and property crimes occurred because Anderson and colleagues (1997) grouped two very different types of crimes (burglary and motor vehicle thefts) into a single category. As was the case with assaults and homicides, temperature might be correlated with only one of the crimes, but the inclusion of the second offense may be sufficient to mask the relationship. Although it might be argued that combining burglaries and motor vehicle thefts into a single category increases the reliability of a composite measure, it is not clear why the rates for the two crimes were not standardized before they were combined, as Anderson and colleagues (2000) have done in previous studies. There is another difference between their study of annual temperatures and past analyses of property crimes: Their most recent study did not include larceny-theft, because “the FBI definition of larceny changed in 1973, producing marked shifts in the rates” (Anderson et al., 1997, p. 1217). Although it is true that the U.S. Federal Bureau of Investigation (1974) expanded the category of larceny in 1973 to include thefts of less than $50.00, Anderson and colleagues did not report results from, for example, an interrupted time-series (ITS) analysis to show that there was, in fact, a “marked shift.” It is worth noting that, in addition to detecting shifts, an ITS analysis could also have been used to control for purported changes in level and slope when assessing the role that a third variable, such as temperature, might play in the epigenesis of larceny.

STUDY 2: STATE-CENTERED CRIME RATES

This study addresses the interrelated problems of insufficient power and restriction of range by moving from the level of the United States as a whole to the level of individual states. Instead of first collecting city data and then aggregating them into a single series, we examined relationships between temperature and crime at the level of individual states. The results are based on a cross-sectional time-series (CSTS) analysis of temperature and crime in 51 geographical units (50 states and Washington, D.C.) over a 39-year period of time. CSTS analysis solves the problem of insufficient power by increasing the sample’s size to 1989 cases (51 units × 39 periods) thus increasing the study's power to more than .99 for detecting Cohen's (1992) small effect size ($r = .10$) at a conventional level of significance. We are also able to reduce the restriction of range caused by aggregation by employing temperatures that ranged from 39.1 to 79.3 °F as our predictor.

However, attempts to pool data from different states are complicated by geographical differences in crime rates. It has long been known that crimes against persons, especially homicides, are more prevalent in Southern than other regions of the country (Corzine, Huff-Corzine, & White, 1999; Nisbett & Cohen, 1996). There is considerable disagreement about the causes of these differences as evidenced by the amount of research aimed at explaining Southern violence. Although geographical differences are sometimes attributed to temperature, there are also historical, cultural, and socioeconomic reasons for regional differences (Parker & Smith, 1979; Rotton, 1993b; Rotton, Cohn, Peterson, & Tarr, in press). However, the debate about Southern violence is tangential to the question posed here: Is there a relationship between annual temperatures and criminal behavior? We used least squares with dummy variable (LSDV) regression analysis to remove geographical differences in crime rates (Sayrs, 1989). This procedure is equivalent to group-centering in a multilevel or hierarchical linear model (Nezlek, 2001); that is, it converts observations into deviation scores around each state's mean, which allowed us to examine temporal changes in temperature and crime that are uncorrupted by spatial differences.

METHOD

The source for data on crime rates in each state and in the District of Columbia was the Web site maintained by the Bureau of Justice Statistics (U.S. Department of Justice, 2002a). The Bureau, in turn, cited the *Uniform Crime Reports* as the original source for files that can be downloaded from the page entitled "Data for Analysis." The Web site also refers users to a report from the U.S. Federal Bureau of Investigation for definitions of the Part I crimes analyzed here: murder/manslaughter, aggravated assault, forcible rape, robbery, burglary, larceny-theft, and motor vehicle theft. In addition to totals and rates for these seven crimes, the Web page gives the population figures on which the rates were based. With one notable exception, the data on crimes in each state spanned the 39-year period between 1960 and 1998. The exception was New York for which data were not available during the 5-year period between 1960 and 1964. These data were replaced by taking the arithmetic average of crime rates from New York and all other states during each of the years when data were missing. The data pages also contain footnotes indicating that government officials had employed various methods to impute missing scores in 10 other instances.[6] To put the figures summarized in Footnote 6 into perspective, it might be noted that they are fewer than the percentage of data described as missing in previous applications of CSTS methodology; for example, Totterdell, Kellett, Bruner, and Teuchmann (1999) observed that a loss of 30% is "not unusual for daily experience studies" (p. 1506).

It was reasoned that the largest city would be more representative of conditions in each state than either its capital or a city located in the state's center. For example, Miami is more representative of the geographical characteristics of Florida than its capital (Tallahassee), and more crimes are committed in and around Miami than in Orlando, which is closer to the geographical center of the state. Accordingly, several sources were consulted to locate annual temperatures in the District of Columbia and the city with the largest population in each of 50 states between 1960 and 1999. The primary sources for temperatures were printed reports (U.S. Department of Commerce, 1950-2000), which were supplemented by four editions of a weather almanac (Ruffner & Bair, 1977, 1987; Wood, 1999, 2000).

The Web site for the Bureau of Justice Statistics also provided population estimates for each state during the 39-year period of this study. In addition to the logarithm of population, we employed data from the previous study to control for annual differences in the consumer price index, income inequality, unemployment, and percentage non-White. It should be noted that these figures apply to the United States as a whole rather than individual states. They were incorporated into this study by using the same averages as controls within each state; that is, controls varied across years but not states.

ANALYTIC STRATEGY

There are several ways to evaluate relationships between exogenous variables and behavior (e.g., crime) in different geographical regions (Dielman, 1989; Greene, 2000; Sayrs, 1989; West & Hepworth, 1991). For example, Rotton and Cohn (2001a) treated indoor and outdoor assaults in Dallas, Texas, as separate variables in two time-series analyses. The predictor in their analyses (temperature) was the same for indoor and outdoor assaults. Analytic difficulties are encountered when both the predictor and the criterion vary across geographical units. Unfortunately, the procedure that econometricians (e.g., Parks, 1967) proposed for pooling data requires more time periods than cross-sections. Consequently, we developed a mixed model (Littell, Milliken, Stroup, & Wolfinger, 1996) that resembles the between-within procedures described in methodological reviews of diary studies (Kenny, Kashy, & Bolger, 1998; Schwartz & Stone, 1998). This study's between-subject factor was composed of 50 (n – 1) dummy variables for the geographical units; its within-subject (or repeated measure) factor was composed of the 39 years of annual temperatures and crime rates. Because the within-subject portion of the design consisted of the average of observations from 51 regional divisions, we assumed that a common first-order autoregression coefficient would suffice to remove serial dependencies. It should be noted that procedures for handling temporal dependencies do not extend to spatial autocorrelation. The latter are usually handled by computing panel-corrected standard errors (Beck, 1985). Regrettably, such procedures are not an option in programs that are used when the number of cross-sections exceeds the number of time periods (K. Meyer, SAS Technical Support, personal correspondence, January 25, 2002).

RESULTS

Table 3 shows that the autoregressive terms in our models were more than 0.90, which most analysts (e.g., McCleary & Hay, 1980) would characterize as unacceptably high and indicative of nonstationary drift. We addressed this problem by first computing differences and then dropping the initial observation in each state so that the series did not overlap (Judge, Griffiths, Hill, Lütkephol, & Lee, 1985; cf. Marco & Suls, 1993). This operation was applied to all of the variables except the one used to estimate trend, which explains why the coefficients for trend reversed signs after the other variables had been differenced.[7]

Violent crimes. Controlling for trend and five social and economic variables, temperature's coefficient attained significance in the analysis of assaults, rapes, and robberies after the series had been differenced. It might be noted that temperature's coefficient fell short of significance before the series for robberies had been differenced, which illustrates the importance of working with stationary series. Replicating results from Study 1, temperature's coefficient did not attain significance in the analysis of murder/homicide rates. These results cannot be attributed to statistical suppression, because similar results were obtained when our analyses did not include controls for trend and socioeconomic variables. Temperature's quadratic trend also attained significance in the analysis of murder rates (linear b = 0.055, quadratic b = 0.004), $t(1879) = 3.67$, $p < .01$. We dropped the control variables in an effort to better understand this unexpected trend; the resulting coefficients indicated that murder rates were a U-shaped function of temperature with a minimum at 50.57 °F. A plot revealed that the curve owed its shape to a larger number of homicides at low than high temperatures.

TABLE 3
Within-State Regression Coefficients for Crimes Against Persons

	Murder		*Assaults*		*Rape*		*Robbery*	
Predictor	*Original*	*Differenced*	*Original*	*Differenced*	*Original*	*Differenced*	*Original*	*Differenced*
Autoregression	0.94	–0.09	0.99	0.19	0.94	–0.11	0.96	0.44
Trend	0.14*	–0.02***	4.72***	–0.59***	0.46***	–0.08***	2.86	–0.77***
Population (log)	–4.39	–3.71	–63.87**	128.75***	1.98	–9.17	–59.19	–120.99**
Consumer price index	0.01	0.05**	0.46	2.17**	0.08*	0.37***	0.49	3.39***
Gini inequality	–6.47	1.37	–137.78	57.68	–64.33***	–28.54	–496.07***	–104.54
Unemployment	0.07	0.00	2.22**	0.53	0.57	–0.23*	4.28***	1.92*
Percentage non-White	6.49	422.35	865.19***	934.87***	52.52	111.02***	–407.32	–138.02
Temperature (T)	.01	0.02	1.02*	1.21***	0.17***	0.20**	0.73	0.84*

NOTE: *df* = 1936 and 1882 for original and differenced series, respectively.
*p < .05. **p < .01. ***p < .001.

Property crimes. As shown in Table 4, temperature was related to rates for burglary and larceny but not motor vehicle theft before as well as after the series were differenced.[8] The relationships also attained significance when temperature was the first variable entered into the regression equation. Temperature's quadratic trend also attained significance in the analysis of larceny rates ($b = –0.42$), $t(1879) = –2.99$, $p < .01$. A plot of state-centered rates failed to disclose any sign of a downturn in rates at high temperatures; instead, larceny rates leveled off in a logarithmic fashion after reaching a high at a temperature of 38.0 °F.

GENERAL DISCUSSION

The results from the second study extend past research on violent crime by showing that annual temperatures predict rapes and robberies as well as assaults. They also indicate that annual temperatures are associated with crimes against property as well as crimes against persons. These results appear to be robust: Temperature attained significance in five out of seven of the analyses that included controls for trend, autoregression, and six sociodemographic and economic controls. The results in Tables 3 and 4 provide some justification for our choice controls; for example, as the frustration-aggression model and theories that emphasize material deprivation predict, unemployment rates were correlated with robbery, burglary, and larceny.

There are three important differences between the results obtained here and the ones that Anderson and colleagues (1997) presented. First, findings from both the first and second set of analyses indicate that it is a mistake to group homicides and assaults into a single category. They reveal that the concept of *lethal assaults* is in reality an amalgamation that masks important differences between murder and assault. The second study confirms results from the first: Temperature was again correlated with rates for assault but not murder. Interestingly, however, temperature's quadratic component attained significance in the analysis of state-centered homicides. This result could be interpreted as support for the GAAM, which, as Rotton and Cohn (2002) observed, predicts more violence and aggression at low as well as high temperatures. However, although the significant regression coefficient for temperature's quadratic component suggests that homicide rates were a U-shaped function of temperature, a plot revealed that homicide rates were highest when temperatures were low. Homicide's departure from linearity appears to be due to the fact that a disproportionate number were committed

TABLE 4
Within-State Regression Coefficients for Property Crimes

	Burglary		*Larceny*		*Motor Vehicle Theft*	
Predictor	*Original*	*Differenced*	*Original*	*Differenced*	*Original*	*Differenced*
Autoregression	0.97	0.31	0.98	0.15	0.97	0.31
Trend	34.44***	–4.18***	45.24***	–7.19***	9.84***	–1.10***
Population (log)	149.68*	19.51	–409.98*	–940.77***	–0.12	–151.69**
Consumer price index	–4.65***	10.80***	3.10**	26.46***	–1.17**	2.39**
Geni inequality	–3042.72***	–828.29	–6625.98***	–8359.05***	–698.41***	–181.58
Unemployed	21.97***	8.88***	52.62***	28.37***	–0.30	–1.33
Percentage non-White	–2617.32***	–1539.81*	5679.19***	8453.52***	1291.55***	1702.24***
Temperature (T)	7.27***	8.16***	8.17**	10.65***	0.50	0.90

NOTE: *df* = 1936 and 1882 for original and differenced series, respectively.
*$p < .05$. **$p < .01$. ***$p < .001$.

in the one state (Alaska) that recorded very low temperatures. Second, it might be objected that the positive associations for rape and robbery are consistent with predictions that can be derived from the GAAM. This objection ignores the arguments that Anderson and colleagues (1997) advanced for their failure to obtain reliable results for rape and robberies. Either the GAAM does or does not predict other forms of violence (rape and robberies). If it does, then Anderson et al. failed to support their own model; if it does not, then the GAAM fails the test of fallibility. Essentially, like psychoanalytic models of repression, the GAAM's predictions cannot be disconfirmed. Third, the GAAM cannot explain the highly significant relationships for larceny and burglary in our second study. These positive results constitute a serious challenge to the GAAM, because Anderson and colleagues also advanced several reasons why temperature would not predict nonviolent (i.e., property) crime. As Rotton (1993b) observed, Anderson went so far as to use the sum of property crimes as a control in a study that examined geographical differences in temperature and violent crime rates.

RA theory provides a more comprehensible and parsimonious explanation than the GAAM for the results obtained in these two studies. First, temperature is correlated with assault but not murder rates. As RA theory predicts, temperature alters routine activities in a way that brings victims into contact with strangers who are the primary perpetrators in aggravated assault, but high temperature does not alter interaction patterns in households between family members where most murders occur. Second, temperature is also associated with rapes and robbery rates. Without entering into debates about whether rape is motivated by a desire to satisfy sexual desires or to dominate the victim, it seems reasonable to regard it as a crime that occurs when a perpetrator locates a victim in a secluded spot (i.e., in the absence of a guardian). Once again, it can be argued that this is more likely to occur when temperatures are comfortable enough to lead individuals to leave their homes. The same is true of robberies, which are also more likely to occur when victims leave their residences (U.S. Department of Justice, 2002b).

Moreover, unlike theories that emphasize affective states (e.g., the GAAM), RA theory can also explain relationships between temperature and property crimes. Indeed, although RA theory was originally formulated to explain predatory crimes (Cohen & Felson, 1979), which include crimes against persons as well as property, the theory's strongest support comes from studies that have looked at larceny and burglary (Cohen & Cantor, 1980, 1981). Much of this research is based on the premise that crime increased during the 1970s and 1980s because victims (primarily women) changed their routine activities. For a variety of economic and social reasons, an increasing number of women left the relatively safe confines of their homes and entered the work force where they were more likely to encounter motivated offenders. At the same time, with more women in the workforce, homes were left unguarded, which contributed to an increase in burglary rates. Much the same reasoning can be applied to explain relationships between temperature and the property crimes of larceny and burglary. First, temperature increases the probability that victims will leave their homes and enter settings where their property can be stolen. Second, the more people stray away from their homes, the more likely that burglars will be able to find unguarded residences (Cohn & Rotton, 2000).

Although reasonable, we cannot prove that temperature leads individuals to spend more time away from their homes. However, Rotton and Cohn (2001a) recently obtained results that would be hard to explain without assuming that temperature alters routine activities. We used police records from Dallas to classify assaults as having occurred inside or outside structures. As was noted in the introduction, we found that relationships between temperature and assaults were stronger for outdoor than indoor crimes; moreover, as Baron and Bell's (1976) model predicts, we also found that outdoor assaults were a curvilinear (inverted, U-shaped) function of temperature, whereas assaults that occurred indoors were a linear (and much weaker) function. These results are consistent with research (Zacharias, Stathopoulos, & Wu, 2001) that indicates that uncomfortably high as well as low temperatures reduce the number of individuals and the amount of time spent in public settings.

This present study's findings are important because Anderson and colleagues (2000) have argued that RA theory cannot explain the results that they previously obtained for annual temperatures and crime rates. On the contrary, as we have shown, RA provides a more parsimonious and reasonable explanation for a study that led to the formulation of the GAAM. Anderson and colleagues have also suggested that RA theory could not explain relationships between temperature and domestic violence. However, as we have suggested, it is very likely that temperature shifts the locus of people's activities from residential to nonresidential locations (including both indoor, commercial and outdoor public settings). Thus, RA also provides a parsimonious explanation for relationships between temperature and domestic violence (Rotton & Cohn, 2001b). None of this should be interpreted as a denial of the relevance of psychological theories. In particular, Baron and Bell's (1976) NAE model provides a more comprehensive explanation for the downturn in assaults that is observed when violence is recorded at more frequent (e.g., 3- and 6-hour) intervals. However, employing broader (daily and yearly) intervals, RA theory is all that one needs to account for relationships between annual temperatures and crime rates. RA theory also provides a parsimonious explanation for hourly, weekly, and seasonal differences in crime rates (Cohn & Rotton, 1997, 2000; Rotton & Cohn, 2002). We realize that these differences are so obvious and so frequently demonstrated that some may dismiss them as unimportant. Thus, it is perhaps worth noting that Richard, Bond, and Stokes-Zoota (2001) recently found that nonpsychologists judge obvious findings to be of greater importance than nonobvious results.

However, it might also be noted that temperature was not correlated with rates for motor vehicle thefts. We recognize that speculating about results that fail to attain significance is risky, but there are two reasons why the lack of a reliable relationship between temperature and motor vehicle thefts is surprising. First, the result is contrary to the stereotype we have of juveniles going for a joyride on a hot, summer day. However, it has been estimated that one in three automobiles is stolen by professional thieves (Clarke & Harris, 1992). Second, items stolen from automobiles comprise the largest percentage (approximately a quarter in all) of larceny-theft. Clearly, further research is needed to determine why temperature is associated with thefts *from* but not *of* motor vehicles. It might be noted that Anderson and colleagues (1997) grouped burglaries and motor vehicle thefts into a category that they termed *property crimes*. The results obtained in this study suggest that aggregation may have masked temperature's correlation with burglary rates in previous research.

FUTURE RESEARCH

Although this study had theory elucidation as its primary goal, we believe that it also makes two important contributions to methods for studying aggressive and criminal behavior. First, one of our goals was to test the limits of the Internet: How much of the data could we locate and then download? We were pleasantly surprised by the amount of data that is available, and we have been encouraged by the increasing availability of older as well as more detailed records as the Internet expands and matures. Second, our results illustrate some of the advantages of combining time series from different geographical regions. We will not pretend that the procedures used here are either new or unique (Kenny et al., 1998; Schwartz & Stone, 1998). They were all that was needed to examine yearly data; however, more frequent (e.g., hourly, daily, and even monthly) data will require that investigators expand their arsenal of analytic techniques to include procedures described in Rotton and Cohn (2002).

IMPLICATIONS

There are several ways to evaluate the practical significance of results on research on annual temperatures and criminal behavior. Anderson and colleagues (1997) attempted to do so by estimating the number of homicides and assaults that might occur if annual temperatures increased by 1 °F. For example, they concluded that a one-degree increase in annual temperatures would lead to a 3.68 per 100,000 increase in lethal and deadly assaults. Our analyses indicate that, although rising temperatures may lead to a higher rate of serious (i.e., aggravated) assaults, they will not have a detectable impact on deadly assaults (i.e., homicides). Further, the results from our second and more comprehensive study indicate that, although significant, the increase is closer to 1.21 additional assaults per 100,000 population if annual temperatures rise 1 °F. Although this projection is less than the one that Anderson and colleagues advanced, it has the advantage of being based on analyses that control for geographical differences in crime rates, trend, and yearly measures of economic hardship.

The regression coefficients in our tables can also be used to estimate increases in other crimes that might accompany rising temperatures. They suggest that a one-degree increase in temperatures in the United States will increase the rate for rapes by 0.20, robberies by 0.84, burglaries by 8.16, and larcenies by 10.65 per 100,000 population. Converting these rates into totals for the United States as a whole and constructing 95% confidence intervals, our results imply that this 1 °F increase will generate between 1,335 and 5,347 additional assaults, 225 and 874 additional rapes, 450 and 4,250 additional robberies, 15,197 and 27,564 additional burglaries, and 16,885 and 43,029 additional larceny-thefts. These figures may be of some use to policy makers when they try to estimate the costs of, for example, property loss, insurance rates, and expenditures for police protection.

NOTES

1. We believe that the model's originators should have followed Rotton and Cohn (1999) who suggested GA as an abbreviation to prevent it from being confused with Therivel's (1998) GAM theory of personality.

2. The U.S. Federal Bureau of Investigation's (2001) definition of murder and nonnegligent manslaughter (i.e., willful killing) excludes "deaths caused by negligence, suicide or accident, justifiable homicides, and attempts to murder or assaults to murder" (p. 19). The word *homicide* is used in this report to refer to any unlawful killing (i.e., recorded murder and nonnegligent manslaughter).

3. These data can be found at the Web site for the U.S. Bureau of the Census (2002) at http//www.census.gov/hhes/income/histinc/h04

4. As the following address suggests, the site is one of many that could be described as *buried* on the Web page for the U. S. Department of Justice (2002a): http://www.ojp.usdoj/gov/bjs/glance/tables/hmttab.htm/

5. A colleague pointed out that our hypothesis implies that temperature predicts different slopes for murder and assault rates; that is, the difference between temperature's slope in the analysis of assault is different from its slope in the analysis of homicides. This point is well-taken, because it is possible for two slopes (of the same sign) to be equal even though one (assault) differs from zero whereas the other (homicide) does not—just as it is possible for two means to be equal although only one of them differs from zero. We explored this possibility by computing the difference between homicide and assault rates after each series had been mean-centered (Aiken & West, 1991). Consistent with our previous results, we found that temperature also attained significance, $b = 20.86$, $t(46) = 2.37$, $p < .05$, in an autoregressive integrated moving average (ARIMA) model of order (1, 1, 0) that had a first-order autocorrelation of $b = –0.30$, $t(46) = –2.06$, $p < .05$. This model's residuals also satisfied McCleary and Hay's (1980) criteria for independence. Although this result captures the essence of the interactive hypothesis, we suspect that the readers will find our separate analysis of murder and assault rates more meaningful and interpretable.

6. The Web page indicates that all crimes were estimated from incomplete data for Kansas from 1993 to 1997, Kentucky in 1988 and from 1996 to 1998, Montana from 1994 to 1998, New Hampshire in 1997 and 1998, Vermont in 1997 and 1998, and Wisconsin in 1998. The site also reports that national statistics were used to estimate rapes in Delaware (1998), Illinois (1985-1988), Michigan (1993), and Minnesota (1993). In addition, we adjusted the Oklahoma homicide rate in 1995 to exclude the 168 individuals murdered in the Murrah Federal Building.

7. Because trend was estimated by creating a series with values ranging from 1 (for the first observation) to 39 (for the last in each panel), computing first differences for the sequence variable would generate a vector of zeroes.

8. Following procedures described in Gottman (1981), a dummy variable was used to assess the change in larceny's definition in 1973 (pre = 0 vs. post = 1), and the variable was multiplied by centered scores for temperature to assess differences between slopes before and after 1973 (Aiken & West, 1991). Nonsignificant coefficients were obtained for the change in larceny's definition, $b = 13.51$, $t(1879) = 0.64$, and differences between slopes, $b = 0.77$, $t(1878) = 0.70$. Given these small effects, it is not surprising that the coefficient relating temperature to larceny/theft was not greatly altered by controlling for changes in larceny's definition.

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