

WEATHER AND CRIME

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In studying the causes of crime, most criminologists have concentrated on traditional socio-demographic variables, such as age, sex, race, and socio-economic status. However, some researchers have investigated the influence of the physical environment on criminal behaviour. There is a recent theoretical basis for research into the influence of weather on crime: the situational approach, rational choice theory, and routine activities theory all suggest that weather could significantly influence crime rates and criminal behaviour. This paper brings together for the first time the accumulated research on weather and crime. It discusses the theoretical background, examines research into the influence of different weather conditions (such as high temperatures, rain, and wind) on various types of criminal behaviour, outlines problems with the current research, and suggests ways of advancing knowledge about weather and crime.

Recently, criminologists have been extremely interested in the possibility of forecasting crime rates well into the future (see e.g. Blumstein 1983). However, these analyses generally focus on long periods of time, considering units of analysis such as years; they ignore the large range of variation in the occurrence of crime within each year that is seen when smaller units of analysis are examined. Official statistics suggest that daily and hourly fluctuations in crime are far more variable than year-to-year shifts. These wide variations, which do not seem to be dependent on long-term changes in socio-demographic variables, cannot be dismissed as random 'noise'. Instead, they appear to co-vary with widely fluctuating aspects of the physical and social environment.

The majority of criminological theories attempt to explain crime by examining socio-demographic aspects of offenders and non-offenders, such as age, sex, race, geographic location, and socio-economic status. However, these traditional criminological variables change slowly over time and cannot explain short-term variations in crime rates. From both the practical perspective of police work and the theoretical perspectives of routine activities and rational choice theories, these daily and hourly fluctuations are important, and may well be predictable. Knowledge of expected short-term increases or decreases in calls for service would allow police departments to use their available manpower and other resources more efficiently and effectively.

One aspect of the physical environment which may have a major impact on human behaviour is the weather. The effect that changing weather conditions have on criminal and aggressive behaviour has long been a subject of interest both to scientists and the lay public. It is popularly believed that 'bad weather can precipitate negative emotional responses' (Garzino 1982: 407). The influence of weather upon suicide rates is a well-studied topic (see e.g. Barraclough and White 1978; Bolander 1972; Durkheim

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1951). However, the relationship between weather and crime and criminal behaviour was not studied seriously until the 1960s, after a series of riots in the United States sparked a popular belief that the causal factor was the summer heat. This belief was reinforced when the United States Riot Commission (1968) published a report showing that the majority of riots in 1967 began on days when the temperature was over 80°F. Since then, a number of researchers have focused their efforts on studying the relationship between high ambient temperatures and aggressive behaviour. A few have also examined other weather conditions, including precipitation, sunlight, wind, and humidity.

The aim of this paper is to examine the accumulated research on climatic variables and types of criminal behaviour in an effort to establish which are the empirically verified relationships among these variables. This review is limited to research published in the English language. All research conducted before 1950 (e.g. Bonger 1916; Dexter 1904; Morrison 1891) has been eliminated because of the highly questionable data collection techniques used. The research on weather and crime is widely scattered in a variety of different journals and disciplines, and has never before been collected into a comprehensive literature review.

The Theoretical Background

Traditionally, theories of crime and criminal behaviour have focused on individual personality traits which 'predispose' people to commit crime, while ignoring the situational contexts and the differences between type of crimes. Like other kinds of behaviour, crimes result from the interaction between individuals and environments, but few theories have considered the immediate situational factors which may help explain why a particular criminal event occurred at a particular time.

Clarke and Cornish's (1985) situational approach to crime, as well as rational choice theory, suggest that immediate crises, events, and conditions are important factors in the offender's decision to commit a crime. This approach is crime-specific, as the motivations involved, and the behaviours required, vary with different types of crime. Unfortunately, proponents of rational choice theory have not yet included climatic conditions, other than sunlight, in their models. This omission has seriously reduced the power of the models to explain and predict crime and to assist in crime prevention techniques.

Although rational choice theory does not specifically include climatic conditions, routine activities theory (Cohen and Felson 1979) does attempt to examine the relationship between these variables and criminal behaviour. This theory suggests that individuals' activities and daily habits are rhythmic, and consist of patterns that are repeated over time. However, changes in the surrounding environment may result in changes in behaviour and activities. For example, during pleasant weather, people tend to spend more time outdoors, resulting in greater opportunities for personal interaction and increased availability of victims, as well as an increase in the number of empty (and therefore more vulnerable) dwellings. Inclement weather, such as cold ambient temperature, reduces the number of persons available as victims, as people tend to stay off the street during bad weather. However, those few individuals who are outdoors during unpleasant weather are more vulnerable as there are fewer potential witnesses to deter the criminal.

There are also two major biological theories about the effect of weather on behaviour. The first considers weather changes or extremes to be stresses. As some individuals are more highly stressed, or more sensitive to stressors, than others, 'if an additional stress is applied uniformly to everyone by a weather change, those who are already highly stressed are more likely to exhibit behavioral or mood changes' (Moos 1976: 101). The second theory considers weather to be 'a simple stimulus to the human organism' which can have both physiological and psychological effects (*ibid.*). The psychological effects may be mediated by physiological changes, by environment-induced changes in arousal that are not physiological, by individual preferences for certain types of weather conditions, and by 'socially learned definitions of certain weather phenomena as significant and important' (*ibid.*).

It is thus clear that the notion of weather affecting criminal behaviour is supported by routine activities theory, rational choice theory, and the situational approach to crime, as well as possibly being biologically based. The remainder of this paper examines current knowledge on weather and crime.

Heat and Crime

The correlational research

A number of field studies examining the correlation between heat and various crimes have been conducted over the past twenty years. Because they were conducted in the field, with no control of extraneous variables, they do not allow for any unambiguous inferences about cause and effect. Uncontrolled variables may account for the fluctuations in crime that occur as ambient temperature changes. Among the types of crimes that have been studied are collective violence, assault, homicide, rape, robbery, and domestic violence.

1. *Heat and collective violence.* Baron and Ransberger's (1978) examination of archival data of serious civil disorders in America between 1967 and 1971 found results that suggest 'a curvilinear relationship between ambient temperature and the incidence of collective violence' (*ibid.* 354). The frequency of riots increased with ambient temperature up through about 85°F, and then decreased sharply as temperature continued to increase. However, they did not take account of the number of days when the temperature was above 90°F. Carlsmith and Anderson (1979) suggested that fewer riots occurred on days with temperatures over 90°F, not because such temperatures lowered the probability of people rioting, but simply because there were fewer such days. When they reanalysed Baron and Ransberger's data, controlling for the probability of high-temperature days, the relationship between temperature and crime became linear, so that the probability of a riot increased steadily with ambient temperature up into the mid-90s. It can be concluded that collective violence tends to increase with temperature at least up to about 85°F.

2. *Heat and assault.* Research on assault provides extremely consistent findings, possibly because the high daily frequency of assault offers greater statistical reliability. With the exception of the cross-jurisdiction study by DeFronzo (1984), all the available published research, as discussed below, has found a positive linear relationship between temperature and the assault rate.

An examination of daily assaults by Feldman and Jarmon (1979) produced a significant zero-order correlation between temperature and assaults ($r = .33$) for one year in Newark, New Jersey. Their multiple regression analysis showed that temperature variables were the most important daily predictors of assault rates, in comparison to precipitation, air pollution, and barometric pressure. Harries and Stadler (1983) also found a significant zero-order correlation between the daily maximum discomfort index (a combined measure of temperature and humidity) and the daily assault count in Dallas, Texas, over an eight-month period in 1980 (which included a record heat wave). A later analysis of the same period plus data from 1981 confirmed these findings (Harries and Stadler 1988).

Michael and Zumpe (1983*a*, 1983*b*) examined sixteen locations around the United States for two- to four-year periods and found that the monthly mean daily temperature and the monthly mean number of assaults were significantly correlated in fourteen of the sixteen locations with within-jurisdiction rank-order correlations ranging from .58 to .97. An ordinary least-squares regression analysis showed significant linear relationships between temperature and assault, and there was a significant positive correlation between the dates of the temperature maxima and the dates of the assault maxima in all sixteen cities. Rotton and Frey (1985) examined daily calls for police service in Dayton, Ohio, over a two-year period and found that the daily mean temperature was a significant predictor of the number of assaults ($r = .48$). Perry and Simpson (1987) found a significant correlation between the monthly minimum temperature and the aggravated assault rate ($r = .28$) in Raleigh, North Carolina. A stepwise regression analysis showed that monthly minimum temperature was a significant predictor of the assault rate.

On the other hand, DeFronzo found no relationship between the number of days with temperatures equal to or greater than 90°F ('Days Hot') and the rate of aggravated assaults in 142 SMSAs (Standard Metropolitan Statistical Areas) in the United States. However, unlike all the research discussed above, which focused on single jurisdictions, DeFronzo conducted a study comparing a number of jurisdictions.

Thus, all the intra-jurisdiction research on temperature and assaults has found that assaults tend to increase linearly as temperature increases.

3. *Heat and homicide.* Unlike the assault research, studies of the relationship between homicide and high ambient temperature have produced more contradictory findings.

Michael and Zumpe (1983*a*, 1983*b*) found positive relationships between heat and homicide over time in Los Angeles, Puerto Rico, and Texas, the three jurisdictions with the highest homicide counts of the sixteen they examined. They also found a strong correlation (Spearman $r = .58$) between the annual mean temperature and the annual mean homicide rate across all sixteen locations. These cross-sectional findings were supported by DeFronzo (1984), who found a slight positive association between year-total homicide data and the number of 'Days Hot'.

On the other hand, Feldman and Jarmon (1979) found no significant zero-order correlations between ambient temperature and homicide in Newark over twelve-month and fifteen-year periods. Michael and Zumpe (1983*a*, 1983*b*) found no significant correlations between monthly temperature and the monthly mean number of homicides in thirteen of the sixteen locations they examined. Perry and Simpson (1987) found no significant relationship between the monthly homicide rate and the monthly minimum temperature in Raleigh during a ten-year period.

Thus, two studies within single jurisdictions (Michael and Zumpe 1983*a*, 1983*b*) and three studies between jurisdictions (Michael and Zumpe 1983*a*, 1983*b*; DeFronzo 1984) have found positive associations between heat and homicide, while fifteen within-jurisdiction studies (Feldman and Jarmon 1979; Michael and Zumpe 1983*a*, 1983*b*; Perry and Simpson 1987) have found no significant associations. This suggests that, while the daily influence of heat on homicide is doubtful, there is evidence of long-term association of homicides with high-temperature climates. However, this association could be mediated by a variety of cultural, regional, and historical factors. There is also the problem of small sample sizes; homicides occur more infrequently than other violent crimes, such as assault, and the small number of homicides examined in many of the studies may have seriously reduced the power of the statistical tests employed.

4. *Heat and rape.* Only very recently have researchers begun to examine the link between temperature and rape. Michael and Zumpe (1983*a*, 1983*b*) found significant positive correlations between the monthly mean temperature and the monthly mean number of rapes (Spearman $r = .64$ to $.97$) in thirteen of their sixteen locations. Perry and Simpson (1987) also found a significant positive correlation between the monthly average minimum temperature and the monthly rape rate ($r = .26$), so that the rate of rape offences increased with temperature. In addition, a stepwise regression analysis showed that the average minimum temperature was a significant predictor of the rape rate, independently of other predictors. On the other hand, DeFronzo (1984) found no relationship between the total number of 'Days Hot' and rape across 142 American SMSAs. However, this study has been criticized by several researchers (e.g. Rotton 1986) because of the possible unreliability of the 'Days Hot' measure of ambient temperature, and because of the large number of predictor variables used (fourteen in all), which increased the probability of Type I (rejection of a true null hypothesis) and Type II (accepting a false null hypothesis) errors. In the light of the other research evidence, it may be concluded that there appears to be a linear relationship between ambient temperature and the rate of rape.

5. *Heat and robbery.* Both Michael and Zumpe (1983*a*, 1983*b*) and DeFronzo (1984) examined robbery. None of their analyses found any significant relationships between high ambient temperature and robbery. Anderson and Anderson (1984) have suggested that this may be because robbery is motivated primarily by economic need and is not a truly aggressive crime.

6. *Heat and domestic violence.* Rotton and Frey (1985) found that daily mean temperature was a significant predictor of the rate of domestic complaints ($r = .68$) in Dayton over a two-year period. They also obtained cross-lagged correlation coefficients to investigate if temperature had any delayed effect on domestic violence complaints, and found that high temperature significantly tended to precede disturbance calls by one day. Michael and Zumpe (1986) found a positive linear relationship between the monthly mean temperature and the monthly number of crisis calls received by battered-women's shelters in five locations around the United States over a two- to three-year period. Also, LéBeau (1988) reported that the temperature-humidity discomfort index significantly predicted domestic assault calls over a six-month period in Charlotte, North Carolina. All three researchers appear to have found similar positive linear relationships between ambient temperature and domestic violence.

7. *Heat and non-aggressive crimes.* DeFronzo (1984) also examined the correlation between 'Days Hot' and burglary, larceny, and motor vehicle theft. A multivariate

regression analysis showed a significant positive association between temperature and burglary, but no relationship between temperature and larceny or motor vehicle theft. However, Feldman and Jarmon (1979) found that temperature variables were more important than other variables such as precipitation, barometric pressure, and air pollution as predictors of the total number of crimes reported to the police over a one-year period in Newark.

The experimental research

Experimental research has several advantages over field research, chief of which is the researcher's ability to make valid causal inferences from the results. In field studies, it cannot be established whether uncontrolled variables other than the weather, such as social, demographic, and economic factors, can explain observed relationships between weather and crime. Because of the experimenter's ability to control conditions and randomize physical variables, the impact of high temperature, for example, in isolation from other variables, can be established more securely in the laboratory. On the other hand, experiments often use unnatural measures of aggression that have no real-world analogues and only a tenuous relation to criminal behaviour outside the laboratory. The laboratory conditions themselves may be extremely restrictive and often differ greatly from the naturalistic social settings of field research.

It is, of course, very difficult to study actual criminal behaviour in a laboratory setting. However, a series of experiments has been conducted on the influence of high ambient temperature on aggressive behaviour (Baron 1972; Baron and Lawton 1972; Baron and Bell 1975, 1976; Bell and Baron, 1976), with aggression measured by the intensity and duration of electric shocks directed against a confederate by the subject. The researchers used two temperature conditions ('hot' being approximately 93°F and 'cool' being approximately 73°F) and two arousal conditions (half the subjects being negatively aroused or angered by the confederate in various ways before being given the opportunity to administer shock). This research suggests that there is a curvilinear, or inverted-U, relationship between aggression and heat (as a measure of negative affect). In other words, aggressive behaviour increases with heat up to about 85°F, and then decreases. This suggests that 'there is a critical range of uncomfortably high ambient temperatures in which aggression may well be facilitated. On the other hand, extremely high ambient temperatures, especially when combined with other sources of irritation or discomfort, may become so debilitating that aggression is no longer facilitated and may well be reduced' (Bell, Fisher, and Loomis 1978: 126).

A later series of experiments (Boyanowsky *et al.* 1981-2), examining temperatures in the high 80s, failed to find support for the inverted-U relationship. Instead, the researchers found, in three separate experiments, that aggression increased with heat. The decrease in aggressive behaviour under conditions of extreme negative affect seen in the Baron research was not observed. However, as Baron generally combined several methods of negative arousal (e.g. the influence of an aggressive model or the lack of a cooling drink in hot conditions), while Boyanowsky *et al.* only used one method (negative feedback on an essay), it is possible that Boyanowsky *et al.*'s subjects were not as highly aroused and therefore were still in the rising portion of the inverted-U curve.

Anderson and Anderson (1984) proposed that the curvilinear effect may be an experimental artifact, because the temperature manipulations were extremely obvious to

the subjects. They suggested that subjects who discerned the experimenter's purpose may have attempted to sabotage the study, or to assert their independence, by behaving in a manner opposite to how they thought the experimenter wanted them to behave. The types of subjects used in the two experimental series are relevant to this theory, as Baron's experiments invariably used students taking a general psychology course (and participation in the experiment was a course requirement; the subjects were not volunteers). Psychology students would be more likely to guess the research question, because of their studies of human behaviour. In addition, if Baron, Bell, and Lawton's subjects resented their forced participation, they might have been more prone to 'attempted sabotage'.

Discussion

In general, the results of the field studies do not concur with those of the laboratory experiments. However, one cause of this seeming inconsistency may be the difference in the settings that were used. In the laboratory, 'hot temperatures are a salient part of the . . . manipulations, and the subjects know that they can escape the aversive temperature when the lab session is over. Ambient temperature in the field, however, is neither as salient a causal factor nor is it as escapable' (Anderson and Anderson 1984: 92). Although temperatures in the laboratory are held constant, this is not true in the field, where temperature varies during the day. While heat in the field can be alleviated, at least in part, by turning on an air conditioner or taking a cool drink, it cannot be escaped completely, as in the laboratory. However, while in the laboratory, the subjects may experience the heat more completely, as they are unable to make any effort to alleviate it. It is possible that the subjective experience of temperature is different in the laboratory setting, where the heat is unnatural and, during the period of the experiment, inescapable, from what it is in the real world, where heat is part of the natural environment. Thus, heat in the field may not be experienced as totally as in the laboratory.

One possible consequence of this is that, in the field studies, the inflection point may not have been reached and only the left, upward, side of the inverted-U curve explored. Of course, at some unspecified high temperature, aggressive behaviour and crime will undoubtedly decrease, if only because extreme heat eventually causes death. Therefore, the presence of an inverted-U relationship is not in doubt; the key issue is where the point of inflection occurs. Another problem is the varied measure of aggression. Laboratory studies use electric shocks, which may have only a tenuous relationship with aggression in the field. Field studies examine a variety of types of criminal behaviour, some looking at rates of specific crimes and others looking at calls for service received by police departments.

Cold and Crime

Although the influence of high ambient temperature has been a popular subject of study, very little research has been done on low temperatures. (The Baron studies of 'cold' actually examined conditions near room temperature.) Boyanowsky *et al.* (1981–2) found that under uncomfortably low temperatures (about 45°F), 'angered subjects

showed significantly increased aggression' (ibid. 85). They also discovered that the patterns of aggression seen under hot and cold conditions were markedly different:

When uncomfortably hot, subjects took longer to respond, their intensity of aggression increased slowly and escalated over time until they were no longer discriminating between occasions where they were being insulted versus those when they were given merely neutral feedback . . . By contrast, aggression in uncomfortable cold was swift and very specific to the degree of insult of the verbal feedback received from the accomplice . . . [and was] . . . more instrumental and appropriate to the situation. (ibid.)

DeFronzo (1984) found a significant positive relationship between the number of days with a maximum temperature equal to or less than 32°F ('Days Cold') and robbery rates in 142 American SMSAs. However, he found no relationship for any other type of crime, including homicide, assault, rape, burglary, larceny, and motor vehicle theft. The positive relationship between low temperatures and robbery, and the earlier findings that showed no relationship between high temperatures and robbery, may be explained by the belief that 'robbery may be less an anger or frustration response than a way of making a living' (Anderson and Anderson 1984: 94). Thus, individuals may commit robberies to obtain the additional goods needed to stay alive during cold weather (warm clothing, shelter, heating, etc.) but are not induced to commit robberies because of emotional upsets possibly caused by extreme summer heat.

Sunlight and Crime

Three studies of ambient temperature and crime have included an examination of sunlight or photoperiod (the length of the day) in the analyses. Heller and Markland (1970) found that the number of hours of daylight was a significant predictor of calls for police service in three United States cities (Chicago, Detroit, and St Louis), so that the number of calls increased with increased hours of sunlight. Michael and Zumpe (1983a, 1983b) found no relationship between photoperiod and homicide, assault, rape, or robbery in any of the locations they studied. However, while Heller and Markland (1970) examined the average number of minutes of sunlight each day, Michael and Zumpe (1983a, 1983b) measured the annual change in photoperiod by looking at the latitude of each location. Michael and Zumpe (1983a) have suggested that, 'since the changes in photoperiod and temperature tend to covary, it is difficult to separate their effects, and the effect due to temperature may have obscured that due to photoperiod' (ibid. 270). Finally, Rotton and Frey (1985) found no relationship between the daily percentage of sunshine and the rate of domestic violence in Dayton, Ohio. However, unlike Michael and Zumpe (1983a, 1983b), they did find a significant, positive linear relationship between sunlight and assault ($r = .13$). Because of these contradictory findings, no definite conclusions may be drawn about the relationship between sunlight and crime.

Rain and Crime

The relationship between rain and crime appears to vary with the type of crime examined. Feldman and Jarmon (1979) have examined the relationship between rain and crime on a day-to-day basis, while DeFronzo (1979) looked at the number of days on which the amount of precipitation exceeded 0.25 mm and Perry and Simpson (1987)

considered monthly amounts of precipitation. All three studies found no significant correlations between precipitation and the homicide rate. Neither DeFronzo (1984) nor Perry and Simpson (1987) found any relationship between rain and rapes, although DeFronzo found a positive relationship between rain and robbery.

The relationship between assaults and rainfall is uncertain, because the empirical results are inconstant. Feldman and Jarmon (1979) found a negative correlation between precipitation and assaults ($r = -.19$) while Perry and Simpson (1987) reported a significant positive correlation ($r = .18$). DeFronzo found no significant relationship between precipitation and assaults whatsoever. Given that Pokorny (1965) has argued that homicide and aggravated assaults are 'basically the same category of behavior' (ibid. 497), one would expect homicide and assaults to be similarly related to other variables, including precipitation. However, while the findings on assault are conflicting, the research results show that homicide and rape are not significantly related to rainfall.

Wind and Crime

Only two studies have considered the influence of wind on criminal behaviour. Rotton and Frey (1985) found a significant but low negative correlation between daily domestic violence complaints and daily windspeed ($r = -.09$) in Dayton over a two-year period. In addition, cross-lagged correlation coefficients were examined for delayed effects, and they showed that changes in wind speed significantly preceded changes in domestic disturbances by one and four days, and preceded changes in assaults by two days.

Miller (1968) examined the relationship between the occurrence of the Santa Ana winds in Los Angeles and the daily homicide count over a two-year period. A sign test Cohn (1988) performed on Miller's data showed that there were significantly more homicides on 'Santa Ana' days than would be expected by chance alone ($p < .05$). While these results appear to contradict those of Rotton and Frey (1985), Miller (1968) studied a special form of wind. The 'Santa Anas' are extremely strong local winds, which occur concurrently with relative humidities below 20 per cent, and reach speeds of fifty miles per hour within Los Angeles. The prevailing direction is generally northerly or easterly, and considerable amounts of dust are often carried along by these winds. It is possible that they produce more emotional stress than the more 'normal' winds studied in Dayton, because the Santa Ana winds are associated with increased physical distress. The Dayton winds, on the other hand, may have reduced air pollution and any accompanying irritability.

Barometric Pressure and Crime

Feldman and Jarmon (1979) found no significant correlation between daily changes in barometric pressure and the rates of homicide or assaults in Newark. Similarly, Rotton and Frey (1985) found that daily barometric pressure was not significantly correlated with calls relating to assaults or domestic violence in Dayton. However, Fisher *et al.* (1984) suggest that, as changes in barometric pressure are generally associated with variations in other weather conditions, it is possible that fluctuations in temperature or

other weather variables could have masked the effects of barometric pressure in these projects.

Humidity and Crime

Finally, only Rotton and Frey (1985) appear to have examined the influence of humidity on crime. Although they found no relationship between humidity and domestic violence calls in Dayton, they found a slight negative correlation ($r = -.11$) between daily humidity and the assault rate. Rotton and Frey have suggested that air pollution may be responsible for the latter effect, as humidity levels are higher before and after a rainfall, which removes pollution from the air.

Problems with the Research

Research on weather and crime, like other kinds of criminological research, has numerous methodological problems, including inadequate sample sizes, weak or inappropriate statistical techniques, and poor control of extraneous variables. Our ability to draw conclusions from the literature is also limited by the lack of consistent definitions.

Definitional problems

Researchers are rarely in agreement when defining high and low ambient temperatures. Some studies have created dichotomous measures of temperatures as uncomfortably hot or not, or uncomfortably cold or not (e.g. DeFronzo 1984), while others have simply looked at the average daily temperature (e.g. Rotton and Frey 1985) or even the average daily minimum temperature (e.g. Perry and Simpson 1987). In some research, a combined temperature-humidity index has been used (e.g. Harries and Stadler 1983, 1988). DeFronzo (1984) considered the number of days when the maximum temperature was equal to or greater than 90°F, a seemingly arbitrary figure. Rotton (1986) objected to this measure, pointing out that 'though every one of his sociodemographic variables had attained significance in past research on criminal behavior, DeFronzo did not cite any studies that had employed *number* of warm, cold, and rainy days as measures of climate' (ibid. 355).

Similar problems are found in studies of other climatic variables. Research into the relationship between sunlight and crime has considered the number of hours of daylight (Heller and Markland 1970), daily percentage of sunlight (Rotton and Frey 1985), and even annual change in photoperiod (Michael and Zumpe 1983a, 1983b). Also, it is not always clear whether snow is included in the analysis of precipitation as well as rain.

There are also problems in measuring the dependent variables. For example, Michael and Zumpe (1986), in their examination of the relationship between heat and domestic abuse, studied crisis calls to battered-women's shelters. However, the number of calls by battered women may only have a tenuous relationship to the number of episodes of domestic assault. Other field research employed measures ranging from calls for police service (e.g. Rotton and Frey 1985) to official crime rates (e.g. Perry and Simpson 1987), which are all subject to similar problems. The experimental research

used the intensity and duration of electric shocks to measure aggressive behaviour, a measure of questionable external validity, as mentioned earlier.

Improper sample size

The number of time period units of analysis is often extremely small or very large, which may affect the statistical power of the tests employed. For example, Feldman and Jarmon (1979) examined daily homicide rates over fifteen years (about 5,480 days).

Statistical and methodological techniques

A number of the studies used questionable statistical methods. For example, DeFronzo (1984) examined fourteen predictor variables. According to Rotton (1986), 'forcing a large number of predictors into a regression equation simultaneously increases the probability of Type I and Type II errors . . . [this can be seen because] . . . DeFronzo (1984) failed to obtain support for obviously valid and previously confirmed correlations' (ibid. 356). A number of DeFronzo's (1984) predictor variables were highly correlated, which may have resulted in unstable regression weights and inflated standard errors. Similarly, Rotton and Frey (1985) employed an extremely large sample size (over 10,000 calls to police about assaults), which will have increased the probability of a Type I error.

Miller (1968) did not perform any significance tests whatsoever, although he did provide raw data which allowed such tests to be carried out subsequently (Cohn 1988). Even when significance tests were performed, researchers frequently did not report the results and/or the significance levels, especially when the findings were not statistically significant (e.g. Feldman and Jarmon 1979).

Few of the studies addressed statistical issues such as multicollinearity (intercorrelated independent variables), or employed any of the time-series modelling techniques that can be used to investigate changes over time.

Conclusion

A few firm conclusions can be drawn from the research conducted to date on the relationship between weather and crime. It appears that assaults, burglary, collective violence, domestic violence, and rape tend to increase with ambient temperature, at least up to about 85°F. The relationship between heat and homicide is uncertain. High temperatures do not appear to be correlated with robbery, larceny, and motor vehicle theft.

In general, it appears that most violent crimes against persons increase linearly with heat, while property crimes are not strongly related to temperature changes. A number of mediating factors have been proposed which may explain the relationship between heat and violent criminal behaviour. These include several variations in social behaviour patterns, such as alcohol consumption, vacations, and leisure time, and the availability of social interaction. Alcohol consumption tends to increase when the temperature is high, which may be a contributing factor to many violent crimes (Amir 1971). Vacations also generally occur during periods of warm weather, resulting in in-

creased social interaction, especially with family and friends. It has been shown (e.g. Walmsley 1986) that the majority of violent crimes occur between family members or friends, rather than between strangers. Uncomfortable heat also tends to cause increased frustration, reducing one's tolerance for annoyances that otherwise might be dismissed. However, non-aggressive and property crimes are less influenced by emotions, which may be the reason why high temperatures do not greatly affect the rates of these crimes.

It is not currently possible to draw any firm conclusions about the relationships between cold temperatures and crime, sunlight and crime, or wind and crime. The research on rain and crime suggests that rainfall does not significantly influence homicide and rape, although the relationship between rain and assaults is not clear. Barometric pressure does not appear to be correlated significantly with homicide, assault, or domestic violence. Humidity has been found to be related to assaults, although not to domestic violence.

It is clear that criminologists have failed to consider many climatic variables that might explain short-term fluctuations in crime rates, despite the strong theoretical basis of routine activities and rational choice theories. Little research has been done on any weather variable except heat, and many weather conditions (e.g. fog, sleet, etc.) appear to have been completely neglected. The research that has been conducted has produced contradictory and conflicting results, and the majority of the studies have methodological problems. In addition, much of the prior research is completely atheoretical.

Future research on the relationship between weather and criminal behaviour must be theoretically grounded and use measures of crime and weather that are justified by theory. The timing of the criminal events that are studied must be as exact as possible, as weather conditions can change between the occurrence of a crime and the time the official report is filed. The most appropriate type of crime data may be calls for service received by police. Taylor, Gottfredson, and Brower (1981) have shown that several types of crimes, including violent crimes, are highly correlated with related calls for service. It is also necessary to employ a causal model that examines a variety of weather variables together, as well as separately, especially considering the weak predictive power of most weather variables in isolation. The analysis of the data should employ more advanced statistical techniques, such as multivariate analysis and time-series analysis.

Currently accepted theories of criminal behaviour, such as routine activities theory, rational choice theory, and the situational approach, support the belief that weather may significantly affect some types of criminal behaviour. Better research into the relationship between weather and crime is necessary to incorporate these variables into new explanations of changing crime rates, increasing our abilities in the areas of explaining, predicting, and controlling crime.

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