Implications of Global Climate Change for Violence Developed and Developing Countries

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Chapter to appear in J. Forgas, A. Kruglanski, & K. Williams (Eds.), *Social Conflict and Aggression*

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Abstract

Global climate change will likely lead to increased violence in highly industrialized and in developing countries, but in somewhat different ways. The likely effects of global warming on violence are explored through factors that both: (a) are likely to be affected by global climate change and, (b) have been linked to violent tendencies at one or more levels (e.g., individual, small group, societal). Examples of such factors that meet both criteria include increased displacement, poverty, and physically uncomfortable living conditions.

Implications of Global Climate Change for Violence Developed and Developing Countries

Rapid global climate change is a fact of 21st century life. "Rapid," in the context of climate change, means major changes that take place over a period of a dozen or so decades rather than millennia. Human activity, especially the production of huge quantities of several greenhouse gases primarily from the burning of fossil fuels, has initiated a general warming trend in our atmosphere and on our planet. All 10 of the warmest years on record (1880-2008) were the last 10. This trend will continue and is expected to accelerate until the composition of our atmosphere returns to a pre-industrial era norm. Because of the longevity of greenhouse gases, a return to normality or even a slowing of the warming trend cannot occur until decades after humans stop producing such a large load of such gases or until such production is offset by equally large scale sequestering of these gases.

The specific climatic effects on specific regions of the earth are expected to vary considerably. Even though most parts of the globe are warming, a few places may experience cooler climates, as ocean and wind currents shift, affecting local climates in ways that are difficult to predict. Some regions are experiencing increased rainfall, whereas many others are having prolonged droughts. In 2007, the Intergovernmental Panel on Climate Change (IPCC) released a report that included a number of projections of likely climate change effects by the end of this century, under varying assumptions of how world governments, industries, and people responded. The best case scenario assumes huge reductions in net greenhouse gas production, beginning almost immediately. In this scenario, climate models predict an average global temperature increase of 1.8°C (5.2°F) and an average sea level increase of 28 cm (11 inches). The worst case scenario, which assumes a business as usual approach to greenhouse gas production, predicts increases of 4.0°C (9.2°F) and 43cm (17 inches). Other projections, some of which have already become apparent, included: increases in heat waves, and heavy precipitation; decreases in precipitation in subtropical areas; increases in tropical cyclones; increased weather variability and drought. More specific projections included: (1) 5-8% increase in the proportion of Africa that is arid and semi-arid; (2) major flooding of heavily populated areas of Asia from rising sea levels and storms; (3) complete inundation of low-lying small islands; (4) severe water shortages in Australia and New Zealand; (5) drought in southern Europe; (6) decreased soil moisture and food crops in Latin America; and (7) increased winter flooding and summer heat waves in North America. More recent research being prepared for the next IPCC report suggests that the new best case scenario will be worse than the old worse case scenario, with sea levels rising a least 1 meter and possibly 2 (Vermeer & Rahmstorf, 2009). Because 13% of the world's population —hundreds of millions of people —live in low-lying coastal areas (Engelman, 2009, p. 41), this latter projection is particularly disturbing. This includes many of the world's largest cities, such as Dhaka, Bangladesh (13 million, 8 meters above sea level), Jakarta, Indonesia (8.5 million, 1-3 meters and sinking), Mumbai, India (19 million, 14 meters), New York (8.3 million, 10 meters), Shanghai (20 million, 4 meters), Tokyo (35 million, 5 meters) and Miami (5.4 million, 2 meters). Indonesia may lose as many as 2,000 small islands in the next 20 years to rising sea levels (Engelman, 2009, p. 3).

In addition to the changes in average temperature and rainfall, the best climate models also predict an increase in extreme weather events. Recent data suggest that this increase has already begun, with dramatic increases in floods, wind storms, and drought disasters in the last 20 years (Engelman, 2009, p. 16, 30). Hurricanes, cyclones, and other tropical storms also are increasing in intensity, just as predicted by the climate models. The problem with rising sea levels is not just the height of high tides, but is more about storm surge. A once a century storm in New York city, for example, causes massive damage costing lives, livelihoods, and millions of dollars. A one meter increase in sea level means that a storm of sufficient intensity to cause “once a century” type of storm surge and flooding will now occur about once every three years (Rahmstorf, 2009). Other cities, at lower elevations and at greater risk for tropical storms, are even more at risk.

Research from psychology, sociology, political science, economics, history, and geography suggest that there are at least three ways that rapid global warming and its consequences increase the risk of violent behavior. One involves the direct effects of uncomfortably warm temperatures on irritability, aggression, and violence. A second involves the indirect effects global warming has on factors known to put children and adolescents at risk for developing into violence-prone adults. The third involves the indirect effects of rapid climate change on populations whose livelihoods and survival are suddenly at risk, effects that influence economic and political stability, migration, and violent intergroup conflict. Various governmental and scientific reports have singled out violent conflicts in the Darfur region of Sudan and Bangladesh as examples in which climate change has exacerbated existing tensions and conflicts.

Heat and Aggression

Much research has established that uncomfortably warm temperatures can increase the likelihood of physical aggression and violence (for comprehensive reviews, see Anderson & Anderson, 1998; Anderson, Anderson, DeNeve, & Flanagan, 2000; for a concise review see Anderson, 2001). Three types of studies have tested and found considerable support for this heat hypothesis. Experimental studies comprise the first type. These studies, usually conducted in controlled laboratory settings, have found that under certain circumstances uncomfortably hot temperatures increase physical aggression. The second type, called "geographic region studies," compare violence rates in different geographic regions to see whether hotter regions are associated with higher violence rates. The third type of heat hypothesis study compares aggression/violence rates within the same region or setting at time periods that differ in temperature.

Experimental Studies of the Heat Effect

Early experimental studies of uncomfortably warm temperatures on aggressive behavior yielded considerable inconsistency in outcomes (Anderson, 1989; Anderson et al., 2000), perhaps because of participant suspicion (e.g., studies in which kerosene heaters were next to participants in the hot conditions) and measurement issues. Later experimental studies provided better tests and cleaner results. For example, Vrij, van der Steen, and Koppelaar (1994) conducted a field experiment in which Dutch police officers were randomly assigned to perform a training session involving a simulated burglary under hot or comfortable conditions. Officers in the hot temperature condition reported more aggressive and threatening impressions of the suspect, and were more likely to draw their weapon and shoot the simulated suspect than those in the cool temperature condition.

Anderson et al. (2000) reported a series of laboratory experiments on both hot and cold temperature effects. Several findings are of particular relevance to the present chapter. In three separate experiments, uncomfortably warm temperatures increased participants' feelings of anger and hostility; their perceptions of hostility in observed dyadic interactions of other people; and their initial retaliatory aggressive behavior against a person whose prior harmful behavior was of an ambiguous nature.

Geographic Region Studies of the Heat Effect

Do hotter regions of the world, for example, cities within the U.S., have higher violence rates than cooler regions? Studies dating back to the 19th century suggest that hotter regions within a country have higher violent crime rates than cooler regions (Anderson, 1989). However, even within the same country different regions differ in many ways other than climate. Some of these other differences (e.g., poverty, unemployment, age distribution, culture) are risk factors for violence. Therefore, the best geographic region studies include statistical controls for such extraneous factors. Even when these other factors are controlled, temperature predicts violent crime rates. For example, hotter U.S. cities still yield significantly higher violence rates than cooler cities, even after statistically controlling for 14 risk factors, including age, education, race, and economic factors as well as culture of violence factors (Anderson & Anderson, 1996).

Time Period Studies of the Heat Effect

"Time period" studies vary considerably in terms of the time periods for which violence and temperature are assessed. One useful characteristic of time period studies is that because comparisons are made within the same region, many violence risk factors that can obscure or confound geographic region studies are controlled by virtue of using the same region.

Overall, the results are remarkably consistent in finding that hotter time periods (e.g., days, seasons, years) are associated with higher levels of violence, even when other relevant variables (e.g., poverty) are statistically controlled. For example, riots in the U.S. are relatively more likely on hotter than cooler days (Carlsmith & Anderson, 1979). Similarly, violent crimes across a wide range of countries and measures occur more frequently during hotter seasons than cooler ones (Anderson, 1989). Of course, other violence-related factors may also differ between hotter versus cooler time periods, even within the same region. For example, in the U.S. large numbers of youth are out of school during the summer months, so one could argue that the routine activities of the population might account for seasonal differences in violence rates. Several studies have addressed this and various other alternative explanations of heat-related time period effects. Although it is clear that routine activities do influence aggressive behavior, it is also clear that such alternative explanations do not parsimoniously account for many observed effects. For example, in two studies Anderson and Anderson (1984) found significant day-of-week effects on daily violent crime rates, in addition to heat effects. Other time-related routine activities, such as youth being out of school in the summer, cannot account for the heat effect found in Study 1 (Chicago), cannot account for the heat effect because that study included only the summer months. Similarly, routine activity theory cannot account for the finding that Major League Baseball pitchers are more likely to hit batters with a pitched ball on hot days than on cool days, even after statistically controlling for the possibility of sweat influencing the pitcher's control (Reifman, Larrick, & Fein, 1991).

Differences in violent crime rates for hotter versus cooler days have been found within cities as varied as Houston, Chicago, and Minneapolis (Anderson & D. Anderson, 1984; Anderson & K. Anderson, 1998). Even after controlling for routine activity effects of time of day and day of week, violent crimes are relatively more frequent in hotter weather (e.g., Anderson & Anderson, 1998; Bushman, Wang, & Anderson, 2005a, 2005b). Interestingly, nonviolent crime rates appear to be unrelated to heat.

When the time period is years (instead of days), the kinds of potentially confounded variables changes. For example, U.S. youth are out of school in the summer regardless of whether the year is slightly warmer or cooler. When considering year-based studies and global warming effects, one might be concerned about whether aggression related factors such as age distribution (e.g., proportion of the population that is in the high crime age range) might be confounded with time and/or systematic temperature changes. We conducted two new studies to examine the effects of yearly changes in temperature on violent and nonviolent crime in the U.S., beginning with 1950.

Study 1: Hot Years and Violent Crime

Method

Data. This study is an extension of Anderson, Bushman, and Groom's Study 1 (1997). The major additions are 13 years of new data and several aggression-related control variables. Data for the years 1950 – 2008 were obtained from a variety of U.S. government sources. From the FBI's Uniform Crime Reports we created two crime measures based on data for the entire U.S.. *Violent crime* was defined as the sum of the homicide and assault rates per 100,000 population. *Nonviolent crime* was defined as the sum of the burglary and motor vehicle theft rates per 100,000 population. These constituted the outcome variables. [1]

The primary predictor variable, annual average temperature, was computed from data from the National Oceanic and Atmospheric Administration. We sampled the same 50 large U.S. cities throughout the continental U.S. for each year, using the same weather reporting station whenever possible, and adjacent stations when the original station was replaced. Because the 50 cites were widely scattered throughout the continental U.S., and they were the 50 largest in 1980, the sample temperatures can be seen as a good indicator of average U.S. temperatures weighted (to some extent) by population.

Control variables were year, age (proportion of the population in the 15-29 high crime age range), prison (number of incarcerated State and Federal inmates per 100,000 population) poverty (percent of families living below the poverty line), and the GINI index of income distribution equality (perfectly equal distribution yields a GINI index of 0, perfect inequality = 1.0). Year effects might reflect a host of cultural and population changes, such as increased reporting of assaults and improvements in trauma care. The other control variables have obvious theoretical links to violence.

Correlated residuals. Time series data often have a problem in which the residuals are

[1] As in prior studies, robbery and rape were excluded for theoretical reasons. Both appear to have a greater mixture of aggressive motives (intent to harm) and non-aggressive motives. See Anderson et al., 1997.

correlated with time. The most common version is when the residuals at any given time period (T) are correlated with the residuals at the subsequent time period (T+1). Such "autocorrelations" make ordinary least (OLS) procedures inappropriate for estimating regression parameters. With a sufficiently large sample of time periods, autoregression (AR) techniques can be used to reduce or eliminate autocorrelations among residuals, and can thus yield more accurate results. In all regression analyses, chi-square tests (Ljung & Box, 1978) were used to assess goodness of model fit regarding the presence of correlated residuals. The chi-square statistic simultaneously tested for autocorrelations in the first six lags of the residuals. When the chi-square statistic suggested that the model provided a poor fit to the data, autoregressive parameters were added to the model. This process was iteratively repeated until the chi-square test statistic indicated nonsignificant autocorrelations in the new residuals.

Thus, the present study addresses five alternative explanations for heat-related time period effects on violent behavior: (a) seasonal fluctuations, (b) correlated residuals, (c) coincidental crime, year and global warming trends, (d) coincidental age distribution shifts, and (e) coincidental income and poverty shifts. The first alternative explanation is dealt with by using year as the unit of analysis. The remaining alternatives are dealt with by statistical controls. Note that the nonviolent crime analyses are included as a point of comparison. Theoretically, hotter temperatures should have relatively little impact on nonviolent crimes in modern, wealthy societies.

Results

Table 1 presents the descriptive statistics and the zero order correlations among the variables. As can be seen, average annual temperature has increased during this 59 year period, as reflected in the positive correlation, r=.54. Also note the substantial zero-order correlations among violent crime, temperature, and year. This suggests that in addition to checking for autocorrelated residuals, a conservative statistical procedure would also control for year effects. Finally, note that nonviolent crime was not strongly correlated with temperature.

Table 1. Correlations among the predictor and outcome variables, Study 1, 1950-2008.

	Year	Temp	Age	Prison	Pov	Gini	Vio	NVio
Year	1.00	0.54	0.04	0.90	-0.75	0.88	0.87	0.52
Temp	0.54	1.00	-0.19	0.61	-0.18	0.61	0.48	0.11
Age	0.04	-0.19	1.00	-0.36	-0.44	-0.30	0.25	0.78
Prison	0.90	0.61	-0.36	1.00	-0.43	0.97	0.69	0.13
Pov	-0.75	-0.18	-0.44	-0.43	1.00	-0.36	-0.71	-0.79
Gini	0.88	0.61	-0.30	0.97	-0.36	1.00	0.72	0.16
Vio	0.87	0.48	0.25	0.69	-0.71	0.72	1.00	0.75
Nvio	0.52	0.11	0.78	0.13	-0.79	0.16	0.75	1.00
Descriptive Statistics								
Mean	1979	57.85	0.227	231	16.1	0.382	239.1	1300
St.Dev.	17.2	0.78	0.025	153	5.6	0.027	127.7	544
Min.	1950	56.60	0.195	93	11.1	0.348	55.7	385
Max.	2008	59.70	0.272	512	32.5	0.432	451.3	2163

Notes: N = 59. If $r > .25$ then $p < .05$.
Temp = annual average temperature. Age = proportion of U.S. population in the 15-29 range. Prison = number of incarcerated State and Federal inmates per 100,000 population. Pov = percent of families living below the poverty line. Gini = index of income distribution equality (perfectly equal distribution yields a Gini index of 0, perfect inequality = 1.0). Vio = serious and deadly assaults per 100,000 population. Nvio = burglaries and motor vehicle thefts per 100,000 population.

Table 2 presents the results of OLS and AR analyses on violent crime (top section) and nonviolent crime (bottom section). OLS regression revealed a large effect of temperature on violent crime; each 1°F increase in average annual temperature was associated with 79 more serious and deadly assaults per 100,000 population. However, the AR test revealed significant autocorrelations among the residuals, $\chi^2(6) = 196$, $p < .05$. We added AR parameters to the model until the autocorrelation test became nonsignificant (three parameters were needed). This greatly reduced the slope relating temperature to violent crime, but this heat effect remained statistically and practically significant. In the next step we controlled for year. The temperature effect on violent crime remained essentially unchanged. The year effect also was significant; each year added 4.90 violent crimes per 100,000 population. We also examined a host of models with the other control variables (age, prison population, poverty, GINI). Only prison rate yielded a significant effect. With three autoregressive parameters, temperature, year, and prison in the model, the temperature effect was essentially unchanged (*b* = 4.19). The year effect became larger. Finally, the greater the proportion of the U.S. population that was imprisoned, the smaller the violent crime rate.

A host of OLS and AR models on nonviolent crime did not yield a single significant temperature effect. Indeed, after appropriate AR parameters were in the model, only age was a significant predictor of nonviolent crime rates. For every 1% increase in the proportion of high crime age individuals in the population, there was an increase of 96 nonviolent crimes per 100,000 population.

Table 2. Destructive testing results using auto-regressive parameters and competitor variables, Study 1, 1950-2008.

Violent[a]	AR test		Temperature Effect								
Model	χ^2	*df*	*b*	*SE*	*t*						
OLS	196*	6	79	19.1	4.15*	Year Effect					
AR-3	3.80	3	4.11	1.25	3.30*	*b*	*SE*	*t*	Prison Effect		
AR-3	4.07	3	4.16	1.25	3.33*	4.90	1.68	2.91*	*b*	*SE*	*t*
AR-3	3.27	3	4.19	1.21	3.47*	8.34	1.88	4.43*	-.42	.203	-2.07*
NonVio[b]	AR test		Age Effect								
Model	χ^2	*df*	*b*	*SE*	*t*						
OLS	186*	6	16,646	1778	9.37*						
AR-3	4.85	3	9645	3321	2.90*						

Temp = annual average temperature. Age = proportion of U.S. population in the 15-29 range.
* $p < .05$. + $p < .10$ if $t > 1.67$

[a] Serious and deadly assault: Assault + homicide.
[b] Non-violent crime: Burglary + motor vehicle theft.

Study 2: Hot Summers and Violent Crime

Method

Data. This study is an extension of Anderson, Bushman, and Groom's Study 2 (1997). It examines violent crime in the summer months in the U.S. relative to non-summer months. The major additions are 9 years of new data and several aggression-related control variables. Data for the years 1950 – 2004 were collected from numerous governmental sources. Seasonal data were not available for years after 2004.

Basically, the data set is the same as for the prior study, with two major exceptions. First, the outcome variable is the difference between the percent of the year's crimes that were committed during the summer months (June, July, August) and the average of the other three seasons, adjusted for number of days in each season. If violent crimes were equally likely to occur regardless of season, then the summer months would account for exactly 25% of them, and the summer effect score used in this study would be zero. If violent crimes were relatively more (less) likely in the summer months, the summer effect score would be greater (less) than zero. Two summer effect scores were analyzed, one based on violent crimes (homicide and assault) and one based on nonviolent crimes (burglary and motor vehicle theft).

The second major difference from Study 1 was the temperature measure. For this study, we used the same city sampling method but recorded the number of hot days that occurred. The official definition of a hot day is one on which the maximum temperature was ≥ 90° F. Because the vast majority of hot days in the continental U.S. occur during the summer months, this measure is a good indicator of how hot each of the 55 summers was across the continental U.S..

Predictions. Two predictions are particularly relevant. First, we expect the summer effect on violent crime to be significantly greater than zero, when averaged across years. Of course, as noted earlier some portion of this effect might be the result of very different routines in the summer months, such as large numbers of youth being out of school. Second, if the summer effect is not merely the result of such routine activity differences, then years with more hot days should yield larger summer effects on violent crime than years with fewer hot days.

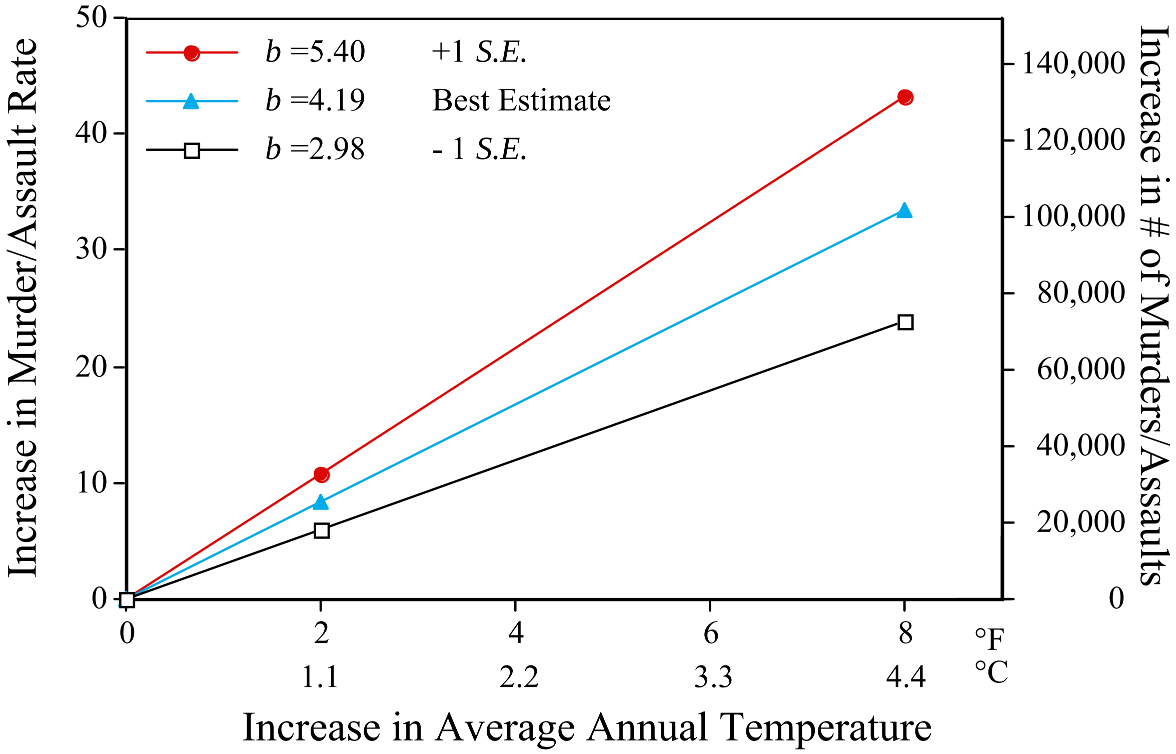
Results

As expected, the average summer effect on violent crime was significantly greater than zero, $M = 2.57$, $t(54) = 18.52$, $p<.05$. Violent crimes are over-represented in the summer months. In fact, in only two of the 55 years was the summer effect negative.

Concerning the second hypothesis, there was no evidence of autocorrelations among the residuals in any of the analyses of violent crime, so OLS analyses were appropriate. The only variable that significantly predicted the size of the summer effect on violent crime was the number of hot days, $b = .068$, $t(53) = 3.07$, $p<.05$. None of the control variables (including year) had a significant effect, nor did they substantially reduce the size of the hot days effect.

General Discussion of the Heat Effect on Aggression

In sum, the heat hypothesis has been repeatedly confirmed—uncomfortably warm temperatures increase the likelihood of physical aggression and violence. Laboratory studies suggest that this effect is largely the result of heat induced increases in irritability and in hostile interpersonal perception biases. There is additional evidence that these effects can be further traced to thermoregulation and emotion regulation areas of the brain (Anderson, 1989; Boyanowsky, 1999, 2008; Boyanowsky, Calvert-Boyanowsky, Young, & Brideau, 1981). The implication for global warming is that at the level of the individual person, increased exposure to uncomfortably hot temperatures will increase the likelihood of interpersonal conflict and violent crime. It is difficult to estimate with confidence how big an impact global warming will have on violent crime in modern societies like the U.S., but Figure 1 provides some rough estimates based on the results of our first study. If average annual temperature in the U.S. increases by 8°F (4.4°C), the best estimate of the effect on the total murder and assault rate is an increase of about 34 per 100,000 people, or over 100,000 more such serious and deadly assaults per year in a population of 305 million.



A common response to high heat in industrialized countries is increased use of air conditioning in buildings, cars, buses, and trains. Although such actions might mitigate the heat-induced increases in aggression, they also increase the production of greenhouse gases. On a global scale, warming and climate change will create a calendar year that resembles the weather patterns of summer which from a criminological perspective is bad news because increased social interaction and heat often result in violence (Cohen & Felson, 1979).

There are no comparable daily, seasonal, or annual data on the heat effect on violent crime in less developed countries. However, given the findings summarized in previous sections suggest that uncomfortably hot temperatures can have a fairly direct effect on aggressive and violent tendencies, perhaps through neuro and hormonal pathways that are common to thermoregulation and emotion.

Development of Violence-Prone Individuals

The heat/aggression link discussed in the previous section operates immediately and directly on the individual. Global warming will likely increase the antisocial and violence risk of many individuals in slower and more indirect ways as well. Some of the economic and social consequences of global warming increase the proportion of children and youth exposed to risk factors known to increase the likelihood of becoming a violence prone individual— someone who frequently uses physical aggression or violence to deal with conflict, to get desired resources, and to impulsively and shortsightedly satisfy one's wants (Gottfredson & Hirschi, 1990; Moffitt, 1993). Studies of violent youth and violent criminals reveal a host of psychological, neuropsychological, genetic, and environmental risk factors that play a major role in determining who becomes a violence prone person. These interrelated risk factors include: male gender; strongly heritable antisocial traits including impulsivity, sensation seeking, low intelligence, and poor self-regulation; poverty; poor prenatal and childhood nutrition; familial dysfunction; growing up in violent neighborhoods; psychopathy; low education; and disorganized and unstable neighborhood (DeLisi, 2005).

Food, Violence, and Antisocial Behavior

Potentially one of the most catastrophic effects of deleterious climate change centers on food availability. Today, one in eight U.S. households with infants is food insecure, which means that the family has limited or uncertain availability of nutritionally adequate and safe foods. In

American households with infants that are below the poverty line, 30% are food insecure. In many parts of the world, food insecurity is a much larger problem. This means that a robust proportion of impoverished children (notwithstanding the multifaceted independent effects of poverty on antisocial behavior) face the specter of poor nutrition and even malnutrition--conditions with severe long-term consequences for crime and violence. A recent study is illustrative. Jianghong Liu and his colleagues conducted a longitudinal study that examined the relationship between malnutrition and subsequent externalizing and antisocial behaviors using a birth cohort of children from the island of Mauritius which lies off the coast of Africa. They found that children who were malnourished at age 3 were significantly more aggressive and hyperactive at age 8, were significantly more aggressive and prone to externalizing (acting out) behaviors at age 11, and were significantly more hyperactive and likely to exhibit symptoms of conduct disorder at age 17 compared to children who were not malnourished (Liu, Raine, Venables, & Mednick, 2004). In short, food scarcity, food insecurity, poor nutrition, and malnutrition pose significant health and behavioral risks to children in the developed and developing world alike.

It is not merely armchair conjecture to assert that food scarcity caused by an environmental pathogen (i.e., global warming) will result in increased violence-prone individuals; history has already told such a story. From October 1944 to May 1945, residents of the western Netherlands were subjected to moderate to severe food scarcity caused by blockade of food supplies into the country by the German army during the Second World War. A cohort of over 100,000 Dutch men born between 1944 and 1946 were studied to examine the effects of gestational nutritional deficiency and subsequent proneness to violence (Neugebauer, Hoek, & Susser, 1999). They found that men exposed to severe maternal nutritional deficiency during the first and second trimesters were 2.5 times more likely than men not exposed to severe maternal nutritional deficiency to develop Antisocial Personality Disorder, a psychiatric diagnoses characterized by recurrent use of violence and display of antisocial behaviors.

Environmental-Genetic Interplay

Children in regions of famine, prolonged droughts, and civil unrest and wars (see next section) are exposed to many known risk factors for the development of violence prone adolescents and adults. Although it sometimes takes years for some of these effects to become apparent, longitudinal studies have shown that even fairly brief exposures (e.g., a few months) to some of these risk factors can put the individual child (or fetus) on a high-risk developmental trajectory. Since the mapping of the human genome was completed in 2003, behavioral scientists have articulated the precise ways that environmental and genetic risks interact to produce violence, antisocial behavior, and other forms of maladaptive behaviors.

The landmark study by Caspi and his colleagues (2002) examined the interaction between monoamine oxidase A (MAOA)—an enzymatic degrader that modulates neurotransmitters—and childhood maltreatment for four antisocial outcomes: conduct disorder, disposition toward violence, antisocial personality disorder, and conviction for a violent offense. For all four outcomes, the association between maltreatment and antisocial behavior was conditional on the MAOA genotype. Although just 12% of the sample had genetic risk (low-activity MAOA levels) and maltreatment, they accounted for 44% of the total cohort convictions for violent crime. Moreover, 85% of youths who had both genetic and environmental risk factors developed some form of antisocial behavior. In the absence of maltreatment, the genotypic risk factor did not manifest itself behaviorally. Substantively similar gene-environment interactions have also been found for early life, environmental adversity and psychiatric outcomes (Caspi et al., 2003; Uher & McGuffin, 2010).

If global warming brings about a world of dramatically increased environmental risk and an unknown number of environmental pathogens, then it is likely that a proportional proliferation of behavioral risks will result as these pathogenic environments moderate genetic and neuropsychological risks within individuals. Recall the pernicious and long-term effects of malnutrition and violent and antisocial behavior. Malnutrition, particularly when it is endured during gestation, causes a host of neuropsychological deficits relating to neuronal reduction, brain toxicity, altered neurotransmission, and other physiological effects. These neuropsychological deficits also interact with genes to predict antisocial behavior. For example, Beaver, DeLisi, Vaughn, and Wright (2010) found that neuropsychological deficits (such as those implicated by prenatal nutritionally deficiency) interacted with the low-activity polymorphism in the MAOA gene to predict violent behavior, delinquency, and low self-control across two periods of data collection.

A final postscript should be considered in that the discussion thus far pertains to the population in developed and developing nations. There is also a population of about 10 million people worldwide who are confined to prisons and other types of correctional facilities. Here we have per capita the most antisocial and violent individuals living in the predictably uncomfortable conditions of confinement. To what extent will increased heat, increased frustration, increased stressors, and currently unknown increased environmental pathogens bear on the confined population? Only time will tell.

Civil Unrest, Ecomigration, Genocide, and War

Both of the prior links between global warming and violence focus on violence at the individual level. This third link focuses on larger groups of people—communities, tribes or clans, societies, and countries. This is a particularly complex set of phenomena. Emerging research from several disparate fields suggests that rapid climate change often leads to dramatic increases in violence. There are several ways that rapid climate change (heating or cooling) can produce this group level effect. For example, in subsistence economies, which are primarily involved in herding, hunting, and/or agriculture, rapid changes in climate lead to a decrease in the availability of food, water, shelter, and other necessities of life. Depending on the level of social/political organization, such shortages can lead to civil unrest and civil war, to migration to adjacent regions and conflict with the people who already live in that region, and even to genocide and war. Although it would be overly simplistic to blame the many bloody conflicts in Africa and Asia during the latter 20^{th} and this first decade of the 21^{st} century on climate change and environmental disasters, it also would be incorrect to ignore the role played by the economic hardships (including starvation) wrought by the prolonged droughts and resulting resource shortages in that region. Civil unrest, revolutions, genocidal wars, and regular wars require recruits and leaders who are willing to risk a lot in order to gain other resources.

Case Studies

Historical research provides evidence that environmental disasters, many linked to relatively rapid climate changes, can lead to increases in group level violence. Of course, not all environmental disasters are caused by climate change. For example, earthquakes, tsunamis, and volcanoes can and do cause environmental disasters, but are not directly related to climate change. However, floods due to excessive rainfall or melting glaciers, droughts, hurricanes and cyclones are climate related, and often lead to environmental disasters. Of primary concern in this section is evidence concerning whether environmental disasters influence violence rates and severity, regardless of whether the environmental disaster was the direct result of climate change.

In the recent past, evidence of such effects comes from the U.S. Dust Bowl of the 1930s, clashes in Bangladesh and India since the 1950s, and hurricane Katrina in the U.S. in 2005 (Reuveny, 2008). The cases differ in many ways, including political organization and strength. But in each case, there is evidence that environmental disaster led to increased interpersonal violence, a result of *ecomigration*, defined as migration of a large number of people as a result of ecological disaster.

Hurricane Katrina. When Katrina hit Louisiana and Mississippi in the fall of 2005, it flooded about 80% of New Orleans and destroyed much of the Biloxi-Gulfport area. More than a million people left the area, many of whom have not returned. This ecomigration was to at least 30 different states, with Texas (especially Houston) absorbing the most, at least initially. Texas officials ran 20,000 criminal checks, and found minimal criminal data on their Katrina immigrants. Nonetheless, Houston recorded huge increases in homicides in the following months, relative to the same months in the year prior to Katrina (Reuveny, 2008). There were other indicators (e.g., polls) of tension between the long-time residents and the newcomers as well. However, there was no outbreak of civil war, and no evidence of armed intergroup conflict. This seems to be generally true of ecomigrations in well organized highly industrialized countries.

U.S. Dust Bowl. In the 1930s, poor farming practices combined with a prolonged drought and strong winds to produce an environmental disaster in the Great Plains, particularly Oklahoma. About 2.5 million people left the area, primarily for adjacent states, but about 300,000 went to California. There are numerous reports of hostility and violence between the residents and the ecomigrants, including police efforts to block the migrants or to scatter them from their settlements, beatings, and shack burnings (Reuveny, 2008).

Bangladesh. Population pressures from a very high fertility rate combined with unsustainable farming practices and environmental disasters (possibly related to climate change) led to large scale migrations to adjacent regions in Bangladesh and across the border to India. From 1976-2000 about 25 million people were affected by droughts, 270 million by floods, and another 41 million by rain and wind storms. Making matters worse, in 1975 the Indian Farakka

Barrage began diverting water from the Ganges river to other parts of India, decreasing the amount flowing into its historic tributaries in Bangladesh. The resulting salt water intrusion from the Indian Ocean and increased silting of the riverbed resulted in additional floods, erosion, and environmental degradation.

An estimated 12 to 17 million Bangladeshis have migrated to adjacent states in India since the 1950s. Clashes between the residents and the migrants have occurred along socioeconomic, religious, ethnic, and national lines, resulting in thousands of deaths, especially after the 1983 elections. Indeed, 1700 Bengalis were killed in a five-hour rampage in 1983.

Time Period Studies

Little Ice Age Effects. Following the Medieval Warm Period, the Little Ice Age (roughly 1300 – 1850) used in cooler temperatures, shorter growing seasons, and a host of other climate-related changes. A number of scholars from a variety of disciplines (history, anthropology, economics, geography) have begun examining the relationships among relatively rapid shifts in climate and a host of human population events, including war. Fagan (2000) weaves a careful story of climate shifts and their impact on Europeans, linking farming practices and outcomes, social and cultural changes, civil unrest, and war. Though careful to avoid the extreme claims of *environmental determinism*, he makes a strong case for viewing rapid climate change (in this case, cooling) as contributing to war and other forms of violence. Basically, rapid climate change disrupted food production, leading to food shortages, famines, civil unrest, and war. This process seems particularly important in agrarian societies that haven't the political and economic resources to effectively deal with food shortages and famine. Indeed, according to Fagan, the French revolution was fueled in part by food shortages that were largely the result of the failure of farming practices to adapt to the changed climate.

Zhang and colleagues (Zhang, Brecke, Lee, He, & Zhang, 2007; Zhang, Zhang, Lee, &

He, 2007) took a more statistical approach to examining the question of whether rapid shifts in climate from 1000 – 1900 were linked to wars. Using data from the Northern Hemisphere and from China, they found statistical support for their model, which is very similar to Fagan's. Basically, rapid climate change can lead to decreased food production, which in turn influences the likelihood of war, revolution, and dynastic change.

Further evidence of such effects comes from a recent study of wars in Africa (Burke, Miguel, Satyanath, Dykema, & Lobell, 2009). After controlling for a number of factors, they found that warmer temperatures led to significant increases in the likelihood of war.

It might seem strange to include studies of rapid cooling in a work that is focused on global warming and violence. However, the basic model is the same regardless of whether a rapid shift in climate is warming or cooling, flooding or drought. A systematic change in climate that threatens basic human resources put stress on economic and social systems. That stress can lead to ecomigration and then to conflict, or directly to war over resources.

Civil War in Africa. Burke, Miguel, Satyanath, Dykema, and Lobell (2009) recently published an analysis of civil war in Africa from 1981 – 2002. In some models they included per capita income and form of government variables, as well as temperature and precipitation. Overall, the results showed a strong positive relation between temperature increases and civil war. For a 1°C increase in temperature, there was a 5.9% increase in civil war. Given the baserate of civil war in this dataset (11%), this represents a 54% relative increase in the likelihood of civil war for each 1°C increase in temperature. These authors further noted that a 1°C increase is projected by 2030, and that if future wars in this region are as deadly as past ones, an additional 393,000 battle deaths can be expected.

Additional Ecomigration and War Related Forms of Violence

A recent report by the United Nations (Engelman, 2009) highlighted a number of additional ways in which global warming will lead to increased violence. Perhaps the most notable is the likely increase in violent crimes committed against women and children as a consequence of their increased vulnerability in subsistence economies that suffer an ecological disaster. With the breakdown of societal norms and increased economic stress comes increases in rape, assault, and homicide. As far as we know, there are no studies directly linking global warming to such effects, but such effects have been documented in the aftermath of severe floods, food shortages, and war ("civil" or otherwise).

Implications

Collectively, these three ways in which global warming leads to increased human violence suggest a rather dire future. However, action can be taken. The most obvious is that the nations of the world need to get serious about reducing greenhouse gas emissions to reduce the magnitude of global climate change.

In addition to all of the technological and lifestyle changes being actively discussed, it also seems worthwhile to consider an infrequently discussed option, the potential benefits of better efforts at population control. One thousand years ago the world population was about 300 million. Currently it is about 7 billion. Some have estimated that the world population will peak at around 10 billion. Most of that increase will take place in developing countries, with huge increases in greenhouse gas emissions as a result of carbon-intensive industrialization and increasing consumption. Generally speaking, as a country becomes more industrialized and wealthy, the carbon footprint per person increases dramatically, and population growth eventually slows. The conundrum faced by the world's population is how to reduce total greenhouse gas emissions while improving the quality of life of the large proportion who currently live in poverty. Interestingly, one recent study found that, "dollar-for-dollar, investments in voluntary family planning and girls' education would also in the long run reduce greenhouse-gas emissions at least as much as the same investments in nuclear or wind energy." (Engelman, 2009, p. 26). Unfortunately, family planning and limiting population growth are such hot political topics that they have been ignored in almost all governmental discussions of the climate change crisis.

Developed and developing countries will be affected differently by global warming. In some ways, developed countries will be less affected, in part because of their locations, but more importantly because they have more resources per capita to deal with the changes. It is unlikely that famines will strike the richest countries, for example. However, no country, rich or poor, will be immune to the violence-potential of global warming. We believe that all three types of global warming related violence processes will affect all types of countries. It seems fairly obvious that the heat effect on individual levels of aggression and violence applies to wealthy countries. In fact, that is where the bulk of the research has been conducted. Similarly, is seems obvious that even wealthy countries are likely to see increases in the proportion of children exposed to known risk factors for the development of violence-prone youth and adults. It is less obvious how wealthy countries will be affected by the third process, which leads to increases in civil unrest, ecomigration, genocide, and war. But even if developed countries do not experience sufficient economic and social stress to induce war (civil or international), civil unrest and ecomigration within them will likely lead to increases in violent crime. Furthermore, increased poverty, civil dissolution, and wars in developing countries influence developed countries. In some cases, such influence derives from the global economy and the need for resources. In other cases, differences between the have and have-not cultures are breeding grounds for international terrorist groups.

What actions could reduce the likelihood of climate change induced violence? There is some limited evidence that the heat/aggression effect on individuals can be reduced by simply making people aware that when they are uncomfortably hot they tend to react to minor provocations in inappropriately hostile ways. However, given the immediacy and subtlety of the heat effect on irritability, hostile perception biases, and aggression, it is doubtful that such an educational intervention will have a large impact.

On the other hand, the other two ways in which global warming increases human violence appear to be good candidates for intervention. If governments began preparing now to feed, shelter, educate, and move at-risk populations to regions in which they can maintain their livelihoods and their cultures, we could dramatically reduce both the development of violence prone individuals and the civil unrest, ecomigration, and war problems. This will cost world governments huge amounts of money, and will require more international cooperation than our planet has ever seen. Failure to do so will result in additional disasters for millions of people.

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