Neighborhood Social Processes and Disaster-Related Mortality: The Case of the 1995 Chicago Heat Wave*

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We draw on recent ethnographic work and developments in neighborhood theory to generate hypotheses regarding differential vulnerability to mortality across neighborhoods during the July, 1995 Chicago heat wave. Using 1990 Census data, Illinois Department of Public Health mortality data, and the Project on Human Development in Chicago Neighborhoods Community Survey, we employ three-level poisson models of neighborhood mortality counts to estimate and model excess 1995 death rates across neighborhoods during the heat wave. Independent of the age, race, and sex composition of Chicago neighborhoods, we find that concentrated economic disadvantage was positively associated with excess heat wave death. Neighborhood social disorder was also positively associated with excess death rates and explained 58% of the concentrated disadvantage effect.

Disaster makes visible the social distribution of vulnerability. Events during the summer of 2003 in Europe suggest that this statement may be especially true of the lethal meteorological events known as heat waves. Estimates indicate over 14,000 Europeans died during the roughly two week period of unusually high temperatures in August, 2003, with evidence suggesting that the victims were largely elderly (Hemon and Jougla 2003). The United States experienced its own heat-related disaster during the mid-1990s. Affecting a swath of the upper Midwest, the July 1995 heat wave produced its most severe consequences in Chicago, where up to 739 residents died due to sustained high temperatures over a several day period (Whitman, Good, Donoghue, Benbow, Shou, and Mou 1997).

Although the heat wave deaths were ostensibly weather-related, Eric Klinenberg's (2002) "social autopsy" of the Chicago disaster suggests that the consequences of the heat wave cannot be considered exclusively "natural" and must be understood in the context of socially produced conditions of vulnerability that place some at far greater risk of harm than others. Indeed, the victims of Chicago's heat wave were primarily older, disproportionately poor and African American, and often isolated (Semenza, Rubin, Falter, Selanikio, Flanders, Howe, and Wilhelm 1996). Beyond individual characteristics, however, disadvantaged *neighborhoods* exhibited considerably higher rates of heat-related death, suggesting that an additional layer of ecological vulnerability contributed to the scope of the disaster. To date, however, no quantitative study has explicitly linked features of neighborhood social context to differences in the rates at which older Chicagoans died during the 1995 heat wave.

We combine neighborhood-based data on mortality rates with census data on the structural characteristics of Chicago neighborhoods and data from the 1995 Project on Human Development in Chicago Neighborhoods Community Survey to examine various hypotheses about the social etiology of differential heat wave vulnerability at the community level. Specifically, we use multilevel poisson models to (1) estimate the excess death rate[1] for older adults (ages 60 and older) during the July, 1995 heat wave, (2) test the hypothesis that excess death rates varied significantly across Chicago neighborhoods, (3) explore the extent to which structural characteristics of neighborhoods (including concentrated poverty, residential instability, population density, and the proportion of the older population who live alone) explain variation in neighborhood level excess death, and (4) examine whether neighborhood level social processes (including social network interaction and exchange, collective efficacy, and social and physical disorder) independently explain excess death variation and account for neighborhood structural effects on this outcome.

Background

THE 1995 CHICAGO HEAT WAVE

The 1995 Chicago heat wave brought several consecutive days of excessive heat, with temperatures reaching well over 100 degrees Fahrenheit (City of Chicago 1995). On Thursday, July 13, the second day of the heat wave, the temperature peaked at 106 degrees with a heat index of 126. These conditions led to widespread heat-related injury and hospitalization and a rapidly increasing mortality rate. Seventy-four and 82 people,

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[1] Excess death can be understood as mortality exceeding the expected level. Our method of estimating excess deaths during the heat wave is described in detail in the Analytic Strategy section.

respectively, died on July 12 and 13, deviating only modestly from the July average of 72 deaths per day. On July 14, however, three days into the heat wave, the per-day death count rose to an alarming 188 deaths and reached 365 by Saturday. Excessive death rates continued through the following week, resulting in an unprecedented number of heat-related mortalities and a disaster of rarely seen dimensions. As the consequences of the disaster became apparent over the ensuing days and weeks, questions arose as to why the death toll resulting from the heat wave was so extreme. City representatives initially denied the extent of the disaster and subsequently attributed the increased death to residents who were already on the verge of death prior to the heat wave and would have likely expired soon after July, 1995 even in the absence of unusually high temperatures.

Emerging evidence, however, suggests that the heat-related mortality was both "real" (i.e., not an acceleration of imminent mortality)[2] and disproportionately affected the most socially vulnerable segments of the population, including older, poor, socially isolated, and African American residents (Semenza, et al. 1996). Moreover, preliminary evidence suggests that the distribution of heat-related mortality was disproportionately concentrated in the most economically disadvantaged (largely African American) Chicago *neighborhoods*. Although age, race, socioeconomic resources, and social isolation clearly contributed to the individual level capacity to cope with the excessive heat, neighborhood level poverty and other forms of structural disadvantage are associated with a range of collective social dynamics that may have independently contributed to excess mortality during the heat wave. Below, we consider a range of

[2] The notion that the heat wave mortality constituted "death displacement" would have been confirmed by evidence that mortality rates for months subsequent to July, 1995 declined by comparison with the average rate. This hypothesis was debunked by a 1997 Illinois Department of Public Health study that found no evidence that mortality rates were stable when averaged over a longer period.

neighborhood characteristics as potential explanations for why some spatially defined populations were more vulnerable during the heat wave crisis than others.

Heat Wave Mortality and the Social Ecology of Vulnerability

We draw on theories of neighborhood social organization and Klinenberg's (2002) account of the Chicago heat wave to develop a number of hypotheses regarding the social ecological underpinnings of the heat wave disaster. Specifically, we focus on recent developments in theoretical approaches to urban disadvantage, including the work of Sampson and colleagues (Sampson, Raudenbush, and Earls 1997) on the role of community level social organization in facilitating beneficial action at the neighborhood level and Skogan's (1990) emphasis on the role of social and physical disorder in shaping urban dynamics.

Rooted in a long tradition of research on urban life (Shaw and McKay 1969; Kornhauser 1978), Sampson, et al. (1997) link key aspects of urban neighborhood structure, including concentrated poverty and residential instability, with variability in dimensions of social organization relevant to neighborhood outcomes. Of central theoretical interest is the concentration of economic disadvantage within contemporary urban neighborhoods. The emergence of stark socioeconomic inequalities at the neighborhood level (Wilson 1987; 1996) and associated patterns of racial segregation (Massey and Denton 1993) during the past few decades have called attention to the consequences of resource-poor *environments* for the well-being of urban residents (Jencks and Mayer 1990). Clearly, the availability of individual level socioeconomic resources will have implications for the ability of older residents to protect themselves from the consequences of intense heat, primarily through access to quality healthcare, air conditioning, and related amenities. Above and beyond individual factors, however, widespread macro level poverty and unemployment substantially limit the availability of neighborhood economic and social resources with which to sustain key institutions, including local voluntary organizations, churches, social services, and more informal neighbor networks (Wilson 1987; 1996). These and related institutions serve as important sources of *social capital* relevant for the well-being of local residents.[3]

The research literature on the detrimental consequences of neighborhood poverty offers strong evidence of a link between economic deprivation and mortality (Anderson, Sorlie, Backlund, Johnson, and Kaplan 1997; Cubbin and LeClere 2000; Haan, Kaplan, and Camacho 1987; LeClere, Rodgers, and Peters 1997; Lochner, Kawachi, Brennan, and Buka 2003; Waitzman and Smith 1998; Yen and Kaplan 1999). Lochner and colleagues (2003), for instance, found powerful effects of a measure of neighborhood material deprivation on 1994-96 mortality rates for four race-sex groupings (African American and white men and women) of Chicago residents ages 45-64. These findings suggest that economic disadvantage may also contribute to differential *excess* mortality due to exogenous disasters.

A second structural emphasis—and a potential outcome of economic disadvantage—is the level of instability in residential tenure. Rapid turnover in local

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[3] *Social capital* may be defined as "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition—or in other words, to membership in a group" (Bourdieu 1983: 249). Coleman has defined social capital as "those aspects of social structure...that can be used by the actors to realize their interests" (Coleman 1990: 305). These definitions of social capital encapsulate a range of social resources potentially relevant for protection from disaster-related vulnerability among older adults. The two social organizational perspectives we describe below (the network and collective efficacy approaches) emphasize aspects of social capital overlapping with Portes and Sensenbrenner's (1998) discussion of 1) *network-mediated exchanges* and 2) *enforceable trust* and *bounded solidarity.*

populations and diminished rates of homeownership inhibit the emergence of viable social networks and weaken sentiments of attachment to local communities (Kasarda and Janowitz 1974). The consequences of economic disadvantage and residential instability—weak local institutions, sparse or fragmented informal networks and attenuated neighborhood attachments—diminish the capacity of communities to come together to achieve common goals, including the informal social support of neighborhood elderly. Structural disadvantage also leads to the accumulation of social and physical signs of neighborhood deterioration with potentially independent consequences for the behavior of local residents (Skogan 1990). The relevance of these social outcomes of disadvantage for the distribution of heat wave mortality is discussed in more detail below.

Additional structural factors that may have contributed to neighborhood level variation in heat-related death rates include the density of population and the proportion of older adults living alone. Klinenberg (2002) highlights population density as potentially important in contributing to ecological dynamics that may benefit older adults, including higher concentrations of local residents in public spaces such as streets, commercial venues, and parks. In an ethnographic account of the dramatic difference in excess heat-related death rates in North Lawndale (a primarily African American community in West Chicago) and South Lawndale (or "Little Village," a primarily Latino community just to the south of North Lawndale), Klinenberg emphasizes the population density of Little Village as a possible explanation for its considerable advantage with respect to heat-related mortality. Klinenberg describes the streets of Little Village as teeming with traffic and commercial activity, potentially contributing to older residents confidence that the many "eyes on the street" would protect them from victimization outside of the security of their homes. Indeed, contrary to the classic accounts of the downside of population density (Wirth 1938), recent research has found protective effects of density. Morenoff, Sampson, and Raudenbush (2001), for instance, found a negative effect of population density on homicide rates, consistent with the expectation that concentrated populations may be more effective at monitoring neighborhood space.

Another important structural factor potentially relevant to heat wave-related mortality is the proportion of older adults who live alone. A high proportion of urban elderly reside alone, potentially complicating access to social support networks, information, and health care and exacerbating fears of victimization and associated neighborhood withdrawal. Although many older adults who live alone are likely to be more mobile and healthier than their institutionalized counterparts, the isolating effects of living alone may have severe health consequences in the context of rapid onset crises such as the heat wave. Thus neighborhoods in which a higher proportion of older adults live alone are likely to have experienced greater excess mortality during the 1995 heat wave.

Thus structural disadvantages, including neighborhood concentrated poverty and residential instability (and, potentially, low population density and the proportion of older adults who live alone), are likely to influence a number of *community-level social mechanisms* that may have been consequential for older adult well-being during the heat wave, to which we now turn.

NEIGHBORHOOD SOCIAL ORGANIZATION, DISORDER, AND HEAT WAVE MORTALITY

Klinenberg's ethnographic account of the mechanisms explaining differential neighborhood level ability to avoid heat-related death intersects nicely with existing social organizational approaches to community self-regulatory capacity. We consider three key neighborhood social processes emphasized in recent neighborhood theory. These include the prevalence of social exchange and support networks; the level of social cohesion and informal social control capacity, or collective efficacy; and the extent of social and physical disorder.

First, the increasingly vast literature on the role of informal social supports in promoting health has fostered interest in the effects of community level social network characteristics on health. Structurally disadvantaged neighborhoods may be less capable of sustaining viable social networks and may suffer from deficits in local social interaction and support (Berkman and Breslow 1983). Berkman and colleagues (Berkman and Glass 2000), for instance, suggest that networks at the community level influence egocentric connectedness and health-enhancing processes such as social support (House 1981), positive influence, and sociability (Berkman, Glass, Brissette, and Seeman 2000; Rook 1990). Evidence of the positive effects of social support on health is overwhelming and consistent (Berkman and Syme 1979; House, Robbins, and Metzner 1982; Orth-Gomer and Johnson 1987), suggesting that the prevalence of social support activity and social engagement at the neighborhood level may also be relevant for health outcomes.

Research on aging suggests that the health benefits of social support are particularly relevant for older adults (Seeman, Kaplan, Knudson, Cohen, and Guralnick

1987). Among elderly residents who live alone, the neighborhood context of network support may have important implications for the availability of health-enhancing and health-protective social capital (Thompson and Krause 1998). In the context of the heat wave, the extent of network interconnectedness at the neighborhood level may have had important implications for elderly residents. More extensive social ties, including nonkin exchange networks and kinship-based affiliations, may have benefited elderly urban residents during the heat wave by providing a set of interested actors capable of intervening on behalf of a potentially vulnerable older adult. Communities that provided ecological settings in which older adults could form network ties were likely better able to buffer the lethal effects of prolonged periods of high temperature (Cannuscio, Block, and Kawachi 2003).

A second perspective highlights the capacity for action on behalf of community goals as the critical intervening mechanism linking community structure with health. Sampson and colleagues (Sampson et. al 1997) have encapsulated this process in the concept of collective efficacy, which emphasizes mutual trust and solidarity (social cohesion) and shared expectations for pro-social action (informal social control) in theorizing the impact of neighborhood social organization on local residents' well-being. Sampson, Morenoff, and Earls (1999) link the concept of collective efficacy to Portes and Sensenbrenner's (1998) definition of social capital as "expectations for action within a collectivity." While acknowledging that local social ties may contribute to this dimension of community social organization, the collective efficacy approach must be seen as distinct from the neighborhood social support and sociability perspective to the extent that it emphasizes the sense of attachment to community and the perceived willingness of community residents to intervene on each others' behalf, regardless of pre-existing social ties.

The pathways through which neighborhood collective efficacy may have influenced heat-related mortality include the social control of conditions that threaten health, access to services and amenities, and psychosocial processes (Browning and Cagney 2002; Kawachi and Berkman 2000). First, communities with high levels of collective efficacy may be more oriented toward the well-being of neighborhood residents in general. Normative orientations that encourage mutual support (as opposed to the reciprocal obligations produced through direct ties) may benefit older residents during times of crisis, as neighbors are more likely to feel a sense of obligation to monitor and intervene on their behalf. Second, collective efficacy may enhance the capacity of communities to attract and to maintain high quality health services and amenities such as community health clinics and safe recreational space. Third, widespread trust and neighborhood attachment may produce a sense of confidence among elderly residents that venturing out into the neighborhood for help during hot spells, a breezy park space, or an air conditioned local commercial venue is prudent—even if they do not benefit from direct network support (Kawachi and Berkman 2000).

Few studies have examined the association between either networks or dimensions of social capital related to collective efficacy and mortality rates at the neighborhood level. However, Lochner, Kawachi, Brennan, and Buka (2003) found that social capital as measured by social trust, reciprocity, and civic participation negatively predicted mortality rates among Chicago adults ages 45-64. Though potentially consistent with both network and collective efficacy hypotheses, this finding points to the potential role of social organizational aspects of communities in limiting mortality—processes that may also be relevant in managing the consequences of heat-related disasters.

Third, building on insights from the criminological literature on the effects of social and physical disorder, an additional perspective argues that visible signs of community decay and social decline contribute to fear of victimization and social withdrawal (Skogan 1990). Abandoned and boarded-up buildings, vacant lots, graffiti, and other physical signs of deterioration combine with indicators of social decline such as public drinking, gang activity, and crime to convey the breakdown of social order and control. In this context, fear of victimization encourages older residents to avoid neighborhood life, and seals them off from contact with potential neighborhood sources of aid in times of crisis. Krause and colleagues (Krause 1993; Thompson and Krause 1998), for instance, found that neighborhood deterioration, as measured by the condition of neighborhood buildings, roads, and the respondent's perceived level of safety from crime in the neighborhood was positively associated with distrust and social isolation and negatively associated with physical health among older adults. Indeed, some elderly urban residents may experience such intense fear of victimization that they live in a state of "self-imposed house arrest" (Dowd, Sisson, and Kern 1981).

Klinenberg emphasizes neighborhood disorder in his discussion of socially isolated older adults and their tendency to be more concerned with security than immediate physical comfort. Neighborhoods characterized by high levels of disorder may have discouraged older residents from venturing out of their homes and apartments to seek help during the heat wave. Although low levels of community trust (a component of collective efficacy) may have a similar impact, visible social and physical cues indicating neighborhood deterioration may be particularly relevant for elderly and less mobile residents, many of whom do not have access to other sources of local engagement and information that could convey a sense of trust. Indeed, neighborhood disorder may influence fears of victimization among the elderly more directly than the actual level of victimization—a less immediately visible phenomenon.

The three dimensions of social (dis)organization we describe are likely to be interrelated. Nevertheless, they capture distinct social processes and may independently contribute to the explanation of heightened levels of heat-related death found in more structurally disadvantaged Chicago neighborhoods.

Data

Three data sources are used to explore the association between neighborhood context and health—the 1990 Decennial Census, the 1994-95 Project on Human Development in Chicago Neighborhoods-Community Survey (PHDCN-CS), and 1990-1996 Illinois Department of Public Health Vital Statistics data on mortality in Chicago. Measures of neighborhood structural disadvantage are taken from census data. Measures of neighborhood social processes are constructed from the PHDCN-CS. The PHDCN-CS is a probability sample of 8,782 residents of Chicago (age 18 and older) focusing on respondent assessments of the communities in which they live. The PHDCN-CS combined 865 census tracts into 343 "neighborhood clusters" (NCs) that maintained relative population homogeneity with respect to racial/ethnic, socioeconomic, housing, and family structure characteristics (NCs average roughly 8,000 people).[4] The three-stage sampling strategy selected city blocks within NCs, dwelling units within blocks, and respondents (one adult, age 18 or over, per household) within dwelling units. The PHDCN-CS sampling strategy was intended to capture a within-cluster sample sufficient to estimate neighborhood characteristics based on aggregated individual level data, ensuring the reliability of neighborhood level measures of social processes. The response rate for the PHDCN-CS was 75%. Finally, Illinois Department of Public Health mortality data are used to construct excess death rates for Chicago NCs during July, 1995.

Measures

The outcome for the analysis is the rate of excess death for the period of the heat wave (July 14 through 20, 1995). Excess death is estimated using a method described below for the total population age 60 and over.

Our analyses investigate the impact of neighborhood structural factors and social processes in the context of models that control for a number of within-neighborhood demographic characteristics. Specifically, we hypothesize that broader social environments will influence excess death rates across neighborhoods above and beyond the compositional effects of age, race, and sex. We adjusted for age by breaking the older population into three groups: 60 to 69, 70 to 79, and 80 and older. Race is a

[4] Respondents were given the following definition of "neighborhood:" "By neighborhood . . . we mean the area around where you live and around your house. It *may* include places you shop, religious or public institutions, or a local business district. It is the general area around your house where you might perform routine tasks, such as shopping, going to the park, or visiting with neighbors."

dummy variable capturing non-Latino whites and African Americans. Latino excess death rates were quite low during the heat wave and were omitted from the analysis.[5]

A number of neighborhood based structural characteristics are included in the analyses. A factor analysis of 8 variables tapping various aspects of structural disadvantage revealed two key dimensions.[6] The first factor—*concentrated disadvantage*—was dominated by high factor loadings for poverty (percent below the poverty line), receipt of public assistance, unemployment, female-headed households, percent under age 18 (concentration of children), and percent African American. Factor loadings exceeded .85 for all measures of disadvantage (the factor loading for percent African American was .60)[7] (Sampson et al. 1997). A second factor—*residential stability*—exhibited high loadings for measures of continuity of residence (percent living in the same house since at least 1985) and the percent of housing occupied by owners (factor loadings exceeded .75). It should be noted that the measure of residential stability also taps wealth through inclusion of the proportion of residents who own homes. Thus, the community level consequences of residential stability are likely to be combined with the implications of aggregated individual level wealth for the capacity of older residents to protect themselves from lethal heat. Both factor scores are standardized. *Population*

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[5] The dramatically different vulnerability of Latino residents constitutes additional evidence of "the Latino Paradox"—i.e., the relative health advantage of Latino immigrant populations (particularly, more recent immigrants) by comparison with equally economically disadvantaged African American and *more* advantaged white populations (Palloni and Morenoff 2001).

[6] The analysis employed alpha-scoring factor analysis with an oblique rotation. Scores from principal components analyses yielded the same pattern of effects in multivariate analyses of 1995 excess mortality.

[7] Ideally, the racial composition of the neighborhood clusters would be considered independently of concentrated disadvantage. Unfortunately, the extremely high correlation between these conceptually distinct dimensions renders investigation of their unique effects statistically problematic. Nevertheless, we included the percent African American and in models of excess 1995 mortality with measures of economic disadvantage included separately. We found no evidence of association between the percent African American and excess mortality while measures of economic disadvantage achieved significance. Taking into account the coincidence of economic and racial segregation in Chicago, we combine racial and economic composition measures in a single index in the analyses below.

density is the natural logarithm of the NC population per square mile divided by 10,000 (mean = .745; standard deviation = .437). We also include a measure of the percentage of residents 60 or over who live alone (mean = 27.977; standard deviation = 11.180).

Collective efficacy was operationalized through combining measures of social cohesion and informal social control. Social cohesion was constructed from a cluster of conceptually related items from the PHDCN-CS measuring the respondent's level of agreement (on a five-point scale) with the following statements: (1) "People around here are willing to help their neighbors," (2) " This is a close-knit neighborhood," (3) "People in this neighborhood can be trusted," and (4) "People in this neighborhood generally don't get along with each other" (reverse coded). Health-related informal social control was tapped through items measuring the respondent's level of agreement with the following: (1) "If I were sick I could count on my neighbors to shop for groceries for me" and (2) "You can count on adults in this neighborhood to watch out that children are safe and don't get in trouble." An additional informal control item asked respondents (3) "If there was a fight in front of your house and someone was being beaten or threatened, how likely is it that your neighbors would break it up?" Responses were given on a five point scale. The informal control items tap expectations for action with respect to health related social support as well as neighborhood supervision of potentially hazardous conditions or violent situations. The seven items were combined to form a single scale of health-related collective efficacy. The reliability of the collective efficacy scale is .73.[8]

[8] Distinct from individual level reliability (e.g, Cronbach's alpha), the reliability of neighborhood level scale scores is dependent upon both the sample size within the neighborhood as well as the proportion of the total variance that is between (vs. within) neighborhoods. The reliability estimates of neighborhood scales are comparable to reliabilities reported in other recent neighborhood research (see Sampson et al. 1999).

The *social network support/reciprocated exchange* scale encompassed a number of items measuring respondent's assessments of the frequency of parties, visits, advice giving, and favor exchange among neighbors. The scale was constructed from questions asking respondents (1) "How often do you and people in this neighborhood have parties or other get-togethers where other people in the neighborhood are invited?," (2) "How often do you and other people in this neighborhood visit in each other's homes or on the street?," (3) "How often do you and other people in the neighborhood ask each other advice about personal things such as child rearing or job openings?," and (4) "How often do you and people in your neighborhood do favors for each other?" These items are intended to tap aspects of community level instrumental, informational, and appraisal support as well as the level of sociability characterizing the neighborhood (House, Landis, and Umberson 1988). The reliability of the social network support /reciprocated exchange scale is .61.

The level of *disorder* in the neighborhood was measured with six items inquiring into respondent assessments of the extent to which litter, graffiti, vacant areas, drinking in public, people selling/using drugs, and groups causing trouble are "A big problem," "Somewhat of a problem," or "Not a problem." The reliability of the disorder scale is .87. The collective efficacy, network, and disorder scales are standardized in the analyses presented below.

The aggregation procedure for neighborhood survey-based measures of collective efficacy, network density/reciprocated exchange, and disorder extracts the empirical Bayes residual from three-level item response models of the component items for each scale (see Raudenbush and Sampson (1999)). Following Sampson et al., (1997), at level one, a linear item-response model adjusts individual level latent scale scores for missing data, taking into account the "difficulty level" of items for which a response was provided. At level two, neighborhood latent scores (intercepts in between-individual models) are adjusted for the social composition of Chicago neighborhoods through inclusion of controls for gender, age, race/ethnicity (African American, Latino vs. White), education, employment status (employed vs. not employed), marital status (never married, separated or divorced vs. married), home ownership, years resident in the neighborhood, and number of moves in the last five years. At level three, adjusted neighborhood intercepts vary randomly around the neighborhood grand mean. The empirical Bayes residual from the level three model constitutes the adjusted neighborhood score to be employed as an independent variable in subsequent analyses of excess mortality. Correlations among neighborhood level independent variables are reported in the Appendix.

Analytic Strategy

Despite the dramatic increase in mortality during the 1995 heat wave, death nevertheless remained a rare event among older Chicagoans. We view the mortality count for the 60 and older population within each NC as sampled from an overdispersed Poisson distribution. Thus, we employ a hierarchical generalized linear model (HGLM) with a log link function to arrive at an estimate of excess death for the relevant heat wave period and to model variation in excess death based on measures of neighborhood structure and social organization. An advantage of the HGLM is the ability to assign each NC a unique "exposure," represented by the number of individuals who reside in the neighborhood within the relevant subgroup (based on age, race, and sex) (Lochner, Kawachi, Brennan, and Buka 2003; Raudenbush and Bryk 2002). The three level HGLM takes the following form:

Level 1 model:

$$ln\left(Y_{itj}\right) = \pi_{0tj} + \pi_{1}\left(AGE\right)_{tj} + \pi_{2}\left(RACE\right)_{tj} + \pi_{3}\left(SEX\right)_{tj} + \pi_{4}\left(AGE * SEX\right)_{tj} + \pi_{5}\left(AGE * RACE\right)_{tj}$$

Level 2 model:

$$\pi_{0tj} = \beta_{0j} + \beta_{1}(Year90-96)_{j} + \beta_{2}(Year95)_{j} + u_{tj}$$

Level 3 model:

$$\beta_{0j} = \sum_{q=1}^{Q} \gamma_{0q} Z_{q} + \delta_{0j}$$

$$\beta_{1j} = \sum_{q=1}^{Q} \gamma_{1q} Z_{q} + \delta_{1j}$$

$$\beta_{2j} = \sum_{q=1}^{Q} \gamma_{2q} Z_{q} + \delta_{2j}$$

Where Y_{itj} is the count of deaths for subgroup i at time period t (the one week July period relevant for the heat wave measured each year from 1990 to 1996) in neighborhood j, π_0 is the intercept, π_1-π_5 represent the within-neighborhood coefficients for age, race, sex and additional significant interactions. At level 2, π_0 is modeled as a function of an intercept β_{0j}, a linear time trend for 1991- 96 β_{1j}, a dummy variable capturing any increase in the mortality rate during the 1995 period β_{2j}, and an error term u_{tj}. At level 3, the β's are allowed to vary randomly and modeled as a function of Q neighborhood structural and social organizational predictors, along with error terms $\delta_{0\text{-}2}$. Since we are interested in explaining variation in excess death for 1995, we focus on the model for β_{2j} in the results presented below.

Results

We begin by examining models for the total population age 60 and older conditional on within neighborhood social compositional characteristics at level one and year variables at level two. By estimating both an intercept and a linear effect of time for the 1990-96 period, we capture both the baseline mortality rates and any overall time trend, allowing for a more precise estimate of excess death in 1995 (e.g., over a simple comparison of the 1995 rate to an average rate for the previous period).

Model 1 of Table 1 demonstrates the powerful effects of social composition on mortality rates. Age, African American race, and male sex increase the log mortality rate substantially, consistent with previous research. Moreover, as age increases, the increased vulnerability of Blacks declines, by comparison with whites, as does the relative advantage of women over men (the interaction between sex and race was not significant). At level two, the effect of the linear time trend from 1990-1996 was negative but did not achieve significance at the conventional level ($p < .10$), suggesting only modest evidence of a decline in the mortality rate across the early 90's. Of interest is the substantial increase in the log mortality rate captured by the dummy variable for July 14-20, 1995. The mortality rate increases by nearly 300% during the 1995 period.

The coefficients from Model 1 are based on a model with both the intercept estimate of baseline adjusted neighborhood mortality rates (β_{0j}) and the dummy variable estimating 1995 excess death (β_{2j}) allowed to vary randomly. Because random effects for the intercept and linear trend in mortality rates were highly collinear and we found less evidence of significant variation in linear time trends, we choose to fix β_{1j}.[9] We did, however, find consistent evidence of significant variation in 1995 excess death rates (β_{2j}) across neighborhoods (variance component from Model 1 of Table 1 = .177; $p < .001$) even after controls for within neighborhood age, race, and sex composition. Evidence of significant variation in neighborhood excess death rates offers further quantitative confirmation of the claim that neighborhoods differed in vulnerability to heat wave death.

Models 2 and 3 add all measures of neighborhood structure and social process to the equation for the intercept (β_{0j}) and add measures of neighborhood structure to the equation for excess death rates (β_{2j}) (only the latter are reported). Model 2 indicates that concentrated disadvantage is powerfully associated with excess death. A one standard deviation increase in the disadvantage scale leads to a .25 increase in the excess log mortality rate. Model 3 includes additional measures of neighborhood structure. None achieve significance and lead to only modest reductions in the significant effect of concentrated disadvantage.

Table 2 reports the results of models including additional neighborhood characteristics tapping key social processes. Model 1 adds a measure of social network

[9] No structural or social process characteristics were added as nonrandomly varying predictors of linear time trends in the models reported. We did run separate analyses to check whether the effects of concentrated disadvantage and disorder on the coefficient for 1995 excess death were robust to the inclusion of neighborhood structural and social process predictors in equations for both the intercept *and* linear time trend. Both disadvantage and disorder effects (as well as the mediating effects of disorder) on 1995 excess death rates remained in these more fully specified models.

support/reciprocated exchange, the coefficient for which is in the expected negative direction but is not significant. The coefficient for concentrated disadvantage is only marginally reduced and remains highly significant, suggesting that social network support/reciprocated exchange was not an important protective mechanism during the heat wave. Model 2 considers the effect of collective efficacy in the absence of other social process measures. Again, the coefficient is negative but does not achieve significance, only nominally reducing the magnitude of the concentrated disadvantage effect over Model 3 of Table 1.

Model 3 of Table 2 adds our measure of neighborhood social disorder in the absence of social network support/reciprocated exchange and collective efficacy measures. In contrast to the effects of networks and collective efficacy, social disorder is a significant positive predictor of excess mortality, as hypothesized. A one standard deviation increase in the disorder scale leads to a .18 increase in the 1995 excess log mortality rate. Moreover, the effect of concentrated disadvantage is reduced by 58% and rendered insignificant at the conventional level.

Model 4 adds measures of networks and collective efficacy to Model 3 to assess the robustness of the disorder effect in the context of this fully specified model. The effect of disorder in Model 4 actually increases modestly and remains significant ($p < .05$), despite the relatively high correlation among independent variables.[10]

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[10] Klinenberg emphasizes the possibility that variation in municipal service delivery impacted differential neighborhood heat-related mortality. Focusing attention on the delivery of services by police in particular, Klinenberg highlights the degree to which community-oriented policing may have been protective for some neighborhoods. We included a police satisfaction measure in Model 3 of Table 1 and Model 4 of Table 2 in order to assess the independent and mediating effect of this process. The police satisfaction measure was based on the level of agreement with five statements: (1) "The police in this neighborhood are responsive to local issues," (2) "The police are doing a good job in dealing with problems that really concern people in this neighborhood," (3) "The police are not doing a good job in preventing crime in this neighborhood," (4) "The police do a good job in responding to people in the neighborhood after they have

Finally, because Chicago neighborhoods are contiguous, we examined the robustness of the concentrated disadvantage and disorder effects to controls for spatial autocorrelation. We ran an OLS regression of the empirical Bayes residuals extracted from the unconditional model of excess 1995 mortality rates on independent variables from Model 4 of Table 2. Although robust Lagrange multiplier tests for the spatial lag and spatial error models offered little evidence of autocorrelation ($p > .10$), we nevertheless ran both spatial regression models on the empirical Bayes residuals. The significance of concentrated disadvantage and disorder effects (and the mediation of disadvantage by disorder) remained in both models, suggesting little indication of bias or overprecision in their coefficient estimates due to spatial clustering of neighborhoods (analyses available upon request).

Discussion

The July 1995 heat wave was a catastrophic event the aftermath of which brought widespread concern about the causes of the massive death toll, particularly among the elderly. Indeed, the July 14-20 event exposed the differential vulnerability of both particular *individuals*—older, African American, and male residents (who are also more vulnerable to mortality during noncrisis periods)—as well as *collectivities*—specifically, economically and socially disadvantaged neighborhoods. Indeed, our analyses offer quantitative confirmation of the claim that neighborhoods varied in their vulnerability to heat wave related mortality, above and beyond their age, race, and sex composition.

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been victims of a crime," and (5) "The police are not able to maintain order on the streets and sidewalks in the neighborhood." Satisfaction with police did not achieve significance in either model and had minimal impact on the coefficients for concentrated disadvantage and social disorder.

Based on Klinenberg's (2002) ethnographic account and recent theoretical developments in neighborhood research (Sampson et al. 1997), we offer a number of hypotheses regarding structural and social sources of neighborhood level vulnerability to heat wave death. Concentrated disadvantage, residential instability, population density, and the proportion living alone were key structural factors hypothesized to increase the exposure of neighborhoods to excess death during the heat wave. Of these factors, however, only concentrated disadvantage contributed significantly to differential neighborhood level excess death. The effect of concentrated disadvantage was powerful and only marginally affected by the inclusion of other potentially relevant structural factors.

The effect of disadvantage, however, calls for a more detailed investigation of the possible mechanisms linking neighborhood level economic deficits with heat wave mortality. Accordingly, we next investigated various neighborhood social process-based explanations for the robust economic disadvantage effects on excess heat-related mortality rates across Chicago neighborhoods. Three key processes were considered: Network interaction and reciprocated exchange, collective efficacy, and social and physical disorder. Each neighborhood level social process has been considered in extant neighborhood research as a potential source of health-related benefit (or detriment). Neither network density nor collective efficacy predicted excess death, however, suggesting that neighborhood social ties and shared expectations regarding informal social control and the promotion of neighborhood well-being were not protective during the heat wave. In contrast, the level of perceived social and physical disorder was positively associated with excess death and largely explained the powerful economic disadvantage effect on heat-related mortality.

Social and physical cues of neighborhood deterioration may operate in the short term during heat-related crises to encourage older residents to remain in their homes. Fear of venturing outside to cooler parks and air-conditioned commercial venues may have contributed to the higher likelihood of death in some communities. Collective efficacy and neighborhood social support networks may not have effectively reduced mortality during the heat wave due to the speed with which the unusually high temperatures took their toll. Communities must have information about local crises and threats in order to reduce neighborhood residents' vulnerability. Yet, a substantial proportion of the heat-related deaths occurred within two to three days of the temperature increase, potentially before community social resources could be mobilized. Perceptions of neighborhood disorder, on the other hand, can operate to discourage neighborhood-based help-seeking among older residents as soon as they encounter a weather-related threat. Thus neighborhood social resources may exert protective effects only after collective recognition of a crisis has occurred—an important question for future research.

Disorder, then, constitutes an important dimension of neighborhood well-being in the context of rapid-onset crises such as the 1995 heat wave. In contrast, other research has demonstrated that disorder or "incivilities" may not function as hypothesized in well-known theoretical approaches to differential crime rates across neighborhoods (Skogan 1990). For instance, the notion that social and physical deterioration cue the breakdown of neighborhood social order and encourage criminal activity has not received support in rigorous investigations of the causal role of disorder (Sampson and Raudenbush 1999).

Disorder, however, may be more relevant for neighborhood residents who do not have access to other sources of information about neighborhood functioning and self-regulatory capacity. Older residents who experience limited mobility are constrained in their capacity to accumulate network-based information on the condition of neighborhoods, some of which may take precedence over information provided by social and physical deterioration. As sources of information constrict with age, visible cues regarding neighborhood functioning—available with a simple glance out the window—may acquire priority in the process of assessing victimization threat.

Although our analyses did consider neighborhood satisfaction with police as a potentially relevant measure of municipal service delivery, other service-related factors including spatially organized access to health care due to the concentration of hospitals on "bypass" (or closed) during the heat wave also may have contributed to differential neighborhood vulnerability. A subsequent heat wave in July of 1999 resulted in significantly fewer heat-related deaths (114) despite comparable conditions with respect to nocturnal temperatures and humidity (Palecki, Changnon, and Kunkel 2001). The substantially different heat-related mortality rates during the two heat waves suggests that the City of Chicago more effectively responded to the latter crisis, while allowing the conditions of vulnerability characterizing some urban neighborhoods to take their toll during the 1995 disaster. Our analyses assume that, while municipal services did affect heat-related mortality rates, the impact of municipal neglect on *differential* neighborhood vulnerability was likely minimal. This conclusion, however, awaits the collection and analysis of more detailed data on municipal service delivery during the heat wave.

Finally, we acknowledge that the neighborhood level factors we consider may be confounded with unmeasured individual level characteristics with which heat-related mortality was potentially associated. Although we control for the age, race, and sex composition of Chicago neighborhoods as well as neighborhood level economic disadvantage and the proportion living alone, we could not assess the independent contribution of economic resources or living alone at the individual level. We emphasize, however, that the measures of social process we employ are purged of their association with individual level socioeconomic, marital, and cohabiting status.

The eclectic nature of sociological method allows for multiple forms of evidence to be brought to bear on research questions. In the current case, Klinenberg's (2002) rich ethnographic observations on spatial variation in the conditions of urban life among the elderly during the crisis offer important insight into sources of differential heat wave vulnerability across neighborhoods. Indeed, a number of hypotheses offered in his "social autopsy" are amenable to quantitative investigation—a task we have undertaken here. The fortuitous timing of the Project on Human Development in Chicago Neighborhoods Community Survey has afforded us a unique opportunity to address the hypotheses offered by Klinenberg from an alternative methodological standpoint, yielding evidence supportive of the claim that differential heat wave death was due, in part, to the level of social and physical disorder characterizing structurally disadvantaged neighborhoods in Chicago.

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Table 1. Three Level Hierarchical Generalized Linear Models of Excess 1995 Mortality [a]

Independent Variables	Model 1	Model 2	Model 3
Age	1.151 ***	1.150 ***	1.153 ***
	(.044)	(.043)	(.043)
Black	.473 **	.477 **	.486 **
	(.140)	(.139)	(.138)
Sex	1.229 ***	1.227 ***	1.228 ***
	(.117)	(.116)	(.115)
Age*Black	-.149 **	-.149 **	-.153 **
	(.057)	(.056)	(.055)
Age*Sex	-.359 ***	-.358 ***	-.358 ***
	(.050)	(.049)	(.049)
Year (1990-1996)	-.020	-.020	-.020
	(.012)	(.011)	(.011)
Excess 1995	1.091 ***	1.122 ***	1.134 ***
	(.057)	(.054)	(.053)
Concentrated disadvantage	-	.250 ***	.235 ***
		(.045)	(.045)
Residential stability	-	-	-.091
			(.075)
Log population density	-	-	.079
			(.131)
Proportion living alone	-	-	-.001
			(.005)
Intercept	-7.857 ***	-7.874 ***	-7.883 ***
	(1.069)	(1.054)	(1.058)

Note: Models include all structural and social process characteristics as predictors.
of β_{0j} (variation across neighborhoods in baseline adjusted mortality rates).

[a] Neighborhood level N=342; Year level N=2,394

* p < .05 ** p <.01 *** p < .001 (two-tailed tests). Standard errors in parantheses.

Table 2. Three Level Hierarchical Generalized Linear Models of Excess 1995 Mortality [a]

Independent Variables	Model 1	Model 2	Model 3	Model 4
Year (1990-1996)	-.020	-.020	-.020	-.020
	(.011)	(.011)	(.011)	(.011)
Excess 1995	1.133 ***	1.133 ***	1.140 ***	1.139 ***
	(.053)	(.053)	(.053)	(.053)
Concentrated disadvantage	.232 ***	.227 ***	.096	.078
	(.046)	(.050)	(.079)	(.078)
Residential stability	-.088	-.086	-.051	-.044
	(.075)	(.076)	(.076)	(.076)
Log population density	.068	.062	.002	-.004
	(.138)	(.139)	(.134)	(.140)
Proportion living alone	.000	.000	.001	.002
	(.005)	(.005)	(.005)	(.005)
Network density	-.016	-	-	-.050
	(.058)			(.069)
Collective efficacy	-	-.022	-	.056
		(.057)		(.076)
Disorder	-	-	.180 *	.216 *
			(.088)	(.096)
Intercept	-7.882 ***	-7.882 ***	-7.885 ***	-7.885 ***
	(1.058)	(1.058)	(1.059)	(1.060)

Note: Models include all structural and social process characteristics as predictors.
of β_{0j} (variation across neighborhoods in baseline adjusted mortality rates). Level one covariates also omitted.

[a] Neighborhood level N=342; Year level N=2,394

* $p < .05$ ** $p < .01$ *** $p < .001$ (two-tailed tests). Standard errors in parantheses.

Appendix. Correlations Among Neighborhood Level Variables in the Analysis

Variables	1	2	3	4	5	6
1. Concentrated disadvantage	1.000					
2. Residential stability	-.042	1.000				
3. Log population density	.115	-.541	1.000			
4. Proportion living alone	-.019	-.665	.268	1.000		
5. Network support/exchange	-.212	.167	-.291	.022	1.000	
6. Collective efficacy	-.393	.309	-.407	-.102	.612	1.000
7. Social and physical disorder	.765	-.288	.346	.053	-.235	-.582