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# Community-level impacts of temperature on urban street robbery

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ABSTRACT

*Purpose:* Conduct the *first* empirical intra-urban examination of community-level connections between street robbery and temperature. Examine whether community socioeconomic status (SES) and crime-relevant land uses strengthen or weaken the temperature impact. A theoretical framework relying on routine activity theory, crime pattern theory, and resident-based control dynamics organized predictions.
*Data and methods:* For Philadelphia census tracts (n = 381), monthly street robbery counts and temperature data for 36 consecutive months were combined with census and land use data, and analyzed with multilevel models.
*Results:* Community robbery counts were higher when temperatures were higher, and in lower SES communities. In support of previous work with property crime, but in contrast to previous work with assault, the effects of temperature were stronger in higher SES communities. In support of the integrated model, commercial land use prevalence and subway stations were associated with heightened temperature impacts on robbery.
*Conclusions:* Community-level fixed and random effects of temperature on urban robbery counts persist when controlling for land use and community structure; further, the random effects depend in part on both. There are implications for understanding indigenous guardianship or informal resident-based place management dynamics, and for planning seasonal police deployments.


"Wednesday I watched the riot / Seen the cops out on the streets / Watched 'em throwing rocks and stuff / And choking in the heat … / Watched while everybody / On his street would take a turn / To stomp and smash and bash and crash / And slash and bust and burn ("Trouble every day", Mothers of Invention, 1966).

## Introduction

Seasonality-crime research dates back well over a century (Baumer & Wright, 1996). Some have traced relevant theorizing back to ancient Greeks (Harries, Stadler, & Zdorkowski, 1984). A resurgence of scholarly interest followed the urban civil disorders in the U.S., like the 1965 Watts Riot referenced in Frank Zappa's song "Trouble every day." Not surprisingly given this past, much research has centered on violent crime, and on crime-temperature associations at the city level. Less than a handful of studies, however, consider crime-temperature links at the intra-urban or neighborhood level. Further, no studies of which these authors are aware consider the community-level crime-temperature connection specifically for street robbery.

That connection is examined here. The current work seeks to advance scholarship in this area in the following ways: by examining the temperature-robbery connection at the community level for the first time (i.e., the fixed effect of temperature); by learning whether this relationship is variable across communities (i.e., the random effect of temperature); and by exploring how that variability may depend on theoretically relevant structural and land use factors. Previous intra-urban research has generated conflicting findings on this last point.

The remaining introduction covers the following. Findings from research at the city level or higher on temperature-crime links are summarized and placed within the broader framework of crime-weather links. Three studies on intra-urban crime-temperature links are summarized, and their limitations noted. The theoretical frames applied to these connections are sketched. These include psychological, structural, and environmental criminological perspectives. The section closes by laying out an integrated model based on the latter two perspectives and on the first author's summertime observations of foot-patrolled communities and conversations with foot patrolling Philadelphia police officers.

## Earlier findings

### *City level and higher*

Weather often affects violent crime frequencies (Cohn, 1990). Meteorological conditions examined include temperature (Feldman &

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Jarmon, 1979), humidity (Cotton, 1986), seasonality (Hipp, Bauer, Curran, & Bollen, 2004) and sunshine (Cohn, 1993). On the outcome side, total violent crime (Cotton, 1986), assault (Cohn & Rotton, 1997), rape (Cohn, 1993), homicide (Cheatwood, 1995), armed street robbery (Mazerolle, McBroom, & Rombouts, 2011) and property crime (Hipp et al., 2004) all have been connected with one or more weather variables. Temperature or temperature via seasonality is the feature most widely investigated. These studies, using units like cities and larger aggregations like standard metropolitan statistical areas (SMSAs), however, do not always find robust net positive connections between temperature, or a temperature-linked variable like seasonality, and violent crime outcomes (Hipp et al., 2004). For example, Peng, Xueming, Hongyong, and Dengsheng (2011) found that in Beijing, China, although robbery was influenced by temporal variables such as holidays and days when schools were closed, it was not correlated with weather variables.

In addition to questions about what factors might underlie inconsistent results, a theoretically-relevant dispute continues about the functional form of the temperature-violence relationship. Is it curvilinear (Bell & Baron, 1976; Cohn & Rotton, 2005) or linear (Anderson & Anderson, 1984; Anderson, Anderson, Dorr, DeNeve, & Flanagan, 2000; Bushman, Wang, & Anderson, 2005)? Further, some recent research suggests the relationship may be moderated by (a) factors such as whether the crime occurs outdoors or indoors in climate-controlled places (Rotton & Cohn, 2004), and (b) whether violent or property crime is examined (Hipp et al., 2004). On this latter point, and relevant to the current study, Hipp et al. (2004) found that city demographic structure moderated the strength of the temperature-crime relationship, but only for property crime. More specifically, although bi-monthly counts for an index of burglary, larceny, and motor vehicle theft were higher in cities with higher poverty and divorce rates, the seasonal oscillation in those cities was *lower*. They cautiously suggested that "[i]ndividuals in these [higher poverty, higher divorce] areas … are generally more cautious … [and] may be less willing to alter their behavior in nicer weather. This is clearly speculative …" (Hipp et al., 2004: 1361). Hipp et al.'s poverty link leads to the broader idea that community SES links positively with the *size* of the temperature impact on property crime.

### *Intra-urban level*

Community-level connections between temperature or seasonality, and crime, could well be different from those seen at the city level and higher given spatial scaling concerns, both analytic and theoretic (Blalock, 1982: 258; Galtung, 1967: 45; Taylor, 2010). Further, "The urban neighborhood seems an appropriate geographic unit as social forces contribute to the genesis of crime, and some degree of homogeneity in social characteristics is demonstrable at the neighborhood level" (Harries et al., 1984: 593).

Harries et al. (1984), focusing on 12 neighborhoods in Dallas (TX), observed a moderated community-level relationship between seasonality and assaults, with the summer counts peaking *more* in *low* as compared to *high* SES neighborhoods. In addition to this random effect (effects of temperature stronger in lower SES communities), there was a fixed effect of temperature on assaults (higher temperature, more assaults). Harries et al. (1984) also found that lower SES communities had more assaults overall. Their work was the first to demonstrate that temperature-crime links were not uniform across communities within an urban municipality. The observed random effect, however, was moderated by status in exactly the opposite way seen by Hipp et al. (2004) at the city level for their three property crime index.

The Harries et al. (1984) study, albeit groundbreaking, has limitations including the following. (1) Land uses like bars and bar parking lots were relevant to assaults (their Table 3), but because their analysis did not examine simultaneous impacts of land use and community SES on the temperature-crime link, the *net* fixed and random effects of temperature on community violent crime were not specified. (2) Their analysis did not control for spatial autocorrelation. Even though the community units examined were large, it is possible that some fraction of the temperature-crime relationship observed was not endogenous to the communities but rather due to adjacency impacts. The current research addresses both these limitations.

Three other studies found intra-urban crime locations were seasonally or temperature dependent. Brunsdon, Corcoran, Higgs, and Ware (2009) analyzed calls for service for disturbances in an unnamed city and found the clustering of calls, relative to the city center, shifted depending on temperature and humidity. In Sao Paulo, Brazil, Ceccato (2005) found that within-city secondary clusters of homicides shifted depending on seasonality. In San Antonio (TX), Schafer, Varano, Jarvis, and Cancino (2010) analyzed nighttime calls for service (CFS) counts in several categories. After controlling for winter season, precipitation, and lunar phase, only the disturbance and aggregated CFS categories linked to temperature in the city's Riverwalk entertainment district. (In the rest of the city as a whole, temperature linked to more CFS categories.) Calls for robbery were not specifically addressed in that work.

## Previous theoretical frames

Two psychological frames have been employed to understand observed temperature-crime connections. The general affect aggression model (Anderson, 2001; Anderson & Anderson, 1984; Anderson et al., 2000; Bushman et al., 2005) suggests higher temperatures cause physiological changes, thereby increasing the probability of hostile and aggressive behaviors. This model expects a monotonic relationship between temperature and crime. By contrast, the negative affect escape model (Bell & Baron, 1976; Cohn & Rotton, 2005) suggests that crime will increase with temperature linearly only up to a certain point; at very high temperatures individuals will attempt to escape the discomfort, and thus there will be less offending. So with this latter model a curvilinear relationship is expected. For both models, the shape of the relationship may depend on whether the location is in a tropical vs. a temperate zone (Ceccato, 2005). Both of these frames have some support in the literature.

In contrast to the physiological perspective of the above two models, frames that exemplify "environmental probabilism" (Harries et al., 1984: 602) also can be applied. Most broadly, the idea is that community structure either buffers or intensifies the impact of temperature on crime or other behaviors of interest. More specifically, in reference to crime, ideas from two theories may be relevant.

Researchers have suggested that routine activity theory (RAT) (Cohen & Felson, 1979) could help explain the temperature-crime connection (Ceccato, 2005; Hipp et al., 2004; Rotton & Cohn, 2004). For example, in Brazil, Ceccato's (2005: 317) results suggested "Long days during the hot season… mean that more people are more in contact with each other and the likelihood of violent encounters is greater." The key routine activity idea is that crime events are more likely when there are more confluences of more potential offenders with more potential victims (or targets) when no capable guardians or place managers are around. In its individual-level or site-level formulation, there are important points of convergence between RAT and the rational offender models underlying situational crime prevention (Eck & Clarke, 2003). At the city level, several different studies provide some degree of support for RAT with Hipp et al.'s (2004: 1363) perhaps being the strongest. They found a seasonal effect on an index of three property crimes "[s]uggesting a concurrence in space and time of potential offenders and targets and a lack of guardians."

Although RAT has been found relevant to crime, especially property crime, at varying spatial scales from the national to the neighborhood and individual level (Miethe & Meier, 1994), and although

RAT has progressively evolved, there are still significant theoretical questions about the model. To take just two examples consider the following. Wikstrom, Ceccato, Hardie, and Treiber (2010: 60) have suggested the model does not explain the process by which the convergence "causes a person to engage in an act of crime." Eck (1995) has argued that the theory cannot be tested unless one has data where time is measured in minutes or seconds and distances between parties are measured in feet.

## Current theoretical framework

We do not propose to resolve those theoretical questions about RAT. But we do think the RAT frame can be deepened with crime pattern theory (Brantingham & Brantingham, 1993) and models of urban residential dynamics (Merry, 1981; Taylor, 1988: 166–196,249-274). Such integration leads to specific suggestions about community-level connections between street robbery counts, temperature, community structure, and land use.

Starting with land uses, subway stations are activity nodes (Brantingham & Brantingham, 1993) in crime pattern theory. These activity nodes increase pedestrian traffic in a neighborhood. From the RAT perspective, this creates more confluences of potential victims and more potential offenders in a given space during a given time. From a resident-based informal control perspective (Taylor, 1988), the increased mixing of outsiders and insiders impairs guardianship because residents or street regulars find it harder to decode events on the street (Merry, 1981), and they are less likely to use outdoor spaces adjacent to heavily trafficked locations.

Although commercial locations in urban neighborhoods may not necessarily create activity nodes, previous work does link commercial presence with resident withdrawal (Baum, Davis, & Aiello, 1978), physical incivilities like graffiti and litter (Taylor, Koons, Kurtz, Greene, & Perkins, 1995), and impaired resident-based informal control (Kurtz, Koons, & Taylor, 1998). All of these suggest greater probabilities of potential victims and potential offenders meeting in the context of weak resident- or street regular-based place management. Hipp et al. (2004) found that cities with more entertainment establishments had both higher crime and greater seasonal oscillation of crime. This last finding may be related to a tract-level relationship, for some crime categories, between commercial presence and translating calls for service into reported crimes (Varano, Schafer, Cancino, & Swatt, 2009). Here, at the community level, we expect communities with either more subway stops or more commercial land uses to not only have higher robbery counts, but also to be places where temperature effects on robbery will be higher because the seasonal changes in foot traffic patterns in such communities will be more marked.

Vacant houses not only create gaps in resident-based surveillance and management, but also can draw users and uses that are problematic from residents' perspective. Prostitution, squatting, and drug use or drug sales are examples. Previous work links vacant unit prevalence to crime and crime changes, and documents links with these problematic activities (Simon & Burns, 1997; Spelman, 1993; Taylor, 2001). Philadelphia foot patrolling police officers conversing with the first author suspected vacant houses were more likely to be occupied and used by vagrant or criminally adept individuals in warmer months. This would suggest a stronger impact of temperature on robbery in communities with more vacant housing.

Turning to demographic structure, past decades of ecological research on community SES and crime clearly suggest less robbery in higher SES neighborhoods (Pratt & Cullen, 2005). As noted above, however, there is disagreement in previous research about the direction of the moderating impact of SES on the temperature-crime link.

Given the focus here on street robbery at the community level, we expect stronger seasonality effects for higher SES communities. The first author, while doing walk-alongs with foot-patrolling Philadelphia police officers during the summer, observed different outdoor use patterns in different SES neighborhoods. Although there was a substantial outdoor presence in both higher and lower SES communities, in the former the majority of persons appeared to be outsiders passing through. In the latter locales, by contrast, the majority appeared to be neighborhood residents, congregating on front steps of their or neighbors' homes to either enjoy the warm weather or escape inside heat. From both RAT (Felson, 1995), and resident-based informal control perspectives (Taylor, 1988), these outdoor-using residents and regulars are potential place managers. These informal observations align with more systematic observations of stoop culture in Philadelphia (Roberts, 2005) and street block behavior profiles in Baltimore (Taylor, Gottfredson, & Brower, 1981).

Turning to other aspects of community structure, based on previous research (Pratt & Cullen, 2005; Sampson, 2002, 2006), robbery counts were expected to link negatively to stability and ethnic/immigrant concentration, and positively to percent African-American. Current theorizing does not suggest that these factors might moderate the variable effects of temperature.

In sum, the current integrated perspective for examining connections between temperature and robbery counts at the community level within a large city suggests net endogenous impacts of community structure, land use, and temperature on crime. Additionally, given earlier intra-urban work, we expect that temperature impacts will vary across locales. Further, if that variation surfaces, we anticipate that land use factors like subways, commercial properties, and vacant properties, and structural factors like community SES, all could shape the strength of the temperature impact. Previous research has disagreed on the direction of the last moderator link.

## Data and methods

### *Outcome, units of analysis, analytic approach*

Philadelphia, the urban core municipality of the fifth largest metropolitan area in the U.S., was the study site. Census tracts (n = 381) were used to approximate a community-level unit of analysis. Street robbery was chosen as the dependent variable because it is an instrumental crime, it takes place outdoors making the connection between the crime outcome and temperature clearer, and it is a crime which police patrolling practices can affect. Commercial robberies were excluded. Street robbery counts were aggregated by month and by census tract for three consecutive calendar years (2007 = 9,760; 2008 = 9,171; 2009 = 7,869). 2000 population for each tract was used as the exposure variable. Data were analyzed using multilevel models (Raudenbush & Bryk, 2002) with months nested within census tracts. Given that the outcome was a count variable, a Poisson distribution with overdispersion was specified. All predictors were grand mean centered.

Four different multilevel models were run: the null or ANOVA model; a model controlling for spatial lag and time varying covariates to verify significant remaining between-tract outcome variation after these were entered; a means as outcome regression model adding tract-level demographic and land use predictors while allowing temperature and time effects to vary randomly across tracts; and finally a full model which added predictors of the varying temperature slopes. Allowing impacts of linear time to vary across tracts provided an extremely stringent control for the potential threat to internal validity of local history. A quintile map of Philadelphia's 381 census tracts' average monthly robbery counts is shown in Fig. 1.

### *Time varying covariates within communities (level one variables)*

Average recorded high temperature for each month in the period was collected from an online weather archive (www.wunderground.com/history) used for previous research (e.g., see Ratcliffe, Taniguchi, & Taylor, 2009). Average high temperatures in peak summer months were in the upper 80s (°F) while the average high in the coldest winter

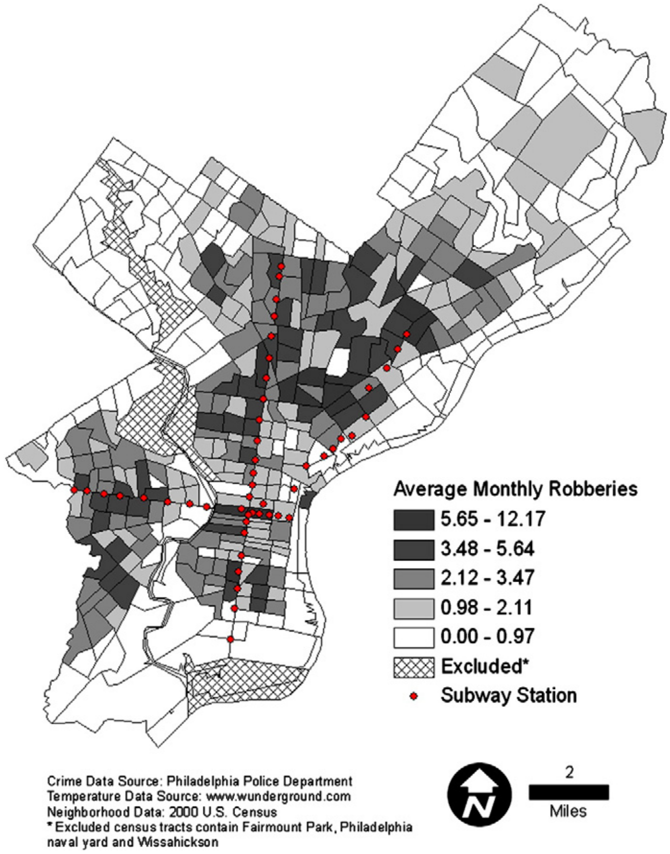


**Fig. 1.** Quintile map of average monthly robberies per tract, 2007–2009.

months was in the mid 30s. To control for differential month length, number of days in the month was included as a variable. To control for medium-term linear temporal trends in robbery and thus local history, a variable for position of month in the data sequence (1–36) was included.

*Community attributes (level two variables)*

Data from the 2000 Census tract level file were used to create indices for neighborhood status (Cronbach's $\alpha = .81$), neighborhood stability (Cronbach's $\alpha = .66$) and ethnic/immigrant concentration (Cronbach's $\alpha = .71$). For each index, variables were z scored then averaged. Status included median household income, median house value, and percent of the population with at least a high school diploma. Stability included percent owner occupied households, percent of households living at their current address at least five years, and (1 minus the proportion of the population aged 20–24). Ethnic/immigrant concentration included percent Hispanic population, percent linguistically isolated households, and percent of the population foreign born.

In addition, two single variables were used for the percent of the African-American population, and the percent of housing units which were vacant. (For the latter, it is recognized that what is of direct interest is the percent of housing units which are long-term vacant, and/or vacant and boarded up. The 2000 Census does not report this number separately.) For subway stations, a 400 foot buffer was built around each subway stop in the city, and a census tract was coded 1 on this variable if a subway buffer intersected with that tract. Otherwise the tract was coded 0. For commercial land use, 2007 data from University of Pennsylvania's neighborhood information system website (*http://cml.upenn.edu/nis/*) reflected the percent of parcels in each tract that were commercial.

Analysis of Empirical Bayes adjusted tract-level robbery counts from a null multilevel model with no predictors indicated significant spatial autocorrelation of robbery counts at the tract level (Global Moran's $I = 0.25$; $p<.05$). A spatial lag variable was created by queen contiguity and was entered at the community level for the remaining models. Examination of the matrix of predictors for potential multicollinearity revealed that all variance inflation factors were below 2.0. Descriptive statistics for all predictors and the outcome appear in Table 1.

## Results

*Between-community outcome variation*

Controlling for exposure (population), significant between-community variation in expected robbery counts appeared ($p<.01$). The residual between-community outcome variation remained significant ($p<.01$) in all models after predictors were entered.

*Temperature fixed and random effects*

In all models, temperature demonstrated a significant positive impact on expected robbery counts, regardless of whether temperature was modeled as a fixed or random effect. In the full model allowing temperature impacts to vary across communities (see Table 2), each ten degree increase in average monthly temperature was associated with about a two percent increase in the expected monthly robbery count ($p<.01$). Given about a 50 degree difference between the coldest and warmest months, the average seasonal oscillation in expected robbery counts was therefore about ten percent. Although this fixed impact aligns with previous seasonality-crime research generally, this is the first demonstration of an intra-urban, community-level connection between robbery counts and temperature. Given the persistence of the effect in different models, before and after controlling for demographic structure, spatial lag, and land use, and regardless of whether temperature is modeled as a fixed or random effect, the connection demonstrated here seems solid.

Beyond the fixed temperature effect, a significant random temperature effect also appeared ($p<.01$). Stated differently, Philadelphia's census tracts experienced the effects of temperature on robbery in

**Table 1**
Descriptive statistics of dependent and independent variables by census tract

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Street Robbery (per tract/month) | 381 | 2.00 | 2.33 | 0.00 | 22.00 |
| Average Monthly Temperature (°F) | 381 | 64.50 | 16.66 | 35 | 88 |
| Status[a] | 381 | 0.00 | 0.87 | −2.16 | 7.23 |
| Stability[b] | 381 | 0.00 | 1.78 | −3.75 | 2.09 |
| Ethnicity/Immigrant Concentration[c] | 381 | 0.00 | 0.76 | −0.66 | 4.07 |
| % African American | 381 | 41.78 | 37.45 | 0.00 | 100.00 |
| % Commercial Properties | 381 | 8.18 | 14.03 | 0.00 | 87.50 |
| % Vacant Properties | 381 | 10.82 | 9.81 | 0.00 | 100.00 |
| Total Population | 381 | 3984.07 | 2409.39 | 0.00 | 10479.00 |
| Spatial Lag | 381 | −7.39 | 0.88 | −10.18 | −3.17 |
| Subway[d] | 381 | 0.22 | 0.42 | 0.00 | 1.00 |

Sources: The Philadelphia Police Department; 2000 U.S. Census; the University of Pennsylvania Cartographic Modeling Lab: *http://cml.upenn.edu/nis*.
Notes: [a] Status = z-scored average of median household income, median household value and percent of the population with at least a high school diploma (Cronbach's $\alpha = 0.81$).
[b] Stability = z-scored average of percent of the population living in the same household for five or more years, percent of owner occupied households and the reverse coded percent of the population between the ages of 20 and 24 (Cronbach's $\alpha = 0.66$).
[c] Ethnicity/Immigrant Concentration = z-scored average of percent of the population that is linguistically isolated, percent of the foreign born population and percent of Hispanic residents (Cronbach's $\alpha = 0.71$).
[d] Subway = census tracts that intersect a 400 foot (approximately 1 street block) buffer of subway stations (Dichotomous: 0 = no 1 = yes).

**Table 2**
Full multilevel model: Predicting robbery counts

| **Predicting Counts** | Coefficient (S.E.) | Event Rate Ratio | t-ratio |
|---|---|---|---|
| Level 2 (census tracts) | | | |
| Status[a] | −1.213(0.369) | 0.297 | −3.291** |
| Stability[b] | −0.321(0.242) | 0.726 | −1.327 |
| Ethnicity/Immigrant Concentration[c] | −0.338(0.147) | 0.713 | −2.297* |
| Subway | 0.108(0.158) | 1.109 | 0.680 |
| % African-American | 0.023(0.009) | 1.024 | 2.493* |
| % Vacant Property | −0.023(0.019) | 0.978 | −1.142 |
| % Commercial Property | 0.054(0.012) | 1.055 | 4.350** |
| Spatial Lag | 0.173(0.060) | 1.188 | 3.005* |
| Level 1 (months) | | | |
| Time (Linear Month Sequence) | −0.005(0.0006) | 0.995 | −9.745** |
| Days in Month | 0.066(0.004) | 1.068 | 14.734** |
| Average Monthly Temperature | 0.002(0.0004) | 1.002 | 6.357** |
| Intercept | −7.192(0.085) | | |
| **Predicting Temperature Slopes** | | | |
| Neighborhood Status | 0.0044(0.0003) | 1.0044 | 11.556** |
| % Commercial | 0.00013(0.00002) | 1.0001 | 7.009** |
| % Vacant Property | −0.0001(0.00005) | 0.999 | −0.121 |
| Subway[d] | 0.0012(0.0005) | 1.0013 | 2.623* |
| Remaining variance | Variance Component | $\chi^2$ | *df* |
| Intercepts | 0.827 | 11605.760** | 372 |
| Slope: Time (Linear Month Sequence) | 0.00004 | 507.450** | 380 |
| Slope: Average Monthly Temperature | 0.00001 | 427.522* | 376 |

Sources: The Philadelphia Police Department; 2000 U.S. Census; University of Pennsylvania Cartographic Modeling Lab: *http://cml.upenn.edu/nis*; *www.wunderground.com/history*.
Notes: Generalized hierarchical model specified as Poisson distribution with overdispersion. Monthly robbery counts per tract = outcome variable and total population per tract = exposure variable. All variables entered grand mean centered.
* p<.05, **p<.01.
[a] Status = z-scored average of median household income, median household value and percent of the population with at least a high school diploma (Cronbach's α = .81).
[b] Stability = z-scored average of percent of the population living in the same household for five or more years, percent of owner occupied households and the reverse coded percent of the population between the ages of 20 and 24 (Cronbach's α = .66).
[c] Ethnicity/Immigrant Concentration = z-scored average of percent of the population that is linguistically isolated, percent of the foreign born population and percent of Hispanic residents (Cronbach's α = .71).
[d] Subway = census tracts that intersect a 400 foot (approximately 1 street block) buffer of subway stations (Dichotomous: 0 = no 1 = yes).

statistically different ways. Mapping the slopes organized by standard deviations (not shown) revealed a complex pattern, with larger temperature impacts (slope above +.5 sd in the distribution of slopes) appearing in the Center City, Art Museum/Spring Garden, Chestnut Hill/Upper Roxborough, lower Northeast, and Southeastern South Philly areas. Many high crime areas including a cluster of census tracts in North Philly and another in the Mantua/West Philly areas had average temperature slopes (−.5 sd - +.5 sd in the distribution of slopes). Clusters of census tracts with weaker temperature effects, i.e., weaker seasonal oscillations (slopes< −.5 sd in the distribution of slopes), appeared in the Northeast, Kensington/Port Richmond and inner City Line Avenue parts of the city.

Following our conceptual model, four predictors were used to predict the temperature slope: SES, percent commercial land use, percent vacant housing units, and presence of subway stops. The full model appears in Table 2.

Community SES exhibited a significant (p<.01) impact; seasonal oscillation in robbery rates was *stronger* for *higher* SES communities. Also positively associated with stronger seasonal oscillation, i.e., stronger temperature impacts, were communities with more commercial land uses (p<.01), and the presence or proximity of subway stops (p<.05).

A standard deviation map of fitted temperature slopes (Fig. 2) revealed how these factors played out spatially. A band of communities extending from University City west of Center City, through Center City and just to the north and south of it, all had large positive predicted temperature slopes relative to other communities. Given extensive commercial land use and numerous subway stops in these locales, and increased summer foot traffic with major events and high volume out of town visitors, the stronger seasonal oscillation for robbery counts in these locales seems plausible. Another cluster of communities with strong impacts of temperature on robbery counts was situated in the outer northwestern corner of the city and included Chestnut Hill, East Mount Airy, Roxborough and Manayunk. Some of these areas have sizable commercial centers which are probably associated with higher pedestrian traffic in the summer. Some of the highest crime and lowest income areas of the city, including tracts in central North Philadelphia, were generally associated with minimal temperature impacts on robberies.

The positive link between community SES and temperature impacts on crime aligns with Hipp et al.'s (2004) city level negative impact of poverty on seasonal oscillation for property crimes. The impacts of land use patterns and subway stops support the environmental criminology/crime pattern theme in the integrated street robbery model.

Although these variables predicted temperature's varying impacts on community robbery counts, significant variation in the temperature slope remained to be explained (p<.01).

### Impacts of community demographic structure and land use

Turning to impacts of community structure and land use, four variables significantly predicted higher expected robbery counts: lower community SES (p<.01), increasing African-American composition (p<.05), decreasing the ethnic/immigrant concentration (Hispanic,

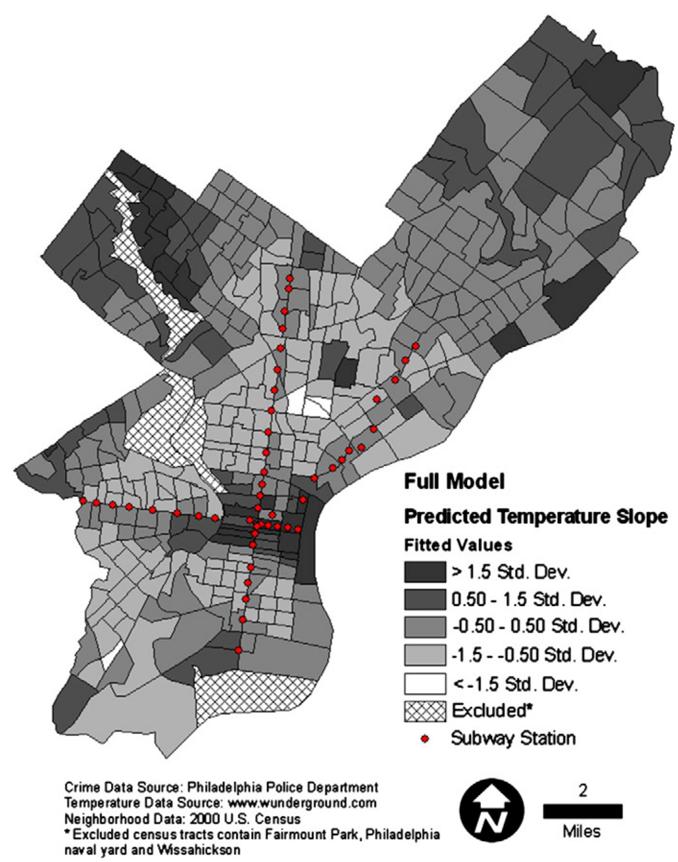


**Fig. 2.** Fitted values of predicted temperature slope by census tract.

foreign born, or linguistically isolated) ($p<.05$), and increasing prevalence of commercial land uses ($p<.01$). In addition, the spatially lagged outcome remained significant in the full model ($p<.05$).

Of the three structural variables, community SES and racial composition had the most sizable impacts. A one standard deviation increase in SES linked to an expected robbery monthly count that was about 62 percent lower. A one standard deviation increase (37 percent) in the proportion of the population African-American was associated with an expected robbery count that was about 89 percent higher. Significant but with a less sizable impact was the presence of an ethnic/immigrant population. A one standard deviation increase in this index was associated with an expected robbery count that was 22 percent lower.

### *Other findings*

Over the 36 month data frame, there was a significant downward linear trend in community monthly robbery counts ($p<.01$). For each additional month, the expected robbery count decreased by about .5 percent, equivalent to a yearly decrease of about 6 percent in expected community counts. Looking at the random effect of linear time (results not shown), a few communities were increasing slightly over time and most were showing no trend or a slightly decreasing trend over time. Looking at the spatial patterning of these random effects suggested most of the small number of areas with slightly increasing rates were clustered in the outer ring of the Northeast or near Manayunk/Roxborough, or in southwest Philadelphia. The bulk of communities, however, were experiencing either no change due to linear time, or slightly decreasing robbery counts over time.

## Discussion

### *Theory*

Based on but also extending earlier works to focus specifically on temperature-street robbery links at the community level in an urban context, we presented an integrated model taking into account fixed and random effects of temperature on street robbery and community-crime structural connections. The model was grounded in earlier empirical work, and theories of routine activities, crime patterns, and informal residential control dynamics. How did those predictions fare?

Perhaps most important are three points about temperature and street robbery. First, as has been observed at the city level with other property crimes and violent crimes (Hipp et al., 2004), and for several categories of calls for service (Schafer et al., 2010), and at the intra-urban level (Harries et al., 1984) for serious assault, the same positive temperature-crime link exists at the intra-urban level for street robbery. This is the first study (of which these authors are aware) to show this temperature-street robbery connection at the community level.

But in addition to this fixed effect of temperature, a significant temperature random effect also appeared. In some places robbery counts were relatively constant all year round, whereas in other locations the counts increased in warmer months. This is the first study (of which these authors are aware) demonstrating the intra-urban random effect of temperature on street robbery.

Third, community status linked to this moderated temperature impact. As noted above, two earlier studies disagreed about whether the random effect of temperature on crime would be larger in higher SES (Hipp et al., 2004) or lower SES communities (Harries et al., 1984). Results here showed larger seasonal oscillations, i.e., stronger positive temperature slopes, in higher SES communities. This extends Hipp et al.'s (2004) city-level property crime finding of higher SES-more seasonal oscillation to an important violent crime, robbery, and to the intra-urban level.

Looking at the spatial distribution of the predictable portion of the random effect suggested possible relevant dynamics. Locations that were near major or moderate sized commercial venues, with moderate or upper income communities located there or nearby, and in some instances well served by subway lines (Center City, University City, South Street, Chestnut Hill, Roxborough), seemed to experience the strongest temperature-linked oscillation in robbery counts. Some of these communities contain or are near venues that are year-round tourist attractions more heavily visited in warmer months, or that are sites of special seasonal events such as runs, concerts, or festivals. Increased outsider pedestrian traffic, as mentioned earlier when discussing informal resident- and regular-based control on streets (Taylor, 1988), makes recognition of street users and decoding of street activities more challenging, thereby perhaps adversely affecting surveillance and/or willingness to intervene.

To back up or disconfirm such speculation probably will require complementing ecological analyses with more detailed work. This could include: examining how robbers think (cf. St. Jean, 2007) about seasonal matters; analyzing journeys to rob or be robbed; and close consideration of site features such as lighting, lines of site, and insider and outsider pedestrian volumes in places where robberies take place at higher frequencies in warmer compared to colder months. Crime pattern, routine activity, and informal resident control perspectives provide rich sources of prediction for this more detailed future work.

Closing out the discussion of theory, three additional demographics and one land use variable merit discussion. Increasing African-American composition linked to higher robbery counts. The racial composition-crime link has been observed, albeit not consistently, in several decades of research (Pratt & Cullen, 2005; but cf. Peterson & Krivo, 2010). Second, increasing ethnic/immigrant population, as reflected in more Hispanics, more foreign born, and more linguistically isolated households, was associated with lower robbery counts. This partly aligns with Ng's (2010) finding that census tracts in Wayne County, Michigan with more foreign born individuals were associated with fewer life offenders residing in them, although, in that study, the percent of Hispanics was found to be insignificant in predicting life offender populations per tract. If robbers are not traveling very far, this supports broader arguments, based on national data and Chicago neighborhood data (Sampson, 2006), that "[i]mmigrants appear in general to be less violent than people born in America, particularly when they live in neighborhoods with high numbers of other immigrants." Our finding that high SES neighborhoods have lower robbery counts aligns with considerable previous research (Pratt & Cullen, 2005). Indeed, SES is the most consistent predictor of community violent crime rates.

Land use, in addition to moderating the temperature-robbery link, also proved an important predictor of robbery counts themselves. Communities with more commercial land uses experienced higher robbery counts. Given ethnographic accounts of street robbers (St. Jean, 2007) this makes sense; more commercial land uses mean both a larger supply of potential victims on foot per hour, and that potential robbers will be less noticeable given the higher pedestrian volumes. It also fits with earlier work examining burglary and violence (Wilcox, Quisenberry, Cabrera, & Jones, 2004).

Finally, one result deserving future theoretical inquiry is the impact of the spatially lagged outcome variable. This significant impact suggests that there is something happening at the supra-community but sub-city level which is creating a broader spatial patterning of community robbery counts. Whether the dynamics are linked to sub-cultural factors or something else deserves investigation.

### *Police practice implications*

Current results could have some implications for practices in the Philadelphia Police Department or other police departments. It would appear that there are some sectors of the city where robbery counts in warmer summer months are much higher than robbery counts in colder winter months. The predictable portion of this seasonal oscillation was relatively clearly patterned. Therefore, commanders concerned with the level of robberies in their police service areas might benefit from increased summer resource deployments along places that have commercial zones, subway routes, and higher SES neighborhoods nearby. Resources might include additional police patrols as well as crime prevention programs and partnerships. Of course, implications for police deployment should be interpreted cautiously. Street robbery was the only crime examined and patrolling officers must respond to and/or seek to prevent all types of crime. Other crimes such as assault or homicide may not follow the same seasonal patterns as robbery, and/or the seasonal variations may not link up spatially the same way. Before firm deployment suggestions by season and location can be offered, the seasonal and spatial dynamics of other key crimes need investigation.

Further, given the subway-seasonal oscillation link, and the commercial-seasonal oscillation link, current results highlight the importance of coordination between the police department, transit police, and business district personnel.

As is true in many other cities, Philadelphia's rail lines have a dedicated transit police force, the Southeastern Pennsylvania Transit Authority (SEPTA) Police. In light of the connections between subway stops and seasonal robbery oscillations, information sharing and co-produced prevention initiatives between SEPTA Police and Philadelphia Police may prove particularly beneficial. Pooling resources and co-managing deployments may prove cost effective for both parties. There is a need for cross-agency collaboration if seasonal deployments are to be planned.

That coordination also should clearly involve Philadelphia's nine business improvement districts (BID) (Hoyt, 2004). Many of these BID's employ forms of security or uniformed personnel to increase surveillance and place management. Seasonal robbery oscillations seemed to be strongest in exactly the locations covered by several of these BIDs and watched over by BID personnel. That may be true for other street crimes like assaults. Again, seasonal deployments of either private security patrols or CCTV monitoring, done in coordination with the Philadelphia Police Department, seems a sensible practice implication once more is known about seasonal variation for other street crimes.

### *Limitations and strengths*

Of course, this study has numerous limitations. (1) Census tracts, as used here, may not be the "best" intra-urban community–level unit. Smaller census block groups might be preferable. Smaller units, however, were not feasible for monthly street robbery counts because of counts that were too low and count distributions with too many zeros. (2) The temporal unit, months, is quite coarse. Although monthly averages are useful for district commanders in developing seasonal crime fighting strategies (Ramsey & Joyce, 2008), different patterns at smaller time scales could appear. Here, an attempt to use smaller units was not feasible because of too many units with too many zero counts. (3) Although the status main and moderating effects seen in this model supported the integrated model, and aligned with expectations based on field work performed by the first author in 60 Philadelphia neighborhoods, the study contained no direct indicators for capable guardianship, effective place managers or place management, potential offenders, or potential victims. Future work on routine activity theory hopefully will move toward clearer, more direct indicators for such dynamics.

Although not a limitation of this work per se, the limitations of using recorded crime are well known. Event data such as ours is of course influenced by police officer decision making (Black, 1980). Further, the conversion of calls for service into recorded crimes is influenced by local structural characteristics (Varano et al., 2009), suggesting that different results might have been obtained had calls data been used. Of course, questions of external validity are always empirical questions about future data, not study limitations per se (Taylor, 1994: 164).

Potentially offsetting these limitations were analyses that controlled for history and local history, separated temporally-varying from place-varying dynamics, and appropriately modeled a count outcome. Furthermore, multi-level models appropriately recognized and controlled for seasonality and time dependency over time and within tracts. They were appropriate here, additionally, because there was a large number of neighborhood (census tract) units (cf. Scarborough, Like-Haislip, Novak, Lucas, & Alarid, 2010).

## Closing comment

Impacts of temperature on monthly street robbery counts in Philadelphia communities at the census tract level were investigated using an integrated theoretical model that relied on structural community-crime connections, crime pattern theory, routine activity theory and informal resident-based control dynamics. In this first-ever intra-urban examination of temperature and street robbery, warmer months were associated with higher robbery counts; higher counts also linked to locations with lower SES, a more predominantly African-American population, a less heavily ethnic/immigrant population, and more commercial land uses. Temperature's impact on street robbery was moderated by community SES in the same way seen by Hipp et al. (2004) for property crimes at the city level: stronger seasonal oscillation in higher SES locales. Further, land uses and subway transit stations also altered the temperature-robbery link in ways aligning with the proposed integrated theory. The significant spatially lagged outcome called attention to spatial robbery dynamics above the community level. Future work will hopefully be able to include direct micro-level indicators of pedestrian traffic, pedestrian status (residents & regulars vs. passers through), routine activity dynamics, and place-management dynamics linked to informal resident-based control. Such indicators are needed to unpack the relevant situational and community dynamics behind these relationships. If similar patterns are observed for other street crimes, these results could have implications for police practices around seasonal deployments.

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