Rutgers Center on Public Security
BRIEF

Integrating Spatial Crime Analysis Techniques for Tactical and Strategic Actions

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Introduction

Work on crime hotspots has generated a great deal of interest in the spatial analysis of crime, leading to a revolution in the ways in which scholars and practitioners consider the origins and dispersion of crime. An extension of hotspot analysis has been the examination of "near repeats" or contagion effects which explain how past crime incidents can serve as predictors of new crime incidence. Hotspot mapping and near repeat analysis have allowed police to more efficiently target criminogenic places, but crime suppression and prevention efforts at these places cannot succeed outside of an understanding of the combined effects of the social and physical environments in which the offender operates. In Cohen and Felson's[1] original article on routine activities, they wrote that "the risk of criminal victimization varies dramatically among the circumstances and locations in which people place themselves and their property" (595).

Criminologists have begun to address the importance of concentration effects of crime patterns based on underlying social contexts. This type of research is based on a form of analysis pioneered in criminology by Brantingham and Brantingham[2] that considers the underlying social and physical "fabric" or environmental backcloth as a framework for action. But two elements need to be clarified to move forward. The first relates to the fact that event dependence is not a linear process but rather, in the interaction that takes place between crime incidents and context, a constantly changing risk dependence that emerges from the actions of all parties and criminogenic features about a location. The second relates to the role that crime incidence has on supporting future crime occurrence. With a better understanding of these elements and how they fit into the broader evolution to crime analysis and forecasting, it becomes clear that each method has unique operational utility for policing, even if the end analytical goals are the same.

It is likely that a hybrid method, to examine both clustered events and environmental risk factors, could provide a more stable and spatially anchored approach to place-based crime control efforts. In other words, the vulnerability of areas defined by the presence of factors that correlate with crime can be combined with the exposure that comes with past crime incidents to enhance the picture of crime occurrence and to better focus strategies for place-based interventions. In this study, we explore the combined practical utility of point pattern analysis, hotspot mapping, near repeat analysis, and risk terrain modeling. We demonstrate that resilient crime hotspots are both a function of the presence of motivated offenders as well as the attractive and/or generative qualities of the environment that serve as cues to offenders that certain places are suitable to commit crimes.

Research Setting

This study emerged out of collaboration with the New Jersey State Police (NJSP) in 2007 in Irvington, New Jersey, an urban community of 2.9 square miles with a population of 65,000. Murder rates for 2007 were 38.7 per 100,000 persons, compared to a national average of 4.9 for similar size cities. The town has a lot of gang-related violence and contains a vibrant drug market.

Violent crime data includes aggravated assaults, homicides, robbery, shootings, and weapon possession (i.e., the targeted violent crime types in Irvington during the study timeframe). Data were provided by the NJSP through the Regional Operations Intelligence Center. There were 57 types of violent crime incidents from April to August 2007 and 32 violent crime incidents from April to August 2008. These address-level data were geocoded to a street-centerline shapefile of Irvington. Geocoding match rates were 91% and 94%, respectively.

Methods and Results

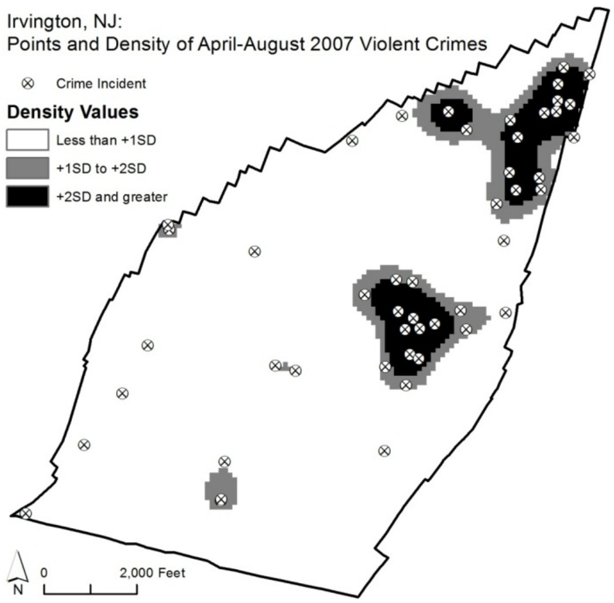
Event-Dependent Analysis

Point pattern analysis and hotspot mapping

Visual inspection of the points in Figure 1 suggests that violent crimes are not uniformly distributed throughout Irvington and may be clustered in certain areas. Results of a NN analysis suggest that the distribution of violent crimes in Irvington is significantly clustered[3].

Figure 1 presents a density map of violent crimes in Irvington, NJ from April through August 2007. The density map is symbolized according to standard deviational breaks, with all places colored in black having density values greater than +2 standard deviations from the mean density value—which statistically puts these places (i.e., raster cells of 100ft x 100ft) in the top 5% of the most densely populated with violent crimes. Because seasonality correlates with crime incidents and should be controlled for with longer-term forecasting, a conventional hotspot analysis, or density map, might suppose that violent crimes from April through August in 2008 would occur at the same "hotspot" locations as existed in 2007. In the 100ft by 100ft places on the map that had a density value above +2 standard deviations in 2007, 17% of violent crime incidents between April through August 2008 occurred within these same places,[4] which total 7% of the area of Irvington.

Figure 1: Points and Density Values



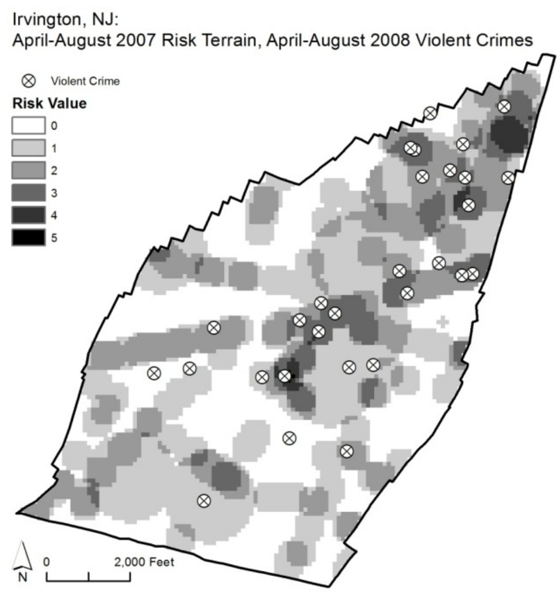
Near Repeat Analysis

Near repeat analysis adds a temporal aspect to point pattern and hotspot analysis by suggesting with a certain level of statistical confidence that new crimes happen within a certain distance of past crimes and within a certain period of time from the prior incident. According to results of a near repeat analysis of Irvington's violent crime incidents during April through August 2007 using the Near Repeat Calculator[5], Version 1.3, there is evidence of an over-representation of violent crimes at the same place up to 7 days after an initial incident ($p<0.05$); the chance of another violent crime incident was about 500 percent greater than if there were no repeat victimization pattern.[6] Near repeat violent crimes were also overrepresented between 8-14 days and within 801 to 900 feet of the initial incident ($p<0.01$)[7], and there was a 153 percent greater chance of a new violent crime incident occurring within 0-14 days at 801 to 900 feet away from the initial incident ($p<0.05$)[8]. Eight hundred feet is about two blocks in Irvington.

Environmental Crime Analysis using RTM

Figure 2 presents a risk terrain map for violent crimes that was produced in accordance with the steps described by Caplan and Kennedy[9]. The map was produced using five risk factors that previous empirical research found to be correlated with said violent crimes. These risk factors are: Gang members' residences; bus stops; schools; public housing; and facilities of bars, clubs, fast food restaurants, and liquor stores. The risk terrain map is symbolized according to unique risk values, which range from 0 (lowest; white) to 5 (highest; black). Higher risk places in 2007 should host violent crime incidents in 2008, unless one or more risk factors are mitigated at these places.

Figure 2: Risk Terrain Map Showing Environmental Criminogenic Context of 2007



Logistic regression results suggest that for every unit increase of a place's (i.e., 100ft x 100ft cell's) risk value, the likelihood of a violent crime occurring there during April through August 2008 increased by 92 percent. For places with one or more risk factors in 2007, we can be 95% confident that if violent crimes happen in 2008 the likelihood of them happening at these places are between 37% and 169% greater than other places in Irvington. When environmental risk is treated as a categorical variable and dummy coded, risk values equal to or greater than 3 appear to be significant predictors of future shootings compared to values of zero[10]. The order of magnitude for risk values' effect sizes confirms that the more environmental risks present at a micro-level place, the greater the likelihood of a future violent crime occurring there[11]. According to results of a Chi-Squared test, nearly 45% of all violent crimes in 2008 happened at places with risk values of three or more, which comprised 10% of the area of Irvington.[12]

Synthesizing all of the results, it appears that occurrences of violent crimes in 2008 at places where violent crimes produced hotspots in 2007 was attributable to criminogenic stagnation—risk factors at micro-level places stayed the same or were not successfully mitigated over time. That is, the locations of schools, bars, etc., do not change drastically from year to year. If risk factors in the risk terrain model are not directly and successfully mitigated, and crimes continue to occur, then they will likely cluster at the same criminogenic places over time, creating hotspots. In this way, crime hotspots were valid measures of where new crimes were likely to occur in the future because they were proxy measures of environments that were chronically most conducive for illegal violent behavior.

Joint Utility of Hotspot Mapping, Near Repeat Analysis, and Risk Terrain Modeling

The joint utility of these crime analysis techniques offers police a unique opportunity to suppress violent crimes immediately by allocating resources to existing hotspots. They can, in addition, prevent violent crimes through interventions at places that are most attractive to motivated offenders given certain characteristics of the environment, even if violent crimes are not yet occurring there. According to a multivariate logistic regression, micro-level places in Irvington with past violent crimes had a 478 percent increase in the likelihood of future violent crimes compared to places that were not host to violent crimes in the previous year, when controlling for environmental risk ($p<0.01$). Places with risk values of 3 or more (as supported by the results presented earlier) had a 458 percent increase in the likelihood of future violent crimes compared to places with lower risk values, when controlling for the presence of prior violent crime incidents ($p<0.001$). These results confirm that violent crimes occur at places with higher environmental risks, especially if violent crimes occurred there already.

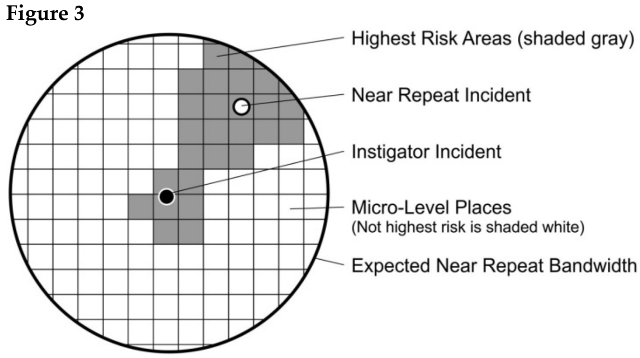
Knowing that the presence of past violent crimes can be a significant predictor of future similar crimes, we can use near repeat analysis to categorize violent crime incidents according to their temporal nature; that is, as instigator or near repeat event. The spatial-temporal linkage of such incidents was identified here using the "Other functions" tool of the Near Repeat Calculator. The joint application of RTM and near repeat analysis can be used to anticipate the distal and temporal limits and locations of near repeat events that follow unpreventable violent crime incidents.

According to results of the aforementioned near repeat analysis, near repeat violent crimes were most likely to occur between 801-900 feet and within 14 days of an instigator event. Near repeat incidents during April through August 2007 were significantly more likely to happen at higher risk places within these bounds. Environmental risk remains significant to the locations of near repeats even when controlling for the presence of instigator events at micro-level places. In fact, this multivariate regression is the best model produced (i.e., in terms of explained variance: Nagelkerke R Square=0.363) for predicting where violent crime incidents were likely to happen.

This finding supports the near repeat phenomena and the relationship it has with environmental risks above-and-beyond crime incidents themselves. "Risk heterogeneity" of environments, as articulated by risk terrain maps, exists prior to the initial victimization and can be enduring without proper intervention efforts. "State dependence" exists at places with instigator crimes, which makes the same target or nearby targets especially attractive. Where risk heterogeneity and state dependence co-exist; that is, when instigator events locate in risky environments, the emergence of new crimes is especially likely.

As illustrated in Figure 3, violent crimes that cannot be prevented and that serve as instigator events (for near repeats) are most likely to attract near repeat incidents at nearby places of high environmental risk—as opposed to micro-level places within the expected near repeat bandwidth that have very low risk. Stated another way, instigator violent crimes may create a "pie" of a certain radius within which near repeat incidents are most likely to happen during a certain timeframe. But within this pie, some "slices" are more likely to have violent crimes than other slices.

Figure 3

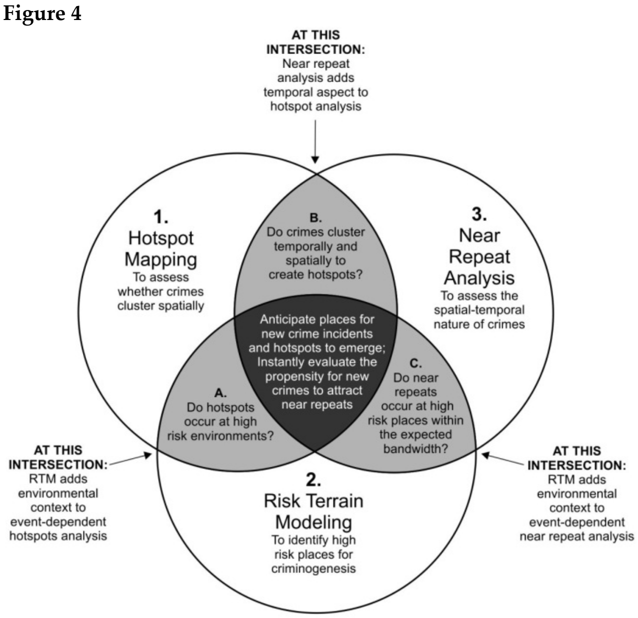


One advantage of knowing that a near repeat phenomenon exists for violent crimes in a jurisdiction and that violent crimes are more likely to occur at high risk places is the ability to prioritize each new crime incident according to its propensity for being the instigator event for near repeat crimes. Assuming that every new violent crime incident is a potential instigator for near repeats, priority can be given to new crimes that occur at high risk places with other high risk places in close proximity. Place-based environmental risk assessment with RTM permits real-time evaluation of the propensity for a new crime to become an instigator for near repeats.

Discussion

We identified a 3-part integration of these approaches for crime analysis and forecasting based on each step's information product, as exemplified in Figure 4. The first step (#1 in Figure 4) is hotspot analysis to assess whether (and where) crimes cluster spatially in the jurisdiction. The second step (#2 in Figure 4) is to model environmental risks with risk terrain modeling to identify high-risk places for criminogenesis. The joint utility of information derived from Steps 1 and 2 (A in Figure 4) is to determine if crime hotspots occur at high risk places or within high-risk clusters. This knowledge can help to explain the underlying environmental risk factors that may attract and generate hotspots. The third step (#3 in Figure 4) is near repeat analysis to assess the spatial-temporal nature of past crimes. The joint utility of information derived from Steps 1 and 3 (B in Figure 4) is to help explain the event-dependent and temporal nature of crime hotspots in the jurisdiction. If a near repeat phenomenon exists, then the joint utility of information derived from Steps 2 and 3 (C in Figure 4) is to evaluate the propensity for new crime incidents to become instigators for near repeats based upon the proportion of high-risk places within the expected near repeat bandwidth.

Figure 4



The culmination of all three steps is information products that can inform short- and long-term strategic planning and at least three tactical deployment decisions. Information product A enables police to respond immediately to places where crimes cluster and crime problems persist, and to respond preemptively to high-risk places. Information product B gives police a temporal window in which near repeat crimes are most likely to follow new crime events. This knowledge can help to reduce the costs of deploying extra resources for long or uncertain lengths of time following new crime incidents. This, in turn, can help to reduce alert fatigue among patrol officers who are assigned to patrol places nearby to new crime incidents. Information product C allows police to prioritize place-based deployments of resources by comparing new crime incidents relative to all others according to the surrounding environment's suitability for hosting new near repeat incidents. Priority can be given—and limited resources (re)allocated, to new crime incidents that have more high-risk "slices of the pie" than other incident locations.

It is reasonable to believe that GIS and multi-method crime analysis procedures can shape police department policies and practices regarding officer deployments. Many police departments are already known to focus activities on various situational and environmental risk factors at certain locations. Incorporating such a holistic approach to crime analysis and resource deployment necessitates "buy in" from agency leadership. This commitment must be institutionalized in a manner that ensures that mid-level executives and those under their command incorporate the approach into daily operations. This could be established and reinforced through standard law enforcement management strategies, such as CompStat. Existing CompStat processes could be leveraged to ensure that commanders put commensurate effort towards mitigating the underlying problems that generate crime. In addition, the "S.A.R.A" model of problem-oriented policing could be embraced in a manner that encourages commanders to devise plans that directly address the risk factors identified in a risk terrain model.

The 3-part approach discussed here could help refine and bolster police operations by providing continuous analysis of crime patterns which can be used to perform "on-the-fly" adjustments of the strategy at hand. While certain types of past crime events might be one of the many appropriate risk factors in a risk terrain model (e.g., knowledge of past armed robberies might be used to anticipate locations of future shootings), hotspots and coldspots of these events could direct analysts to places where physical audits of these environments would reveal other (underlying) aggravating or mitigating risk factors. Or, in an attempt to most accurately forecast future crime locations, a near repeat analysis of past events could reveal the best time period to model risk for in a RTM. Deployment could be informed by the findings of near repeat analyses to ensure adequate coverage in areas where crime may be likely to emerge. Patrols could be designed according to the "crackdown-back off" strategy advocated by Sherman[13] in which efforts are rotated amongst numerous target areas. Patrol could be allocated to a particular area in anticipation of near repeat incidents and then re-deployed elsewhere once a near repeat analysis suggests the potential emergence of a new hotspot.

In *Illinois v. Wardlow,* the Supreme Court held that presence in a high-crime area is one of only two factors necessary for creating reasonable suspicion to stop an individual[14]. Police, therefore, could define official "high-crime areas" for Fourth Amendment purposes[15]. But the integration of event-dependent and environmental crime analysis techniques offers a statistically valid way to more holistically articulate and communicate vulnerable areas in a way that is consistent with Fourth Amendment principles. In a prospective manner, the 3-part approach described above can articulate areas that are most likely to have higher incidences of crime based on knowledge about past crime events and the environmental attractors/generators of crime above-and-beyond crime incidents themselves. Officers can be deployed to these areas. When they observe suspicious activity, they can stop suspects based on those suspicions within the context of the high-crime/high-risk area. The 3-part approach could also be used to (retroactively) validate police officers' intuition about criminogenic places. Risk factors and other features of the environment (including past crime incidents) that comprise aspects of the totality of the circumstances of the arresting officer's actions can be studied holistically. This model of the officer's "perceptions of risk" can be empirically validated against the known spatial and temporal distributions of recent-past crimes. In this manner, "reasonableness" can be empirically validated—even in hindsight. With the information products of hotspot mapping, near repeat analysis, and risk terrain modeling, police officers can testify at trial, or another point in time (e.g., a suppression hearing), that his/her actions were reasonably influenced by personal knowledge and observations about the suspect and the criminogenic context of the environment. This reasonable, articulable, and statistically-validated rationale can factor in to the totality of the circumstances, and may justify Terry stops in a way that satisfies the requirements of *Wardlow*.

Most often a crime analyst's measure of the presence of offenders is designated as the number of crime incidents reported or arrests that are made and tabulated by police in crime reports. But there are other types of measures to use that are more enduring than the crime incident. Natural areas, according to human ecologists, are settings that have certain characteristics that lead to predictable behavioral outcomes, regardless of the character of the people living in or passing through these areas. Tying predictions of crime to geographic locations and their characteristics provides the basis for connecting attributes of space to actual behavior that occurs at these places, such as high frequencies of crimes (i.e., hotspots) or near repeat victimizations. It also takes the police beyond a tactical response to crime occurrence to one that is more strategic, anticipating where resources will be needed to respond to and prevent newly emerging crime problems.

Endnotes

[1] Cohen, L. E. & M. Felson, 1979 "Social Change and Crime Rate Trends: A Routine Activity Approach", American Sociological Review, 44 (4), 1979, pp. 588-608.

[2] Brantingham, P. & Brantingham, P. 1995. "Criminality of Place: Crime Generators and Crime Attractors." European Journal on Criminal Policy and Research 3:1-26.

[3] Observed Mean=492.27; Expected Mean=601.95; NN Ratio=0.82; Z Score=-2.51; $p=0.01$

[4] Pearson Chi-Squared value=2.78; df=1; $p<0.10$

[5] Ratcliffe, J. H. (2009, August). Near Repeat Calculator (version 1.3). Temple University, Philadelphia, PA and the National Institute of Justice, Washington, DC.; It uses the XY-coordinate and date of criminal incidents to test for statistically significant spatial-temporal patterns between all points within the data set. The patterns found are then compared to an expected pattern if no near repeat phenomenon were to exist using the Monte Carlo method.

[6] Iterations requested: 99, Spatial bands/bandwidth: 10/100, Temporal bands/bandwidth: 24/7; Manhattan

[7] Iterations requested: 99, Spatial bands/bandwidth: 10/100, Temporal bands/bandwidth: 24/7; Manhattan

[8] Iterations requested: 999, Spatial bands/bandwidth: 10/100, Temporal bands/bandwidth: 12/14; Manhattan

[9] Caplan, J. M. & Kennedy, L. W. (2010). Risk Terrain Modeling Manual: Theoretical framework and technical steps of spatial risk assessment. Newark, NJ: Rutgers Center on Public Security. [Available at www.riskterrainmodeling.com]

[10] Conceptually, risk is rarely or never absolutely zero. Therefore, environmental risk values of zero should be interpreted as the risk for crime at these places is no greater than any other place under normal circumstances.

[11] A Moran's I test indicates no spatial autocorrelation present, so a spatial lag variable was not created as a control.

[12] Pearson Chi-Square=31.40, $p<0.001$, n=4039

[13] Sherman, L. W. (1990) "Police Crackdowns: Initial and Residual Deterrence" in Michael Tonry and Norval Morris, eds., Crime and Justice: an Annual Review of Research, Volume 12, pp. 1-48. Chicago: University of Chicago Press.

[14] *Illinois v. Wardlow* 528 U.S. 119 (2000), 183 Ill. 2d 306, 701 N. E. 2d 484, reversed and remanded. See also: Andrew Guthrie Ferguson, *Crime Mapping and the Fourth Amendment: Redrawing High Crime Areas*, 63 Hastings L.J. 101 (forthcoming Dec. 2011). Andrew Guthrie Ferguson & Damien Bernache, *The "High-Crime Area" Question: Requiring Verifiable and Quantifiable Evidence for Fourth Amendment Reasonable Suspicion Analysis*, 57 Am. U. L. Rev. 1587, 1588–89 (2008).

[15] See e.g.,*United States v. Wright*, 582 F.3d 199, 222–23 (1st Cir. 2009) (Lipez, J., dissenting); *United States v. Wright*, 485 F.3d 45, 53–54 (1st Cir. 2007); *United States v. Bonner*, 363 F.3d 213, 218 (3d Cir. 2004) (Smith, J., concurring); *United States v. Montero-Camargo*, 208 F.3d 1122, 1143 (9th Cir. 2000) (en banc) (Kozinski, J., concurring).