JUSTICE QUARTERLY VOLUME 29 NUMBER 4 (AUGUST 2012)

Deterrence, Firearm Arrests, and Subsequent Shootings: A Micro-Level Spatio-Temporal Analysis

Brian R. Wyant, Ralph B. Taylor, Jerry H. Ratcliffe and Jennifer Wood

Do police firearm arrests reduce later shootings in nearby locations and in the days immediately following the arrest? This question is examined at a more detailed level than in previous work in order to better describe the spatio-temporal dynamics linking these two event types. All firearm arrests (n = 5,687) and shootings (n = 5,870) in Philadelphia from 2004 to 2007 were

Brian R. Wyant is an assistant professor in the Department of Sociology, Social Work, and Criminal Justice at La Salle University. He earned his Ph.D. in Criminal Justice from Temple University in 2010. His research interests include fear of crime, perceptions of the police, and the variation and causes of crime over time and space. His publications have appeared in the *Journal of Research in Crime and Delinquency*, *Criminology and Public Policy*, and *Criminology*. Ralph B. Taylor is a professor of Criminal Justice and (courtesy appointment) of Geography and Urban Studies at Temple University where he researches, teaches, and advises graduate students. Publications are listed online at www.rbtaylor.net/pubs.htm. Current projects include metropolitan area look-ahead crime predictions at the MCD level with Drs. Liz Groff and David Elesh, a crime risk surface heterogeneity and prediction effort led by Dr. Jerry Ratcliffe, an undergraduate quantitative literacy and competencies-building course in "Urban Crime Patterns" built substantially around season 2 of *The Wire*, and a forthcoming volume (NYU Press) tentatively titled *Communities and Crime: Metamodels Matter*. Jerry H. Ratcliffe is a professor and the Chair of the Department of Criminal Justice at Temple University, Philadelphia. He is a former police officer with London's Metropolitan Police (UK), has a Ph.D. from the University of Nottingham, and is a Fellow of the Royal Geographical Society. He has published over 60 research articles and four books, the most recent of which is *Intelligence-Led Policing* (2008, Willan Publishing). Research, training, and consulting areas include environmental criminology, intelligence-led policing, spatial analysis of crime, and crime reduction. More details at jratcliffe.net. Jennifer Wood is an associate professor at the Department of Criminal Justice, Temple University. She was previously a Fellow at the Regulatory Institutions Network, Australian National University. She is co-author of the book, *Imagining Security* (Willan Publishing, 2007) with Clifford Shearing and co-editor of *Democracy, Society and the Governance of Security* (Cambridge University Press, 2006) with Benoît Dupont as well as *Fighting Crime Together* (University of New South Wales Press, 2006) with Jenny Fleming. Dr. Wood has a Bachelor of Social Sciences (1994) from the University of Ottawa and an MA (1995) and PhD (2000) from the University of Toronto. Correspondence to: B.R. Wyant, Department of Sociology, Social Work, and Criminal Justice, La Salle University, 1900 West Olney Avenue, Philadelphia, PA 19141, USA. E-mail: wyant@lasalle.edu

ISSN 0741-8825 print/1745-9109 online/11/040524-22

http://dx.doi.org/10.1080/07418825.2011.576689

Routledge
Taylor & Francis Group

analyzed using a modified Knox close-pair method. Following a firearm arrest shootings declined significantly, 28–47% up to a couple of blocks away. These significant declines, however, lasted for just a few days. Overall, results suggest police firearm suppression effects occur, may extend up to two blocks away from a firearm arrest, but also are short-lived. Potential implications for deterrence are discussed.

Keywords deterrence; firearm violence; policing; space–time clustering

Introduction

Do arrests for illegally carried firearms suppress later firearm violence? Moore (1980) was one of the first to argue that illegal firearm carrying bred violence and that it was reasonable to expect that carrying a firearm into public places increased the likelihood of lethal violence. Therefore proactive strategies—confiscating illegally carried firearms by maximizing the number of police–citizen contacts, ensuing frisks, and/or ensuing searches of pedestrians or automobiles to increase detection of illegally carried firearms—seem like reasonable and effective police aims for preventing firearm violence (Kleck, 1991; Moore, 1980).

Several published studies have found that enforcing laws forbidding carrying concealed weapons without a permit deters illegal firearm carrying and subsequent shootings (Cohen & Ludwig, 2003; McGarrell, Chermak, Weiss, & Wilson, 2001; Moore, 1980; Sherman & Rogan, 1995; Villaveces et al., 2000). Important questions about and limitations of this work, however, remain.

Previous work has not yet explored the spatio-temporal relationships between firearm arrests and later levels of shootings using a micro-level analysis. For the purposes of this research micro-level spatio-temporal means small scale or fine-grained associations in space and time, on the order of hundreds of feet and days; such an analysis is conducted here. Looking at these links in a more disaggregated form may align the examination more closely with corresponding police and offender dynamics. Further, Berk and MacDonald (2009) have noted "crime can vary at more micro levels in interesting and important ways" and capturing fine-grained spatial and temporal variation in crime may "ultimately contribute to theory development" (972). Specifically, the current research examines micro-level spatio-temporal links between earlier police arrests for illegal possession of a firearm and later shootings, from 2004 through 2007, in Philadelphia. The goal is to learn whether firearm arrests are associated with fewer nearby shootings in the period immediately following compared to a null hypothesis of no spatio-temporal association between the two event types.

Conceptual Framework

Emphasizing the enforcement of laws forbidding carrying concealed weapons without a permit by increasing the number of firearms police seize may not

only temporarily incapacitate those who may criminally use a firearm, but also has the potential to act as a deterrent to those illegally carrying a firearm or considering doing so (general deterrence) (Nagin, 1978, 1998). The latter effect may work through either an increased police presence and/or the spread of information about arrests. If arresting people for illegally carrying firearms reduces shootings and that link depends not only on incapacitation but also general deterrence processes, and the latter are socially and spatially limited, then shootings should decline in locations near where there has been at least one arrest on charges of illegally carrying firearms for at least a short time after the arrest. Therefore, it is appropriate to consider previously cited limitations in deterrence work, and how deterrence issues intersect with questions about temporal and spatial aggregation and disaggregation, and how deterrence theorizing suggests what localized social processes may underlie the effectiveness of directed patrolling.

Research has recognized that the findings of deterrence studies are "sensitive to the levels of spatial aggregation" (Chamlin, Grasmick, Bursik, & Cochran, 1992, p. 379). Cousineau (1973) warned that areal units, used in ecological deterrence research are often too large to be homogeneous social units, and even smaller units of analysis are sometimes heterogeneous. Furthermore, these fixed boundaries may conflate or not capture the distribution of homogenous social units, which he argued is desirable for ecological deterrence research (Cousineau, 1973). Kane (2006) added "the identification of the spatial unit of aggregation that best estimates the potential for the transmission of sanction-related information via social networking across territorial areas" (190) is paramount to ecological deterrence research.

Chamlin et al. (1992) also argued that large, often heterogeneous units are inappropriate for testing the ability of police to deter crime. The transmission of information concerning police activity to potential offenders is most likely to be conveyed within neighborhoods rather than within larger areal aggregations (Bursik, Grasmick, & Chamlin, 1990). Further, Mastrofski, Weisburd, and Braga (2010) noted there is "considerable variation *within* the larger geographic spaces" in which police organize their activities (251). They hoped that attention to these micro-variations "will yield substantial gains" in determining the effectiveness of police action on crime (Mastrofski et al., 2010, p. 251). Even with the knowledge that risks of punishment vary across spatial units, the degree of variation within these spatial units "is an empirical question" (Bursik et al., 1990, p. 434).

Temporal variation is relevant as well. The appropriate temporal level of aggregation should match the dynamics implicit in processes triggering deterrence. Unfortunately, deterrence theory provides very "little guidance" in the selection of the lag (Bursik et al., 1990, p. 436). Thus far ecological deterrence impacts have been found to appear in very short order, for example within a day (D'Alessio & Stolzenberg, 1998) or three months (Taylor et al., 2009), but not when a lag of a year is used (Greenberg, Kessler, & Logan, 1979).

In short, theoretical consideration about the spatial heterogeneity of policing activities in a location, and the work in ecological deterrence suggesting such processes can happen on short time or spatial scales, drives attention to more micro-level dynamics. There are additional theoretical considerations also directing attention to the micro-level. These concern the role of indirect experience learned from others in one's social network.

Risk perceptions will be based not only on one's own experiences, but also those in one's social networks (Cook, 1979). Others have drawn similar conclusions. A study of burglary offenders for example revealed they in part calculated their risk of apprehension through not only their own experiences but also via social networks (Parker & Grasmick, 1979).

More recently, Stafford and Warr's (1993) reconceptualization of deterrence theory made similar points. Specifically for illegal firearm carrying, Stafford and Warr (1993) argued that direct experience with apprehension and punishment for various crimes might diminish future illegal firearm carrying. If one consistently commits crimes without being detected, however, and/or hears about others who have done so, he or she may feel more confident in illegally carrying a firearm. The same holds true for indirect experiences with punishment and punishment avoidance. Offenders might know others who have been arrested or people who have committed crimes and were not detected, thereby influencing the offender's perceptions of apprehension and thus their own behaviors.

Policing Illegal Firearm Carrying

The empirical work linking earlier police actions and later crimes is quite diverse. It focuses on a broad range of police actions, including firearm carrying itself, and often relies on some type of ecological deterrence model (Cousineau, 1973). The ecological deterrence literature is far more extensive than presented here, and includes studies examining deterrence at the city level with a year lag (Greenberg & Kessler, 1982; Greenberg, Kessler, & Logan, 1981; Greenberg et al., 1979) or a day lag (D'Alessio & Stolzenberg, 1998), as well as some work at the police district level (Taylor et al., 2009). Further, geographically targeted policing has been associated with reduced crime across a wide range of offenses, even though the impacts may be short-lived (Skogan & Frydl, 2004). That work is not reviewed in detail here given its scope and perhaps limited relevance, and in light of the size of the spatial and temporal units used in the current work. The broader theoretical frame within which that work is conducted is nonetheless examined and extended later in the section.

Perhaps the most widely known study of the effectiveness of directed police patrol and firearm seizures to reduce shootings was conducted by Sherman and Rogan (1995) in Kansas City, MO. It is presented in detail, as are two others that sought to replicate it. Concerns and limitations are then noted. Using a

quasi-experimental design Sherman and Rogan (1995) tested whether greater enforcement of laws prohibiting the carrying of concealed weapons would reduce shootings. Beginning 7 July 1992, and ending 27 January 1993, the Kansas City Police department deployed extra patrol officers in a target beat (0.64 square miles) with a homicide rate several times the national average. Before the intervention, during the first six months of 1992 there were 46 firearms seized in the target beat. By contrast, in the last six months of 1992 with directed patrol of firearm hotspots, there were 76 firearm seizures (Sherman & Rogan, 1995). The increased firearm seizures was accompanied by a decrease in firearm crime, specifically, 86 firearm crimes were reported during the six months of intervention compared to 169 in the preceding six months, nearly a 50% decline.

An attempted replication in Indianapolis in 1996 used a pre-posttest quasi-experimental design with a non-equivalent control group (McGarrell et al., 2001). Two treatment beats with some of the highest rates of drug distribution, violent, and property crimes received directed patrol and additional officers. Researchers compared changes in the number of firearm seizures and firearms-related violent crime for the 90-day period during directed patrol with the same 90-day period in the prior year (McGarrell et al., 2001). Important design differences between the Kansas City and Indianapolis study included using two target beats (north and east) rather than one, and a much larger treatment area, approximately four times larger than the target beat in the Kansas City study.

During the intervention a total of 42 firearms were seized in the north target area and 45 firearms in the east target area, representing, respectively, 8% and 50% increases compared to the same period a year previous. In the north beat, firearm crimes decreased by 29%, other firearm assaults and armed robberies dropped 40%, and homicides decreased from seven to one compared to the same 90-day period the previous year. In the other target area, the east beat, there was a decrease in homicide compared to the same period a year previous, from four to zero, but total firearm crimes increased (McGarrell et al., 2001).

The second attempted replication took place in Pittsburgh. Two of the city's six patrol zones received extra evening patrols for a 14-week span during the fall of 1998. Police in the intervention areas worked proactively, focusing on the detection of illegally carried firearms and not responding to citizen calls for service. The two intervention patrol zones were about nine square miles each with approximately 55,000 and 80,000 residents, and had the highest crime rates in Pittsburgh. Seeking to avoid using control areas located elsewhere, directed police patrols only occurred Wednesday through Saturday within the target areas permitting the comparison of treatment and control days within the same locations (Cohen & Ludwig, 2003). Daily time-series analysis showed treatment days associated with reductions in both shots fired (34%) as reported to police and hospital-treated assault gunshot injuries (71%).

During the treatment days ($14 \times 4 = 56$) two firearms were confiscated in one patrol zone, 12 in the other (Cohen & Ludwig, 2003).

Conclusions, Limitations, and an Extended Conceptual Framework for the Link

What conclusions are suggested by these works on police patrol-based firearm interdiction? Studies of intensive police patrol in areas with high levels of shootings have produced results suggesting intensive patrol in places with high violent crime rates may reduce shootings (Koper & Mayo-Wilson, 2006). Sherman (2001) has argued that uniformed patrol of firearm hot spots is one of only a few strategies aimed at reducing firearm violence that is known to "work" (17).

How solid is this conclusion? This group of studies has weaknesses. Koper and Mayo-Wilson in their 2006 systematic review on the impact of police crackdowns on illegal firearm carrying and firearm crime noted that the "inferences are limited" due to a "small number of available trials (which were not all independent), variability in study design and analytical strategies, and the absence of randomized trials" (248). Of course study proponents such as Sherman (2003) have argued that great care was taken to make comparison areas comparable to control areas to better "draw substantial inferences even without random assignment" (243). But, Koper and Mayo-Wilson (2006) have cautioned that the target areas and comparison areas may differ in significant ways. Further, Kleck (1997) has noted that in the cases of Kansas City the impressive drop in firearm crime may have been a result of a regression to the mean as pre-experimental firearm violence was unusually high and states it "remains to be seen" whether greater enforcement of laws prohibiting the carrying of concealed weapons reduces firearm crime (210).

Perhaps even more importantly, as McGarrell et al. (2001) warned, the causal mechanisms producing the reduction in firearm crime as a result of directed patrol remains unclear. They hoped future studies would "isolate the causal mechanisms of directed patrol initiatives" (145). If the studies had found roughly temporally or spatially corresponding increases in firearms confiscated and decreases in shootings or injuries reported, it would be clear that firearms were being removed and shootings were decreasing correspondingly. Not only were firearm removals generally low in many of these studies, the temporal and spatial parameters of six months/0.64 square miles in Kansas City (Sherman & Rogan, 1995); 90-days/2.79 square miles the North District Indianapolis; 90-days/1.69 square miles in the East District Indianapolis (McGarrell et al., 2001); 14-weeks/8.9 square miles in Patrol Zone One; 14-weeks/9.4 square miles in Patrol Zone Five in Pittsburgh (Cohen & Ludwig, 2003) might have obscured the role of the arrests on later firearm violence. The intensity, length and type of areas required to elicit optimal deterrence

are not clear (Sherman, 1990). On one hand, the long-term accumulation of police actions over larger areas might produce the strongest deterrent effect. On the other hand, perhaps the study areas were too large for detecting the relevant casual dynamics.

The conceptual implications are the following. First, when considering the impacts of police firearm arrests on later shootings it makes sense to focus on the most immediate socio-spatial surrounds, because it is through localized networks that others will learn about firearm arrests. Urban residential street life is often organized on the streetblock basis in the core neighborhoods of older eastern industrial cities (Taylor, 1997). This suggests an area around a shooting with about a 400-foot radius, comparable to a street block's length. Of course, residents have social ties off the block and nearby, so impacts spreading to nearby blocks also may show patterns of decreased shootings following firearm arrests. Large spatial units might not identify or might conflate relevant spatial disparities affecting illegally carried firearms, police arrests for illegally carried firearms, and shootings occurring within these spatial units. Further, even smaller spatial units developed to portray homogeneous populations still may not capture the spatial variation influencing offender and police behaviors; these dynamics may connect across the spatial units used because events in one unit may be influenced by dynamics in nearby but separate spatial units. Unfortunately, the appropriate level of spatial aggregation to measure dynamics related to offender and police behavior around shootings is not known. Multiple dynamics might be operating at different levels.

Second, research has observed deterrence effects taking place within a day (D'Alessio & Stolzenberg, 1998). Further, as described in the above dynamics, impacts of more intensive policing action can fade quickly (Ross, 1982). Data analyzed yearly, quarterly, or monthly may obscure key features of links between police arrests for illegally carried firearms and shootings. Therefore, it makes sense to concentrate at the scale of days rather than weeks.

In sum, an investigation at a more micro-level than has previously been researched may be a valuable complement to earlier studies focusing on illegal firearm reduction. Despite the previously mentioned studies it is not clear whether police firearm arrests themselves play a causal role in reducing firearm violence. Examination of the link at a finer spatial and temporal scale aligns with described localized theoretical processes and may reduce these ambiguities; the challenge now is to locate a technique that permits the proposed micro-level explorations. The Knox close-pair method can be appropriately adapted for current purposes.

Data and Methodology

The data used in this study were comprised of shootings, including criminal homicides, robberies, and aggravated assaults by firearm, as well as Violations of the Uniform Firearms Act (VUFAs) occurring within the City of Philadelphia from 1 January 2004 to 31 December 2007. These data were obtained from the Philadelphia Police Department's (PPD) Incident Transmittal System (INCT).

The INCT data are primarily the result of two sources, citizen-prompted police response and police-initiated responses. Citizen calls placed to 911 are transmitted to the Philadelphia Police Department's Computer-Aided Dispatch (CAD) system where calls are prioritized by seriousness and officers dispatched accordingly. Calls that result in an officer dispatch, and which at the time of the response the officer deems a credible incident are then classified according to the FBI's Uniform Crime Reporting (UCR) system. Unlike calls for service that may generate numerous calls in response to a shooting, the INCT collapses these multiple calls and/or a police-initiated response into a single incident.

In addition to shootings in Philadelphia, the current research also examined arrests for carrying a firearm without a license in Philadelphia. The Pennsylvania Uniform Firearms Act (UFA) introduced in the early 1990s, and subsequently passed in 1995, detailed in part that a person may not carry a firearm in public, concealed on his or her person or in a vehicle, without a valid and lawfully issued license (Title 18, Chapter 61, Section 6106). When an individual breaks at least one of the specific statutes in the UFA, he or she is subject to penalties detailed in the Act. The charges may be referred to as Violations of the Uniform Firearms Act or VUFAs.

Based on INCT data, during the years 2004—2007 there were 5,870 total shootings, 1,152 of which resulted in death (homicide) and 4,718 that did not (aggravated assaults and robberies by firearm). During the same period there were 5,687 total VUFAs (see Table 1).[1]

1. Although some research has highlighted the importance of sentencing enhancements as part of effective law enforcement initiatives to decrease violent crime (e.g. Rosenfeld, Fornango, & Baumer, 2005), arrests alone may still elicit a deterrent effect. It is certainly true that an arrest does not always lead to a conviction and additional sanctions, but the arrest itself arguably constitutes a type of sanction. Further, the arrest follows soonest after a shooting. Survey results of an adult population in three states revealed that most people did not differentiate in terms of the unpleasantness of being arrested, convicted, or incarcerated (Tittle, 1973 as cited in Tittle & Rowe, 1974). Arrests, therefore, with or even without additional sanctions might function as punishments for and potential deterrents to criminal activity. Additionally, the use of arrest data may be more desirable than focusing on the certainty and severity of punishment after an arrest. Kohfeld (1983, p. 460) pointed out potential criminals may know if "arrests occur in their neighborhood" but argued "it is unlikely that criminals know either clearance rates or arrest ratios." The immediacy of a visible arrest is likely to resonate with potential criminals. The arrest creates a heightened threat of apprehension, whereas potential criminals are likely uninformed about the proportion of those arrested who are ultimately convicted, and about the sanctions arrestees receive. Although arrests may be a suitable measure, future research would be served by considering the sanctions attached to arrest, particularly in light of findings that firearm violence might be decreased as a result of sentencing enhancements (e.g. Rosenfeld et al., 2005).

Table 1 Yearly shooting and VUFA totals: 2004–2007

	Shooting totals	VUFA totals
2004	1,384	1,462
2005	1,425	1,427
2006	1,656	1,498
2007	1,405	1,300
Totals	5,870	5,687

Totals based on INCT data provided by the Philadelphia Police Department.

For the purposes of the current study, shootings were geocoded [assigned (x) and (y) coordinates] to incident locations[2] and VUFAs were geocoded to the street address of the arrest. It was not possible to distinguish between apartments in the same building. Overall, out of a total of 11,557 shootings and VUFAs recorded by the Philadelphia Police from 2004 to 2007 over 99% (11,511) were successfully geocoded. The geocoding hit rate (successfully geocoded) for shootings and VUFAs was well above the 85% threshold suggested by Ratcliffe (2004) as a first estimate of a minimum reliable geocoding rate. Using the standard projected coordinate system for South Pennsylvania (NAD 1983 State Plane Pennsylvania South FIPS 3702 Feet), the locations of each shooting and VUFA were recorded in feet to best facilitate the calculation of Manhattan distances.

Analytic Method

A spatio-temporal clustering technique was used to determine whether the number of VUFAs and shootings are associated in space and time at a micro-scale, or if VUFAs and shootings are independent of each other. Stated differently, the current investigative method was a new approach to determining whether shootings link to arrests for illegal firearm carrying at the scales of days and hundreds of feet.

The method used in this study draws from the Knox close-pair method, originally used to study the communicability of disease. The Knox method identifies whether an excess of observed event pairs occur more closely in space and time than one would anticipate based on chance (Townsley, Homel, & Chaseling, 2003). The Knox close-pair method, a modified version of which is used here, was first used to identify space–time clusters of childhood

2. Two patrol districts, 77 and 92, cover Philadelphia International Airport and Fairmount Park, the latter a large urban park/green space. Both of these differ significantly from the patrol districts because of land use and the lack of residential population (Philadelphia Police Department, 2007) and were therefore excluded from analyzes.

leukemia. In a study of the epidemiology of childhood leukemia, Knox (1964) observed that cases of childhood leukemia clustered in space *and* time.[3]

Originally the Knox method called for a comparison of the observed values from each cell of the contingency table with the adjusted residual value for each cell. Ratcliffe and Rengert (2008) pointed out, however, that since the Knox method assesses the significance of the departure of observed values in the contingency table from the expected values conditional on the marginal totals, it possibly violates an assumption of independence of observations.

To combat the potential issue of a lack of independence, researchers (see, Johnson & Bowers, 2004a, 2004b; Ratcliffe & Rengert, 2008; Townsley et al., 2003) built on the work of Besag and Diggle (1977) using a Monte Carlo simulation to shuffle dates for each event. They randomly shuffled the dates repeatedly (the exact number of times is at the researchers' discretion but 99 permutations are common) to create a number of contingency tables. For each cell, these shuffles created a distribution of expected values. The observed value for each cell could thus be placed on the distribution of expected values for that cell, generating both an expected ratio (observed values/mean of expected values), and a pseudo-probability with the latter based on the placement of the observed value on the distribution of expected values.

The Knox method can be applied to behavioral or social phenomena following spatio-temporal patterns (Jones & Jones, 2000). For example, research has examined if past burglaries increase probabilities of later burglaries nearby (Townsley et al., 2003) or if past shootings increase chances of future shootings nearby (Ratcliffe & Rengert, 2008). More recently, one study to date has examined whether two different types of crime (burglary and theft from motor vehicles) were spatio-temporally connected (Johnson, Summers, & Pease, 2009). When used to study crime, researchers (e.g. Johnson & Bowers, 2004a; Johnson & Bowers, 2004b; Ratcliffe & Rengert, 2008; Townsley et al., 2003) have noted that the primary benefit of using the Knox method is its ability to test for clustering of events in both space *and* time. The present work goes beyond the earlier work by testing whether *different* phenomena, in this case shootings and police arrests for illegally carried firearms, are linked spatio-temporally, using a modified version of the Knox (1964) close-pair method to describe the patterning.

3. Knox (1964), to identify these interactions in space and time, paired each childhood leukemia case with every other childhood leukemia case; thereby N cases produce $N(N-1)/2$ distinct pairs (Townsley et al., 2003). Spatial and temporal distances between all possible pairs were aggregated into a contingency table where rows and columns outlined spatial and temporal intervals. Examining 185 cases of childhood leukemia in the North of England over a 10-year period, Knox considered cases in a pair close in space if the two events were less than one kilometer apart. Cases in a pair were considered close in time if they occurred within 60 days of each other (Knox, 1964). Next, the number of pairs of childhood leukemia cases considered close spatially and temporally were compared to the expected count if the pairs had been distributed randomly in both space and time. Case pairs exceeded what would be expected under the assumption of random spatio-temporal processes generating random patterns. The non-random arrangements, he concluded, arose from contagion processes (Knox, 1964).

Analysis Plan

Using much of the same logic and methods described above, the current research explores whether there is evidence of space–time clustering of a VUFA and later shootings. The data were analyzed using a C#.NET program originally written by Dr. Jerry H. Ratcliffe to specifically compute multiple simulations of the expected values, and modified for this research. Using C# programming language to create an executable program for Windows, the program, originally created to examine space–time relationships between a single type of phenomenon, was modified to read the data and create an observed matrix of space–time associations among two different types of phenomena, in this case VUFAs and shootings.

The distance parameter is 400 feet and the time parameter two days. The 400-feet increments were selected because the Philadelphia streetscape supports using bandwidths of 400 feet, as many city blocks are approximately 400 feet and street blocks serve as important settings for both crime (Taylor, Gottfredson, & Bower, 1984) and reactions to crime (Taylor, 1997). Turning attention to the selection of the temporal parameters, relatively small time increments (two days) were used as offenders consider the "immediate characteristics of the situation" when contemplating whether to commit a crime (Cusson, 1993, p. 60).[4]

The 400 feet/two-day increments were extended up to 2,800 feet (approximately one-half mile) and up to 14 days. The remaining event pairs with distance and temporal periods greater than 2,800 feet and 14 days are calculated and aggregated in the final column or row.[5] This results in a contingency table with 8 columns and 8 rows. Finer increments are not feasible because the resulting cell frequencies are too small.

Given the above discussions about deterrence dynamics, of most interest in these analyses will be cells reflecting just a few days, say up to about a week, and reflecting just two or three blocks, say up to about 1,200 feet.

Once the contingency table is developed and populated, the cell counts are contrasted with the null-hypothesis condition (the expected values based on a random distribution). Contrary to the prior work in the near-repeat framework, the current work seeks to uncover patterns where the observed values of shootings will be *lower* than the expected values. Additionally, in contrast to

4. In order to determine whether the patterns observed were dependent on the cutoff points chosen additional analyses were conducted (not shown) where the spatial and temporal periods were lengthened and shortened.

5. Research has noted that as the distance intervals increase so does the area covered. Stated differently, a distance of 400 feet from an event encompasses a much smaller area than a distance of 800 feet which encompasses an area more than twice as big as the first interval (Rengert, Piquero, & Jones, 1999; Turner, 1969). The equal radius buffers result in different areas with larger areas allowing more opportunities for events to be present. This potential limitation is not problematic as the Monte Carlo simulation takes into account the base rate differences between areas that shape the observed counts by distance.

traditional near-repeat analyses that generate events pairs by calculating the distance and time between all events, the modified program calculates the distances and elapsed times focusing only on VUFAs that occurred before a shooting. Since it is expected that a VUFA influences the likelihood of later shootings, event pairs between a later VUFA and earlier shootings are not constructed. A finding that the observed number of shootings are less than the expected count every time results in a pseudo *p*-value of .01. An effect size below one indicates that observed shootings are less likely to occur than expected under a random distribution.

Results

Table 2 shows Knox ratios (observed values over the mean expected value) for VUFA and later shooting pairs analysis across Philadelphia for the years 2004—2007.

Given Maltz's (1994) discussion of the potential pitfalls of focusing only on statistical significance, observations on the general patterning of the ratios are offered first. The general pattern in Philadelphia of the Knox ratios in the top left of the table—the three closest periods and distances—are theoretically the most relevant.

Three Knox ratios in the top left corner of the table are slightly above one, but the majority of Knox ratios in the top three rows and three left-most columns of the table are below one. Knox ratios below one indicate an under-representation of shootings compared to expected values.

In the first row (1—400 feet), within about a block of the arrest, it appears that shooting incidents continue at around the expected rate very close to the

Table 2 Philadelphia observed over mean expected frequencies (VUFA and later shootings: 2004—2007)

	Days between events							
Distance between events	0—2 days	3—4 days	5—6 days	7—8 days	9—10 days	11—12 days	13—14 days	15 + days
1—400 ft	1.05	1.17	**0.53***	0.84	0.89	1.76	1.06	1.00
401—800 ft	1.22	**0.72***	0.75	0.79	1.18	0.80	0.97	1.00
801—1200 ft	0.77	0.95	0.90	0.85	**0.65***	0.94	0.79	1.00
1201—1600 ft	1.02	0.93	0.98	0.87	0.84	0.86	0.95	1.00
1601—2000 ft	0.81	0.95	0.99	0.84	0.85	0.88	0.80	1.00
2001—2400 ft	0.92	0.83	0.89	0.84	1.13	0.92	0.85	1.00
2401—2800 ft	0.85	0.98	0.81	0.89	1.02	0.99	0.92	1.00
2801 ft+	**0.95***	**0.97***	**0.94***	**0.94***	**0.97***	**0.97***	**0.93***	1.00

Events = 11,511 (VUFA *n* = 5,652; shooting *n* = 5,859); event pairs = 17,347,253. *p = .01.

VUFA, but incidents decline noticeably after a few days. Specifically, Knox ratios are initially and non-significantly above expected values, but after four days the statistically significant Knox ratio of 0.53 in the 5—6 days cell indicates the chance of a shooting incident after a VUFA was about 47% lower than if there were no spatio-temporal connection.

About two blocks away, in the second row (401—800 feet), shooting incidents were initially slightly above one but subsided fairly quickly. Later in the 3—4 day (0.72) cell the Knox ratios dropped significantly below one; therefore following a single VUFA arrest a block to two blocks away shooting incidents after a slight delay were significantly suppressed by 28%.

In the third row (801—1200 feet), two to three block distance from the preceding arrest, Knox ratios were below one, as anticipated. In contrast to the results from the first two rows, however, none of the Knox ratios at this distance in the period immediately following a VUFA were statistically significant.

Another way to describe the pattern is by focusing on the nine top-most, left-most cells, and examining the line separating ratios above one from ratios below one. For the first three distance buffers and the first three periods that line separates ratios into two clear sets of cells and the positioning of the line perhaps traces two competing dynamics. In Philadelphia at least, shootings beget more shootings nearby and soon after (Ratcliffe & Rengert 2008). It is possible that a shooting which preceded the initiating VUFA for each even pair analyzed here had set in motion a "shooting begetting shootings" dynamic whose echo explains these ratios slightly above one.[6] But competing against this dynamic, VUFAs might be creating deterrence, reflected in ratios below one, that progressively encroaches on the first dynamic, eventually, surfacing within a block's radius.

Stated differently, the initial Knox ratios slightly above one might suggest that police are encountering spates of shooting incidents, the near-repeat phenomenon for shootings identified by Ratcliffe and Rengert (2008), and responding by making firearm arrests. Further, the initial Knox ratios slightly above one might outline the duration and distance of shooting flare-ups; therefore, in the first two days after a VUFA, and up to about two blocks away from the arrest, a diminishing violence flare-up continues in space and in time. Whether the violence flare-up would have been more elevated, or more prolonged, or more spatially extensive without the VUFA, is not known.

Perhaps most importantly for policy and theory, the observed patterns arguably suggest that firearm arrests might play a role in driving down later shootings nearby. The depressed levels of shootings offer support for a deterrence

6. Ratcliffe and Rengert (2008) found a significant over-representation of shooting incidents within 14 days and 400 feet of previous incidents. In contrast to the Ratcliffe and Rengert (2008) study, the current research considered the temporal order of events and also used finer temporal parameters (2 days); thus, it is not clear if a near-repeat pattern would have been discovered by Ratcliffe and Rengert using smaller time intervals or if the near-repeat patterns would be much more pronounced when they are closer in time to the initiating incident and wane as time passes.

perspective. Because the depressed levels appear closer in space and time than has been seen in earlier works, the suggestion of causal dynamics is stronger.

Although many of the Knox ratios throughout the table are below one, because they are not statistically significant at the 0.01 level, are not clearly temporally patterned, and are farther away in space or time or both, it is unlikely these depressing effects are due to a single firearm arrest. The small but significant string of cells in the 2801+ feet rows was statistically significant in the theoretically expected direction. The significant ratios discovered almost one-half mile away, however, do not likely reflect deterrence as the declines generally appear too far away from the initiating VUFA rather than soon after in the cells in the very small-scale area as theoretically anticipated. The patterning is likely a result of the general spatial patterning of firearm violence throughout the city. In Philadelphia from 2004 to 2007 over half of the shooting incidents analyzed occurred in only seven of the 25 police districts, primarily in portions of North and to a lesser degree West and South Philadelphia. Arrests concentrated in one "hot spot" of violence are paired with the shooting incidents concentrated in other areas of the city that are at least half a mile away.

To summarize, although the observed pattern of non-significantly elevated space—time clustering of shootings soonest after and closest to the initiating arrest is initially the reverse of anticipated, it may be consistent with what is known about near-repeat patterns of shootings, and eventually there does appear to be a rather abrupt drop in shootings—at least for a time—as theoretically predicted.[7]

Discussion

The section below offers potential explanations regarding the observed patterns of VUFAs and shootings in relationship to deterrence theory and incapacitation.

7. Prior research has demonstrated that police and criminal responses to arrests may vary under different community conditions (Klinger, 1997; Kohfeld & Sprague, 1990; Smith, 1986). Therefore, additional analyses were conducted separately by each of the six city police divisions in Philadelphia to explore possible variation in the patterns uncovered across different sections of the city. The varying community composition and violence levels found in each division, however, did not considerably alter the results. Conducting analyses by police divisions potentially introduces the analytic concern of edge effects but performing only a city level analysis may mask variation occurring in different parts of the city. Hence, analyses are conducted across both the entire city and by police divisions. The portion of the analysis that examines whether or not results are replicated across differing parts of the city is in part dependent on the construction of the areas under study. Although the use of different boundaries within the city may result in different findings, the use of very small boundaries is not feasible as the cell frequencies are not large enough to conduct the analysis. Additionally, the use of an event-centered conception of location and multiple microspatial increments within these given boundaries may best capture underlying dynamics that may influence offender and police behavior, thus assuaging this concern. However, an important next step for future research is to better determine the spatial complexity of the relationships between firearms arrests and subsequent shootings by better situating the events in smaller and better defined geographies to highlight the social ecological contexts within which these events occurred.

Perhaps the most important practical implication of the current results comes from the finding that, after a short temporal and spatial lag, shootings drop significantly below expected levels within about a week and within a block or two from the initial arrest. This finding could support the idea that firearms arrests suppressed later shootings. Although the Knox ratios were initially slightly above one (top left corner of table), the decline in shootings after a VUFA is what would be expected with a fading of a near-repeat shooting phenomenon. Having the ratios dip *significantly* below their expected level is in line with a deterrence model. Soon after and close to a firearms arrest, the chances of a subsequent shooting incident were about 25—50% less than expected if the events were not spatio-temporally related.

Generally, studies have not been explicit about how much time must pass before an arrest affects later criminal activity, or about the strength of those associations. This confusion was noted by Cousineau (1973), and work since then has suggested deterrent temporal lags of a day to a year, depending on the unit of analysis.

Instead of a VUFA prompting an immediate decline, fewer shootings appeared to show up a short time later. Specifically, the patterns suggested that significant effects of an illegal firearms arrest on later shootings did not materialize for approximately two days. Why the lagged or sleeper effect?

Assuming deterrent effects are mechanisms leading to the decline, the delay may represent the time needed for information about police actions to reach others in nearby locations (Stafford & Warr, 1993). Alternatively, if near-repeat shooting dynamics (Ratcliffe & Rengert, 2008) were operating locally in relationship to an even earlier (and unmeasured here) shooting that led to the VUFA in the first place, those dynamics may have taken time to dissipate. Further work can hopefully investigate which process better explains the lag structure.

So significant suppression of later shootings following a VUFA appeared. But how long did suppression last? Although past work has demonstrated that ecological deterrence effects from police crackdown actions per se are often short-lived (Ross, 1982; Sherman, 1990), there is still considerable ambiguity about the longevity of deterrence effects. Here, shootings remained underrepresented for about a four-day period in the nearest/closest cells. Non-significant Knox ratios below one extended up to ten days but with increasing time and distance causal possibilities become clouded. Thus two to six days may represent the approximate time span in which shootings are clearly suppressed following a VUFA. The long-term prevention implications for effort levels needed in programs centered on police seizing illegal firearm are both troubling and daunting. The temporally lagged appearance of Knox ratios nearby significantly below one might be evidence that incapacitative effects were *not* responsible for the patterns seen here. Removing a dangerous individual may reduce local tensions and shootings in a small-scale area. It is less likely, however, to be associated with a reduction in shootings over a much wider area. Incapacitative effects, given the small sized buffers used here,

arguably should have produced more immediate and spatially narrower impacts.

In addition to exploring the amount of time that must pass before an arrest affects later shootings, the current research sought to clarify the spatial patterning. In Philadelphia, from three to six days after a VUFA, two Knox ratios were significantly below one. In the 5—6 days and 1—400 cell as well as the 3—4 days and 401—800 feet buffer shootings were below expected values — approximately the equivalent of a city block or two from the initial arrest.

Because the lower-than-expected shootings were well patterned only in a small area, there may be theoretical implications. If one assumes deterrence dynamics were operative, one might rule out deterrence via the dissemination of a threat estimate through media outlets. The information did not appear to reach a wider audience than local social networks alone would permit. Instead, the localized nature of the patterns suggest that the transmission of the threat estimate may be a result of a local social learning process, one shared through local criminal networks as argued by Stafford and Warr (1993).

In sum, despite the initial slight over-representation of shootings observed after VUFAs, patterns seen here support the shooting-reducing capacity of police effort in the form of VUFA arrests. After the firearm arrest and following a slight temporal lag, shootings began to calm down, as shown by the temporal and spatial drop-offs to levels significantly below expected. The calming down could represent the fading of a near-repeat shooting pattern followed by localized deterrence dynamics. Arguably implicit in the findings is that risk-related information about police actions is transmitted rapidly, but *not* instantaneously.

Broadly speaking, this pattern of findings highlights some of the difficulties gauging deterrence; potential impacts appear to be very short-term, very spatially limited, and differentially operative at micro-spatial scales. If this is the case broadly, it is unlikely that well-patterned deterrence impacts could have been uncovered in other studies using larger space and/or time lags. Even temporal increments of one-week might have conflated the initial non-significant over-representation with the subsequent significant under-representation. Likewise, even relatively small spatial units such as census block groups might have failed to differentiate these sudden changes in shooting levels. The relevant work does appear to reduce firearm violence, just not for very long time or for very far.

Turning attention to the non-significant over-representation of shootings primarily in the 1—400 feet/0 to 2 days, 1—400 feet/3 to 4 days, and 401—800 feet/0 to 2 days cells: Assuming police are reacting to specific areas characterized by a temporary flare-up of shootings, as would be expected given previous findings about near-repeat patterns of shootings in Philadelphia (Ratcliffe & Rengert, 2008), and making a firearm arrest, it may be expected that high levels of violence are occurring near and soon after a VUFA. Therefore, if police officers are reacting to violence and making firearm arrests in the temporal/spatial center of a flare-up, one would expect a slightly high level of shootings

there. In this instance, the firearm arrest is construed not as having an immediate impact to reduce firearm violence, but rather as an organizational response centered spatially and temporally on a prior shooting incident.

Limitations and Strengths

The present study sought to extend knowledge about policing and deterrence by better capturing close associations in space in time between VUFAs and shootings. The results, however, must be considered in light of important study limitations.

First, given the method used here, it would be improper to conclude that results demonstrate a direct causal link. The modified version of the Knox approach uncovers spatio-temporal patterning and determines when these patterns are significantly different from what would be expected if the events were completely independent. There is an endogeneity problem, that is, the potential for omitted and therefore unmeasured variables (see, Dietz, 2002; Duncan, Magnuson, & Ludwig, 2004). It was not possible to distinguish whether the police, other criminal justice organizations, or non-criminal justice agencies conducting operational strategies or programming might have influenced crime and the manner in which police conducted themselves over the four-year period.

More broadly, processes at higher levels of spatial or temporal aggregation may be linked to shootings over time and space (Ratcliffe & Rengert, 2008) in spatially or temporally covarying ways. For example, economic growth (Becker, 1968), changing demographics (Blumstein, 2006), concentrated disadvantage (MacDonald & Gover, 2005), and expanding drug markets (Levitt, 2004) are just a few common explanations for changes in crime and shootings. Clearly, these factors can have impacts independent of police efforts to detect and remove firearms.

On the other hand, some of these broader exogenous factors may not be relevant here. These factors are often operationalized at too macro a level to synch up with the short-term changes in nearby locations considered here. Another important avenue for future research is the development of a more comprehensive micro-ecological theory about variations in shootings (Cork, 1999), and how those micro-ecological dynamics are simultaneously conditioned by but also can shift more macro-level dynamics and conditions.

Second, the current research was not able to make distinctions among various circumstances surrounding VUFAs and shootings. For example, an illegal firearms arrest made at a time and place that is highly visible and thus witnessed by others might convey a greater deterrence message than a firearms arrest that occurs in a household.

Third, the observed patterns are based on incident pairs with single initiating events. The underlying assumption is that a single VUFA can drive down later shootings. But, the accumulation of VUFAs might result in larger reduc-

tions of subsequent shooting suggestive of deterrence. Further, it is not clear what other types of arrests were happening in the same period and nearby, particularly arrests for serious crimes that involved the use of a firearm. Criminals may not distinguish among the specific types of arrests (Cornish & Clarke, 1987). An ideal approach would be to create polygons around multiple VUFAs (and potentially other arrest types) occurring close to each other in space and time, and to analyze each polygon. The currently modified program, however, does not have that capability, but examining impacts of multiple events may be a valuable avenue for future research.

One final limitation emerges from the current analytic procedure used. Given the newness of this technique, it is not certain whether Monte Carlo procedures for generating expected distributions are likely to generate an inflated experiment-wise alpha rate across an entire set of cells. In order to counterbalance this potential concern, attention was focused just on the nine cells in the three time buffers and distances soonest after and closest to an initiating event, which also were the most theoretically relevant given earlier work; ratios which were not well patterned were not emphasized; and considerable attention was devoted to the patterning of the ratios within these nine cells, following Maltz's (1994) advice.

Perhaps partially mitigating these limitations is the current work's focus on micro-level spatio-temporal patterning. Arguably the close temporal and spatial proximities of the VUFAs and shootings highlighted here—up to six days apart, and up to three blocks apart—strengthen the likelihood that the two event types are meaningfully rather than spuriously related. This idea and association illustrates the first law of geography, "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236). An additional strength is that the current work, in contrast to prior research using the Knox approach, takes into account the sequence of events. By doing so it narrows the range of relevant plausible causes.

Conclusion

When police made a firearm arrest, a violence prevention benefit in the form of fewer people being shot did appear after a lag. A single firearm arrest did eventually, after a couple of days, result in fewer shootings. Shootings remained (non-significantly) higher than expected immediately after an arrest, in support of previously documented near-repeat shooting patterns in Philadelphia, but following a step-like pattern, and in line with a deterrence model, dropped to significantly lower-than-expected levels.

There are, of course, serious counter-arguments to such policing procedures. For example, scholars question whether the police tactics will be racially neutral (Fagan & Davies, 2000) and whether, even with training, police are capable of carrying out searches where a high proportion of their stops, even at high gun crime times and high gun crime places, will result in a confis-

cated weapon (Moss-Coane, 2006; Moss-Coane, 2008). Intrusive policing can be very tough on innocent citizens (McArdle, 2001). But proactive policing which results in the detection of illegal firearms also, at least given the research in this area, can get firearms off the street and increase safety.

Future research on police arrests for illegal possession of firearms and shootings might benefit by considering finer-grained spatial and temporal units. Data analyzed across entire cities, police districts, patrol beats, census tracts and yearly, quarterly, or monthly intervals is certainly valuable but at the same time might conflate various localized impacts, and thus obscure basic features of associations between police arrests for illegal possession of a firearm and later shootings.

Acknowledgments

The first author was partially funded by Grant # 2009-IJ-CX-0026 from the National Institute of Justice, Ralph B. Taylor, Principal Investigator. Materials included here represent neither the opinions nor the official policies of Temple University, the Department of Justice, the National Institute of Justice, or the Philadelphia Police Department. The authors would like to thank Alison LaLond Wyant, Evan Benshetler, Travis Taniguchi, John M. MacDonald, the editor, and three thoughtful reviewers for helpful comments on earlier drafts, and the Philadelphia Police Department for data access.

References

Becker, G. (1968). Crime and punishment: An economic approach. *Journal of Political Economy, 76*(2), 169-217.

Berk, R., & MacDonald, J. (2009). The dynamics of crime regimes. *Criminology, 47*(3), 971-1008.

Besag, J., & Diggle, P. J. (1977). Simple Monte Carlo tests for spatial patterns. *Applied Statistics, 26*, 327-333.

Blumstein, A. (2006). The crime drop in America: An exploration of some recent crime trends. *Journal of Scandinavian Studies in Criminology and Crime Prevention, 7*, 17-35.

Bursik, R. J., Jr., Grasmick, H. G., & Chamlin, M. B. (1990). The effects of longitudinal arrest patterns on the development of robbery trends at the neighborhood level. *Criminology, 28*(3), 431-450.

Chamlin, M. B., Grasmick, H. G., Bursik, R. J., Jr., & Cochran, J. K. (1992). Time aggregation and time lag in macro-level deterrence research. *Criminology, 30*(3), 377-395.

Cohen, J., & Ludwig, J. (2003). Policing crime guns. In J. Ludwig & P. J. Cook (Eds.), *Evaluating gun policy* (pp. 217-250). Washington, DC: Brookings Institution Press.

Cook, P. (1979). *A unified treatment of deterrence, incapacitation, and rehabilitation: A simulation study*. Durham, NC: Duke University.

Cork, D. (1999). Examining space—time interaction in city-level homicide data: Crack markets and the diffusion of guns among youth. *Journal of Quantitative Criminology, 15*(4), 379-406.

Cornish, D. B., & Clarke, R. V. (1987). Understanding crime displacement: An application of rational choice theory. *Criminology, 25*(4), 933-947.

Cousineau, D. F. (1973). A critique of the ecological approach to the study of deterrence. *Social Science Quarterly, 54*(1), 152-158.

Cusson, M. (1993). Situational deterrence: Fear during the criminal event. In R. V. Clarke (Ed.), *Crime prevention studies* (Vol. 1, pp. 55-68). Monsey, NY: Criminal Justice Press.
D'Alessio, S. J., & Stolzenberg, L. (1998). Crime, arrests, and pretrial jail incarceration: An examination of the deterrence thesis. *Criminology, 36*(4), 735-762.
Dietz, R. D. (2002). The estimation of neighborhood effects in the social sciences: An interdisciplinary approach. *Social Science Research, 31*, 539-575.
Duncan, G. J., Magnuson, K. A., & Ludwig, J. (2004). The endogeneity problem in developmental studies. *Research in Human Development, 1*(1 & 2), 59-80.
Fagan, J., & Davies, G. (2000). Street stops and broken windows: Terry, race, and disorder in NYC. *Fordham Urban Law Journal, 28*, 457-504.
Greenberg, D. F., & Kessler, R. C. (1982). The effect of arrest on crime: A multivariate panel analysis. *Social Forces, 60*, 771-790.
Greenberg, D. F., Kessler, R. C., & Logan, C. H. (1979). A panel model of crime rates and arrest rates. *American Sociological Review, 44*(5), 843-850.
Greenberg, D. F., Kessler, R. C., & Logan, C. H. (1981). Aggregation bias in deterrence research: An empirical analysis. *Journal of Research in Crime and Delinquency, 18*, 128-137.
Johnson, S. D., & Bowers, K. J. (2004a). The burglary as clue to the future: The beginnings of prospective hot-spotting. *European Journal of Criminology, 1*(2), 237-255.
Johnson, S. D., & Bowers, K. J. (2004b). The stability of space—time clusters of burglary. *British Journal of Criminology, 44*, 55-65.
Johnson, S. D., Summers, L., & Pease, K. (2009). Offender as forager? A direct test of the boost account of victimization. *Journal of Quatitative Criminology, 25*(2), 181-200.
Jones, B. J., & Jones, D. R. (2000). The contagious nature of antisocial behavior. *Criminology, 38*(1), 25-46.
Kane, R. J. (2006). On the limits of social control: Structural deterrence and the policing of "suppressible" crimes. *Justice Quarterly, 23*(2), 186-213.
Kleck, G. (1991). *Point blank: Guns and violence in America*. New York: Aldine.
Kleck, G. (1997). *Targeting guns: Firearm and their controls*. New York: Aldine.
Klinger, D. A. (1997). Negotiating order in patrol work: An ecological theory of police response to deviance. *Criminology, 35*(2), 277-306.
Knox, G. (1964). Epidemiology of childhood leukemia in Northumberland and Durham. *British Journal of Preventive Medicine, 18*, 17-24.
Kohfeld, C. W. (1983). Rational cops, rational robbers, and information. *Journal of Criminal Justice, 11*, 459-466.
Kohfeld, C. W., & Sprague, J. (1990). Demography, police behavior, and deterrence. *Criminology, 28*(1), 111-136.
Koper, C. S, & Mayo-Wilson, E. (2006). Police crackdowns on illegal gun carrying: A systematic review of their impact on gun crime. *Journal of Experimental Criminology, 2*, 227-261.
Levitt, S. D. (2004). Understanding why crime fell in the 1990s: Four factors that explain the decline and six that do not. *Journal of Economic Perspectives, 18*(1), 163-190.
MacDonald, J. M., & Gover, A. R. (2005). Concentrated disadvantage and youth-on-youth homicide: Assessing the structural covariates over time. *Homicide Studies, 9* (1), 30-54.
Maltz, M. D. (1994). Deviating from the mean: The declining significance of significance. *Journal of Research in Crime and Delinquency, 31*(4), 434-463.
Mastrofski, S. D, Weisburd, D., & Braga, A. A (2010). Rethinking policing: The police implications of hot spots of crime. In N. A. Frost, J. D. Freilich & T. R. Clear (Eds.), *Contemporary issues in criminal justice policy* (pp. 251-264). Belmont, CA: Wadsworth.
McArdle, A. (2001). Introduction. In A. McArdle & T. Erzin, (Eds.), *Zero tolerance: Quality of life and the new police brutality in New York City* (pp. 1-19). New York: New York University Press.

McGarrell, E. F., Chermak, S., Weiss, A., & Wilson, J. (2001). Reducing firearms violence through directed police patrol. *Criminology & Public Policy, 1*(1), 119-148.
Moore, H. (1980). The police and weapons offenses. *The Annals of the American Academy of Political and Social Sciences, 452*, 22-32.
Moss-Coane, M. (Producer). (2006, December 14). Whither stop-and-frisk [audio podcast]. Retrieved from http://www.whyy.org/podcast/121406_100630.mp3.
Moss-Coane, M. (Producer). (2008, January 31). Rudovsky responds to ramsey plan [audio podcast] Retrieved from http://www.audio/20080131_rudovsky_responds_to_ramsey_plan.mp3.
Nagin, D. (1978). General deterrence: A review of the empirical evidence. In A. Blumstein, J. Cohen & D. Nagin (Eds.), *Deterrence and incapacitation: Estimating the effects of criminal sanctions on rates* (p. 110-174). Washington, DC: National Academy of Sciences.
Nagin, D. (1998). Criminal deterrence research at the outset of the twenty-first century. *Crime and Justice, 23*, 1-42.
Parker, J., & Grasmick, H. (1979). Linking actual and perceived certainty of punishment. *Criminology, 17*, 366-379.
Pennsylvania Uniform Firearms Act. 18 Pa.C.S. § 6101. (1995). Retrieved February 25, 2010, from Pennsylvania crime code offenses http://www.pacode.com/secure/data/204/chapter303/s303.15.html
Philadelphia Police Department. (2007). Philadelphia Police Department: Patrol district crime statistics—2006. Retrieved July 22, 2008, from http://www.ppdonline.org/hq_statdist_06.php
Ratcliffe, J. H. (2004). Geocoding crime and a first estimate of a minimum acceptable hit rate. *International Journal of Geographic Information Science, 18*(1), 61-72.
Ratcliffe, J. H., & Rengert, G. F. (2008). Near-repeat patterns in Philadelphia shootings. *Security Journal, 21*, 58-76.
Rengert, G. F., Piquero, A. R., & Jones, P. R. (1999). Distance decay reexamined. *Criminology, 37*(2), 427-446.
Rosenfeld, R., Fornango, R., & Baumer, E. (2005). Did ceasefire, compstat, and exile reduce homicide? *Criminology & Public Policy, 4*(3), 419-450.
Ross, L. H (1982). *Deterring the drunk driver: Legal policy and social control*. Lexington, MA: DC Health and Company.
Sherman, L. W (1990). Police crackdowns: Initial and residual deterrence. In M. Tonry & N. Morris (Eds.), *Crime and justice: A review of research*. Chicago, IL: University of Chicago Press.
Sherman, L. W. (2001). Reducing gun violence: What works, what doesn't, what's promising. *Criminology and Criminal Justice, 1*(1), 11-25.
Sherman, L. W (2003). Policing gun crimes: Comment by Lawrence W. Sherman. In J. Ludwig & P. J. Cook (Eds.), *Evaluating gun policy: Effects on crime and violence* (pp. 240-243). Washington, DC: Brooking Institute.
Sherman, L. W., & Rogan, D. P. (1995). Effects of gun seizures on gun violence: "Hot spots" patrol in Kansas City. *Justice Quarterly, 12*(4), 673-693.
Skogan, W. G, & Frydl, K. (2004). *Fairness and effectiveness in policing: The Evidence*. Washington, DC: National Academies Press.
Smith, D. A (1986). The neighborhood context of police behavior. In A. J. Reiss & M. Tonry (Eds.), *Communities and crime* (pp. 313-341). Chicago, IL: University of Chicago Press.
Stafford, M. C., & Warr, M. (1993). A reconceptualization of general and specific deterrence. *Journal of Research in Crime and Delinquency, 30*(2), 123-135.
Taylor, R. B. (1997). Order and disorder of streetblocks and neighborhoods: Ecology, microecology and the systemic model of social organization. *Journal of Research in Crime and Delinquency, 34*, 113-155.
Taylor, R. B., Gottfredson, S. D., & Bower, S. (1984). Understanding block crime and fear. *Journal of Research in Crime and Delinquency, 21*, 303-331.

Taylor, R. B., Harris, P. W., Jones, P. R., Weiland, D., Garcia, R. M., & McCord, E. S. (2009). Short-term changes in arrest rates influence later short-term changes in serious male delinquency prevalence: A time-dependent relationship. *Criminology, 47*(3), 657-697.

Tittle, C. R., & Rowe, A. R. (1974). Certainty of arrest and crime rates: A further test of the deterrence hypothesis. *Social Forces, 52*, 455-462.

Tobler, W. R. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography, 46*, 234-240.

Townsley, M., Homel, R., & Chaseling, J. (2003). Infectious burglaries: A test of the near repeat hypothesis. *British Journal of Criminology, 43*, 615-633.

Turner, S. (1969). Delinquency and distance. In T. Sellen & M. E. Wolfgang (Eds.), *Delinquency: Selected studies*. New York: Wiley.

Villaveces, A., Cummings, P., Espitia, V. E., Koepsell, T. D., Barbara, M., & Kellermann, A. L. (2000). Effect of a ban on carrying firearms on homicide rates in 2 Colombian cities. *The Journal of the American Medical Association, 283*(9), 1205-1209.