

EXAMINING THE SPATIO-TEMPORAL LINKS BETWEEN ARRESTS FOR ILLEGAL  
FIREARM CARRYING AND SHOOTINGS IN PHILADELPHIA

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A Dissertation Prospectus  
Submitted  
to the Temple University Graduate Board

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In Partial Fulfillment  
of the Requirement for the Degree of  
Doctor of Philosophy

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May, 2009

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## ABSTRACT

### EXAMINING THE SPATIO-TEMPORAL LINKS BETWEEN ARRESTS FOR ILLEGAL FIREARM CARRYING AND SHOOTINGS IN PHILADELPHIA

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This work examines how police arrests for illegally carried firearms might connect in both space and time with shooting incidents. Four years of arrest and shooting data in Philadelphia, Pennsylvania from 2004 to 2007 are analyzed to describe these connections. Key questions include: 1) Does detecting and arresting people illegally carrying firearms suppress the number of later shootings nearby as deterrence theory suggests (Moore, 1980; Sherman and Rogan, 1995)?; and 2) Does more criminal activity, specifically, more shooting incidents, link to later increases in arrests for illegal firearm carrying nearby (Jacob and Rich, 1980; Kohfeld, 1983)? Much previous research has examined these links. Those evaluations, however, have been limited in several ways.

Research in this area may have incorrectly assumed a unidirectional or recursive causal structure between police arrests for illegally carried firearms and firearm violence. Further, previous work used spatial units whose boundaries may not have corresponded closely to underlying social, demographic or organizational geographies in places studied. Consequently, estimates for the two links described above may have been inaccurate and/or imprecise. Better estimates might be obtained by looking at how specific local incidents of one type connect with specific incidents of the other type. Additionally, previous work used temporal units which may have masked key features of these connections.

The present study will use the Knox (1964) close pair method, a spatio-temporal clustering technique first used to study contagious diseases. This method should better capture close associations in space and time, if they exist, between detected offender behaviors, shootings, and certain classes of police activity, arrests for firearms violations. The current work seeks to make a theoretical contribution by bringing together disparate and partial conceptual views about these connections, and by developing a view of these dynamics which is both more integrated and specific. Results may provide strategic information to law enforcement agencies, and may inform how these agencies structure some types of deployments or interventions.

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## CHAPTER 1: INTRODUCTION

### Research focus

This study examines the potential links between police arrests for illegal possession of a firearm and shooting incidents between 2004 and 2007 in Philadelphia. Two possible spatio-temporal relationships between firearm arrests and shooting will be explored. 1) Are firearm arrests associated with fewer nearby shootings in the period immediately following? 2) Are shootings associated with nearby firearm arrests in the period immediately following?

Findings may have implications for both theory and practice. Theoretically, the proposed research may refine our knowledge of ecological deterrence and police responsiveness to crime. Examining these links in a more detailed manner permits gauging if the links align with corresponding suggested offender and police dynamics. Considering practice, findings from the first question may add valuable information about police efforts to discourage illegal firearm carrying in public places as a means to reduce firearm violence. Additionally, findings from the second question may clarify contours of police responsiveness to this type of crime in space and time.

Traditionally, firearm violence has been one of the most serious problems facing the United States (Zimring and Hawkins, 1998). Philadelphia has been especially hard hit, consistently ranked as one of the most dangerous cities in the United States (Maykuth, 2007). Since the year 2000, Philadelphia has averaged over 100 shootings per month (Ratcliffe and Rengert, 2008) and over 300 homicides per year. There were 406 homicides in 2006. About three-quarters of Philadelphia homicides involve firearms (Moore, 2005).

Much research has found various links among police arrests for illegally carried firearms and firearm violence. At least two clearly distinct perspectives have informed research on these links.

Reducing the number of illegally carried firearms via arrests and threats of arrest appears to result in less firearm violence (Cohen and Ludwig, 2003; McGarrell, Chermak, Weiss, and Wilson, 2001; Moore, 1980; Sherman and Rogan, 1995; Villaveces et al., 2000). Emphasizing the enforcement of laws forbidding carrying concealed weapons without a permit by increasing the number of firearms police seize appears to have two effects. It will not only temporarily incapacitate those who may criminally use a firearm, but will also act as a deterrent to those illegally carrying a firearm or considering do so. 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 firearm violence and that link depends not only on incapacitation but also general deterrence processes, and the latter are somewhat place-dependent, shooting incidents will decline in locations near where there has been at least one arrest for illegally carrying firearms for at least a short time after the arrest.

Second, some research has argued that instead of arrests suppressing later crime, increased arrests indicate an informed police response to earlier changes in crime (Decker and Kohfeld, 1985; Jacob and Rich, 1980; Kohfeld, 1983; Kohfeld and Sprague, 1990). Police administrators reacting to firearm violence can allocate more officers to the troubled locations and/or increase pedestrian and vehicle stops. The shifting of police tactics might produce more illegal firearms detected by police and therefore more arrests for illegal firearm carrying. If the dynamics apply here, areas with high or increasing numbers of shootings, or locations nearby, might experience more arrests for firearm violations soon thereafter.

## **Gaps in knowledge and proposed method**

The previous arguments highlight that arrests for illegal firearm carrying and shooting incidents can be theoretically linked and likely occur in close proximity to each other in space and time. A principal issue for research on changes in risk apprehension across geographic territories and crime rates, referred to as ecological or structural deterrence, is identifying the most valid and/or reliable units of spatial and temporal aggregation (Cousineau, 1973; Kane, 2006). Research on illegally carried firearms, police arrests for illegally carried firearms, and shooting incidents, however, would benefit from using finer spatial and temporal units to better capture the underlying geography and shorter or longer changes of the phenomena under study. The current study attempts to overcome three main challenges to creating units of spatial and temporal aggregation.

First, previous work has used spatial units such as states, cities, census tracts, or patrol beats that may not have captured important area dynamics influencing offender and police behaviors. Underlying social, demographic or organizational geographies will likely shape, among other things, criminal opportunities, the rate at which police react to crime, the social networks that may communicate information about police activity to criminals, and the spread of information about the proliferation of illegal firearm carrying. Large spatial units might not identify or might conflate relevant spatial disparities affecting illegally carried firearms, police arrests for illegally carried firearms, and shooting incidents occurring within these spatial units. Further, even smaller spatial units developed to portray homogeneous populations may still not capture the spatial variation influencing offender and police behaviors; these dynamics may connect across the spatial units used as 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 operative at different levels.

Second, in a similar vein but temporally, data analyzed yearly, quarterly, or monthly may obscure key features of links between police arrests for illegally carried firearms and shooting incidents. Potentially, offenders might learn quickly about how police have responded to a shooting; this could swiftly alter offenders' perceived risks of apprehension in some locations. If offenders learn quickly about what police are doing differently where, using longer temporal units of aggregation in research may obscure such dynamics. Alternatively, if the temporal units used are too short, there might not be enough time for the responsiveness of offenders to emerge in the data. It is not clear what temporal units best capture the underlying dynamics creating these links.

The use of multiple spatial and temporal increments may provide a sensitivity analysis of the hypothesized associations among illegally carried firearms, police arrests for illegally carried firearms, and shooting incidents. Lengthening or shortening the spatial and temporal increments may provide insight into relevant dynamics operating at different space and time scales. Dynamics suggested by earlier researchers should be more or less apparent, depending on the spatial scales and temporal lags specified. If this expectation is supported, it sharpens our understanding of these dynamics and clarifies existing theory. In addition, using these varied spatial and temporal increments may illuminate additional dynamics, which may operate at different and possibly overlapping levels of space and time.

Third, in addition to a lack of clarity regarding appropriate levels of spatial and temporal aggregation, any spatial aggregation process must consider the modifiable areal unit problem (MAUP) and the closely related issue of edge effects. The MAUP arises when areal data are

assigned to artificial boundaries generating artificial spatial patterns (Openshaw, 1984). A researcher studying some type of crime incidents across space must decide within those boundaries how to aggregate the data; however, these units may be arbitrary in nature, and even if they are purposefully designed, different areal units will result in different graphic results (Ratcliffe and McCullagh, 1999).

Closely related to the MAUP and especially relevant to the study of whether shooting incidents and police arrests for illegally carried firearms are connected is the problem of edge effects of bounded space. Crime incidents and their antecedents may extend beyond the established boundaries of the data available to researchers. This is especially true as the spatial units used for analysis get smaller. Data analyzed within artificial boundaries do not take into consideration the proximity of events to the established boundaries (Rengert and Lockwood, 2008). The use of artificial boundaries of any size (e.g., census blocks, census tracts, counties, cities) will result in the exclusion of events close to the edge but outside a geographic boundary. Phenomena occurring outside a boundary may be excluded, and estimates close to the edge of the boundary may be statistically biased (Rengert and Lockwood, 2008). If a shooting occurs in one spatial unit but an arrest occurs just outside that unit, then that shooting and arrest may not be considered spatially linked when in fact they may be. Based on the configuration of the boundaries of a study, shooting incidents and arrests could be viewed as being in the same or different geographic units.

With this in mind, the use of an event-centered conception of location will be used. Instead of aggregating shootings and arrests within geographies, each event's location will be the center of the spatial unit. Concentric circles will be applied around the event of varying sizes (e.g., 400 feet, 800 feet, etc.) called buffers. Using an event-centered conception of location, and

allowing the events and the corresponding buffers around each event to serve as the spatial units, provides the opportunity to explore the extent to which there are relationships within various possible distances from the events themselves. The event-centered conception of location moves away from simply using the readily available geographic units and decreases potential edge effect problems. Instead of embedding data within specific geographic areas the current research uses all shooting and firearm arrest incident locations.

A comparable sensitivity is brought to thinking about how to model time. Instead of analyzing and comparing changes in yearly, quarterly, or monthly aggregate data, the current method allows for the measurement, comparison, and analyses of individual incidents over researcher-specified periods. Calculating the spatial lags and temporal distances between later shooting incidents and prior arrests, and calculating the reverse lags and distances – later arrests and prior shooting incidents -- avoids excluding an event because it is outside a somewhat artificially defined geographic region or temporal period.

The use of smaller and varying spatio-temporal units and event-centered conception of location should provide a better gauge of the temporal and spatial parameters that bound the plausible underlying dynamics such as the communication of information about police activity assumed to trigger the processes of deterrence or the ability of police to share and react to information regarding firearm violence that may influence offender and police behavior. The current research should not only aid in identifying if arrests for illegally carrying firearms and shootings are related, but also the strengths and scale of those associations. Although crime incidents may be concentrated in certain places, empirically demonstrating that these incidents are linked can be challenging. Simply because one finds, for example, that arrests for illegal firearm carrying and shooting incidents occur close together, does not necessarily demonstrate

they are causally linked. In fact, one may expect to find an excess of shootings and arrests in some high crime areas.

Determining if two or more seemingly separate events are in fact associated is not new in the study of crime. It has long been known that crime is not randomly distributed and that victimization tends to be concentrated on particular people and in certain areas (Chainey and Ratcliffe, 2005). In the last 30 years, attention has turned to the notion that earlier criminal victimization increases the future likelihood of victimization (Sparks, 1981). Later termed repeat victimization, Polvi and colleagues (1991) found that homes burglarized were often re-burglarized within a month. Other offenses have displayed a similar pattern (see Farrell, 1995). Overall, work in the areas of repeat victimization has drawn attention to the possibility that one crime or victimization incident may increase the odds of one or more later crime or victimization incidents. Unlike temporal patterns of unrelated crimes occurring at irregular intervals, repeat victimization is characterized by a strong temporal clustering of repeats occurring almost immediately following initial victimization. The clustering suggests that the two (or more) criminal events may be causally linked (Bottoms and Costello, 2008).

More recently, research has focused not only on repeat victimization but also on the greater probability of future victimization for places near an initial crime event; this is termed near repeat victimization (Townsend, Homel, and Chaseling, 2003). Whereas repeat victimization focuses on the increased future vulnerability that a particular victimized person or place has for another victimization incident of the same type within a specific period of time (Weisel, 2005), near repeat victimization highlights increased victimization probabilities of places nearby, for the same type of crime incident during a limited time window soon after the initial crime incident. In a near repeat framework, after an apartment is burglarized, other apartments close by for a short

time after the original event have a higher risk of being burglarized (Bowers and Johnson, 2004; Johnson and Bowers, 2004a). Research on property crimes such as residential burglaries and on violent crimes such as shootings has demonstrated near repeat patterns (Ratcliffe and Rengert, 2008; Townsley, Homel, and Chaseling, 2003).

Although the recognition of repeat and near repeat victimization has been both an important theoretical discovery and can be used as a tool to concentrate police resources so as to achieve reductions in crime, Townsley, Homel, and Chaseling (2003, p. 616) point out that studying repeat victimization may be complicated by “other features of victimization patterns.” For example, Townsley Homel, and Chaseling (2000) found that burglary “hotspots” may or may not prove stable over time. The authors concluded the latter hotspots resulted from repeat victimizations while the former arose from lasting features of the surrounding socio-demographic and physical environment (Townsley Homel, and Chaseling, 2000).

To test for repeat and later near repeat victimization patterns, researchers have employed a method originally used to study disease contagion. In a study of the epidemiology of childhood leukemia, Knox (1964) observed that cases of childhood leukemia occurred in clusters in space and in time. He also noted, however, the methodological and conceptual problems inherent when analyzing this phenomenon. Knox (1964) concluded that an accurate analysis of clusters in space and time required a:

separate examination for the three components of epidemicity: (a) concentration in space, over the whole of the time of the study; (b) concentrations in time over the whole of the area of the study; (c) interactions between space and time concentrations (p. 17).

In order to identify interactions between space and time clusters, Knox proposed an examination of all possible pairs of childhood leukemia cases to determine whether small physical distances were positively associated with short time intervals between pairs of events (Knox, 1964). A fuller description of the Knox method can be found in Chapter Three.

Even though the Knox method was originally used to study contagion via micro-organisms, processes with both biological and social components, strictly behavioral or social phenomena such as burglaries or shootings are fully compatible with the known epidemiology of antisocial behavior (Jones and Jones, 2000).

Antisocial behaviors may spread through peer influences and social networks. Different names, including differential association, contagion, social learning, and others, have been applied to such dynamics. The premise is that the more common crime and delinquency are among one's family or close social group (Sutherland, 1939), or community (Jones and Jones, 2000), the more likely one is to engage in criminal or delinquent behaviors. Perhaps the association or concentration in space and time of a social phenomenon is generally prevalence-driven (Jones and Jones, 2000) because people are influenced by the behavior of those with whom they interact (Burt, 1992).

Some models extend the contagion idea to explain the nonlinear acceleration of some social problems. Crane (1991) suggested the incidence of social problems will remain at a relatively low-level equilibrium if the prevalence rate is below a critical point or threshold. If a social problem incident rate goes above the critical threshold, however, the problem rate is more likely to increase at a faster rate. These ideas about modeling, imitation, and social learning among offenders may have some applicability to firearm carrying.

## **Key hypotheses explored**

Although the Knox approach has been used to study repeat and near repeat victimization, to date no research has used the Knox method to examine whether two theoretically related but different phenomena are spatio-temporally connected. Stated differently, research has examined if past burglaries increase probabilities of later burglaries nearby (Townsend, Homel, and Chaseling, 2003) or if past shootings increased chances of future shootings nearby (Ratcliffe and Rengert, 2008). No study using the Knox method, however, has tested whether different phenomena like police arrests for illegally carried firearms and shooting incidents are linked spatio-temporally. Applying the Knox approach to administrative data of confirmed shootings supplied by the Philadelphia Police Department, and of arrests where the lead charge is carrying a firearm without a license, supplied by the Philadelphia Adult Parole and Probation Department (APPD), the current study considers whether firearm arrest and shooting incident distributions demonstrate more spatio-temporal proximity than would be anticipated were the two types of events completely unrelated. Specifically, whether detecting and arresting people illegally carrying firearms link to later drops in shootings nearby and whether shooting incidents link to later increases in police arrests for illegal firearm carrying nearby.

## **Implications of focus**

In sum, the current study may improve upon prior research in several ways. Finer, point-based data sources permit detailed disaggregate examinations of spatio-temporal shooting-arrest links. Looking at those links in a more disaggregated form may align the examination more closely with the corresponding offender and police dynamics. It will test for spatio-temporal associations between police arrests for illegally carried firearms and shooting incidents. More broadly, this work may advance our understandings of ecological deterrence and police

responsiveness to crime. Practically speaking, results may provide potentially useful strategic information to law enforcement agencies, perhaps assisting in problem-oriented deployments or interventions.

## **CHAPTER 2: LITERATURE REVIEW**

This chapter presents an overview of research linking police arrests for illegally carried firearms and firearm violence. More specifically, this chapter introduces theoretical and empirical foundations related to two key questions 1) Do police firearm arrests link to later drops in shootings nearby?; and 2) Do shootings link to later increases in police arrests for illegal firearm carrying nearby. Lastly, this review details limitations of previous work and how the current study addresses these limitations.

### **Policing firearm carrying**

The first key question is: Do arrests for illegally carried firearms suppress later firearm violence? After briefly reviewing work on ecological deterrence, the current work describes and takes a critical look at one of the most popular strategies for reducing firearm violence: police crackdowns on illegal firearm carrying to detect, confiscate, and dissuade the illegal carrying of firearms. The current research concludes by outlining how the proposed analytic technique contributes to this body of research.

Many homicides and other predatory crimes are unplanned, carried out by armed people acting impulsively in public places. Moore (1980) was one of the first to argue that illegal firearm carrying bred violence. He argued that it was reasonable to expect that carrying a firearm into public places increased the likelihood of lethal violence.

There are numerous reasons for people carry firearms illegally (e.g., creating or maintaining a positive social identity in certain neighborhoods, for self-defense, or to commit a crime). The mere presence of a firearm, however, may turn a conflict lethal as people think firearms can help handle disagreements (Moore, 1980). Ethnographic work by Wilkinson and Fagan (1996) with serious violent young offenders has supported Moore's assertion that firearms

are seen as a legitimate tool for resolving disputes. Further, people who casually carry a firearm during their daily activities may take advantage of those perceived to be vulnerable. A large part of firearm violence in the United States is a result of “young guys walking or driving around with guns and then doing stupid things with them” (Ludwig as quoted in Dubner, 2008, para. 4). Therefore, reducing the illegal carrying of firearms seems like a reasonable and effective police aim for preventing firearm violence (Kleck, 1991; Moore, 1980).

### **Theoretical foundations**

Empirical tests grounded in the deterrence perspective have examined the notion that police, and specifically police patrol strategies including arrests and stops, may curb crime (e.g. Wilson and Boland, 1978). Essentially, deterrence theory holds that police may reduce firearm violence through greater enforcement of laws forbidding the unlawful carrying of firearms. The key to controlling firearm violence, according to Moore (1980), is through arrests and successful prosecutions of people who illegally carry firearms. These actions will incapacitate some potentially dangerous individuals and dissuade less dangerous others from casually carrying firearms. If people knew police were likely to seize firearms in certain places they should be less likely to carry firearms illegally in those areas. Potential offenders would avoid illegally carrying a firearm because others have been apprehended and punished (general deterrence). Also, individuals who were found illegally carrying a firearm may be less willing to do so again due to fear of additional punishment (specific deterrence) (Nagin, 1978) as well the hassle and expense of replacing a firearm (Sherman and Rogan, 1995).

Overall, when a person perceives sanctions to be more certain, he or she is less likely to engage in the illegal behavior (Nagin, 1998). These risk perceptions will be based on one’s own experiences and those in one’s social networks (Cook, 1979). Others have drawn similar

conclusions; Tyler (1984) noted that people rely in part on others through vicarious experiences to develop perceptions of risk. Furthermore, a study of burglary offenders revealed they in part calculated their risk of apprehension through not only their own experiences but also via social networks (Parker and Grasmick, 1979).

More recently, Stafford and Warr's (1993) reconceptualization of deterrence theory made similar points. Deterrence may operate not only as a result of punishment in the traditional sense, but when people avoid punishment they may be less likely to view law enforcement as competent and therefore feel safe committing more crimes. 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 with 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.

In the case of illegal firearm carrying, perceptions of apprehension risk may be produced primarily by impressions shaped by the police being proactive in enforcement activities (Sherman and Rogan, 1995). Potential offenders may be less likely to offend initially as they fear detection by authorities, but the uncertainty of further police presence also may escalate fears of apprehension and longer-term or residual deterrence (Sherman, 1990).

Theoretically, enforcing laws forbidding the unlawful carrying of firearms in certain areas could result in some degree of spatial displacement of both firearm carrying and crimes. Diffusion of benefit, of course, is also possible and has been observed more often than

displacement (Clarke and Weisburd, 1994). Crime does not necessarily spill over into close areas, but instead crime might be reduced in areas surrounding the intervention areas (Clarke and Weisburd, 1994; Eck, 1993). Potential offenders may believe that intervention strategies such as increased police enforcement activities have been implemented more widely than the actual target areas and/or for a greater time period (Clarke and Weisburd, 1994; Eck, 1993). These potential offenders may also believe that they are at an increased risk that they will be detected and apprehended for carrying a firearm.

Evidence for a diffusion of benefit to surrounding areas has been found in various crime control efforts. For example, research examining increased street lighting (Painter and Farrington, 1999) and directed police patrol in drug hotspots (Weisburd and Green, 1995) both discovered a diffusion of benefit. Overall, however, measurement of displacement and diffusion of benefits is extremely difficult and in general there has not been extensive empirical research in this area (Ratcliffe and Makkai, 2004). Koper and Mayo-Wilson (2006) noted in their systematic review of police crackdowns on illegal firearm carrying that research in this area “did not consistently address crime displacement in its various manifestations” (p. 250).

Furthermore, arguing against displacement, Sherman and Rogan (1995) speculated based on the tenets of routine activities theory that displaced firearm crimes occurring outside target areas will be substantially lower than those in the high risk target areas. In lower risk, non-targeted areas there should be fewer interactions between likely victims and armed predators carrying firearms; therefore, increased enforcement of laws against people illegally carrying a firearm may still reduce firearm crime. Relevant data are lacking.

## **Proactive policing**

Moore (1980) summarizes some mechanisms that may lead police to make arrests for the illegal possession or carrying of a firearm. First, the discovery of a firearm may be a by-product of enforcement activities geared toward other offenses. Reactive investigations into serious crimes such as rape or murder might result in a weapon arrest once suspects or people of interest are questioned and searched. Additionally, proactive investigations of illegal narcotics or extortion rackets may lead to weapons arrests for similar reasons. Random patrol operations primarily designed to respond to calls for service and enforcement of traffic violations may lead to firearm arrests. Police responding to a call of a discharged firearm may arrive quickly at a scene and make an arrest, or when a police officer stops a person suspected of driving under the influence, a subsequent frisk of the driver may reveal a firearm (Moore, 1980). In addition to weapons arrests as by-products of other activities, these arrests might result from special organizational initiatives. In a study in five large cities Moore (1980) discovered that cities with more aggressive police forces (measured by total arrest rates for drunkenness and various part II offenses reported in the Uniform Crime Reports) generated higher numbers of weapons arrests (1980).

What Moore (1980) termed aggressive policing therefore calls for proactive strategies to confiscate illegally carried firearms by maximizing the number of police-citizen contacts, ensuing frisks, and/or ensuing searches of pedestrians or automobile to increase probabilities of detecting illegally carried firearms (Rudovsky, 2001). Pedestrian stops are an important tool for police: among other things, they generate information about criminal activity or identify those who have outstanding warrants (Rudovsky, 2001). The Supreme Court has ruled that in order for police to forcibly stop or detain a person, a police officer must have a reasonable suspicion that

the person is involved in criminal behavior. Further, when a police officer fears for his or her safety, the police officer may frisk the subject's outer layer of clothing to detect weapons (Fyfe, 2004).

In addition to pedestrian stops, police rely on automobile stops and searches to detect and confiscate firearms. When police witness a traffic violation they may stop the vehicle; firearms in plain view may be seized and constitute probable cause for arrest. Furthermore, during the stop an officer might secure consent to search the person or the vehicle potentially leading to more found firearms. Lastly, during a stop if the officer feels a person in the vehicle presents a danger to the officer, the officer may frisk the subject. Again, a firearm might be detected (Rudovsky, 2001). Efforts to increase pedestrian and automobile stops that may result in the detection and confiscation of illegal firearms have included increasing the number of police officers, encouraging more police-citizen contacts, and freeing police from calls for service.

### **An overview of police crackdowns on illegal firearm carrying**

Although political support is strong, and at least eight published studies (Sherman, 2003) have suggested that concentrated police efforts may deter illegal firearm carrying and subsequent firearm violence, questions remain about how effective these efforts are. Arguably the most widely known study regarding the effectiveness of directed police patrol and firearm seizures to reduce firearm violence was conducted by Sherman and Rogan (1995) in Kansas City, Missouri. It merits detailed consideration.

Using a quasi-experimental design Sherman and Rogan (1995) tested whether greater enforcement of laws prohibiting the carrying of concealed weapons would reduce firearm violence. Beginning July 7, 1992, and ending January 27, 1993, the Kansas City Police department deployed extra patrol officers in a target beat (.64 square miles) with an extremely

high homicide rate that was several times the national average. Officers working overtime were not required to answer calls for service but instead concentrated on firearm detection via safety frisks, those seen in plain view during traffic stops, and searches incident to arrest on other charges (Sherman and Rogan, 1995).

Before the intervention, during the first 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 and Rogan, 1995). Additionally, firearm crime went down in the target beat. Eighty-three fewer firearm crimes (86) were reported during the six months of intervention compared to the preceding six months (169), nearly a 50% decline. Importantly, a comparison beat not receiving increased patrol showed no significant changes in the numbers of firearms seized or firearm crimes (Sherman and Rogan, 1995). Lastly, Sherman and Rogan (1995) reported that firearm crimes did not increase significantly in any of the seven beats adjacent to the target areas, suggesting no spatial displacement of firearm crimes. Others have attempted to replicate the finding from this seminal study to better understand halting firearm violence.

Although not directly asked in this investigation, along a related line a 1996 National Institute of Justice (NIJ) funded study sought to further evaluate whether directed patrol reduced firearm crime in Indianapolis. Using a pre-posttest quasi-experimental design with a non-equivalent control group, the 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. Additionally, changes in two areas identified as among the highest rates of drug distribution and violent and property crime where extra patrol officers were deployed (target beats) were compared with changes in citywide crime (McGarrell et al., 2001).

Beyond utilizing two target beats, the Indianapolis study target beats also consisted of a much larger area covering a territory of almost three square miles, approximately four times larger than the target beat utilized in the Kansas City study (McGarrell et al., 2001).

Illegal firearm seizures increased in the two areas receiving directed patrol compared to the same time period a year prior. An additional 42 firearms were seized in one target area and 45 firearms were seized in the other target area, representing an 8% and 50% increase compared to the same time period in the previous year (McGarrell et al., 2001). The number of officers assigned to each target area was not specified, but McGarrell et al. (2001) noted the north target area received considerably fewer officer hours than the east. Overall results were very encouraging. In the North beat, where officers were instructed to be more selective in whom they stopped, focusing specifically on those “suspected to be involved in illegal behavior,” (p. 130) 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 of the previous year. The other target beat did experience a decrease in homicide from four to zero, but total firearm crimes actually increased (McGarrell et al., 2001).

A second sequence of analyses using interrupted time series was conducted to examine changes in firearm crime over time in the target areas compared to the city as a whole. Examining 158 weeks prior to the intervention, 13 weeks during the intervention, and 13 weeks post-intervention they found an increase in firearm crimes in the comparison areas (about 1.5 per week). But they found a decrease in the number of firearm crimes (almost two per week) in the north target area, whereas they did not find a decrease in the east target area (McGarrell et al., 2001). Lastly, the authors noted a slight increase in firearm crime in the five beats surrounding the target areas, but added that the effects were not statistically significant.

Despite a total of over 5,000 vehicle stops and 992 arrests (84 felony, 654 misdemeanor, and 254 warrant) in both directed patrol districts identified by the authors as predominantly African-American and low-income, they noted a great deal of public support for the police and for the directed patrol strategy. Further, Indianapolis police officials received zero complaints tied to the directed patrol project (McGarrell et al., 2001).

After identifying perceived limitations of both the Kansas City and Indianapolis studies, Cohen and Ludwig (2003) presented results of the police program targeting illegal firearm carrying in Pittsburgh, Pennsylvania that sought to “isolate the impact of the police patrols from the effects of other confounding factors that cause crime rates to vary across areas and over time” (p. 219). Two of the city’s six patrol zones received extra evening patrols for a 14-week span beginning July 1998 and ending in October 1998. Police in the intervention areas were to work proactively and focus on the detection of illegally carried firearms and not respond to citizen calls for service. The two intervention patrol zones were about 10 square miles, had approximately 55,000 and 80,000 residents, and had the highest crime rates in Pittsburgh. Unlike previous studies, the directed police patrols only occurred Wednesday through Saturday within the target areas. The authors argue that this unique aspect permits the comparison of trends across areas but also on days the police patrols were launched versus days they were not (Cohen and Ludwig, 2003).

Using daily time series analysis, the authors found that in general, the treatment areas experienced reductions in both shots fired (34%) as reported by police and hospital-treated assault gunshot injuries (71%). Only two firearms were confiscated in one intervention area and 12 were confiscated in the other intervention area (Cohen and Ludwig, 2003).

Similar to the previous work in the areas of suppressing homicide, Villaveces and colleagues (2000) using another quasi-experimental design tested the effects of a ban on carrying firearms in Cali and Bogotá Columbia. The mayor and local police in both cities banned the carrying of firearms, even by those with permits, on weekdays after paydays, on holidays, and on election days, time periods with traditionally elevated homicide rates. After the public was notified about the ban via various media outlets, police searched people at checkpoints, as part of traffic stops, and as people went into bars (Villaveces et al., 2000). The intervention was applied on designated days in Cali from the beginning 1993 until the end of 1994. Overall, in Cali police seized 230 firearms during nonintervention days (0.8 per day) compared to 307 firearms during the intervention days (four per day). Unfortunately, similar data were not available for Bogotá. In Bogotá, however, using interrupted time-series with multiple replications, the authors did find a lower homicide rate during the intervention periods (Villaveces et al., 2000).

It would appear that studies examining the effects of intensive police patrol to reduce firearm violence in areas with high levels of firearm violence have produced results strongly suggesting intensive patrol in places with high violent crime rates reduces firearm violence. Overall, Koper and Mayo-Wilson in their 2006 systematic review on the impact of police crackdowns on illegal firearm carrying and firearm crime concluded that “directed patrols focused on illegal gun carrying reduce gun violence at high-risk places and times” (p. 248). Furthermore, Sherman (2001b) has argued uniformed patrol of firearm hot spots is one of only a few strategies aimed at reducing firearm violence that is known to “work” (p. 17).

### **Key remaining questions**

The studies outlined above have demonstrated consistent results, and great care was taken to make comparisons to control areas to better “draw substantial inferences even without random

assignment” (Sherman, 2003, p. 243). Despite the successful results of directed patrol studies, McGarrell et al. (2001) warned that the causal mechanisms producing the reduction in firearm crime remains unclear and hoped future studies would “isolate the causal mechanisms of directed patrol initiatives” (p. 145). Others have added 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” (Koper and Mayo-Wilson, 2006, p. 248). Further, Koper and Mayo-Wilson (2006) have cautioned that the target areas and comparison areas may differ in significant ways, and firearm reductions may have resulted from regression to the mean.

These observations still leave some unanswered questions about the relationship among law enforcement’s use of street searches and arrests of people illegally carrying firearms and firearm violence. The current research hopes to build on and extend the existing work on structural deterrence, specifically the reduction of firearm violence via arrests, in the following ways.

First, research has recognized that the findings of deterrence studies are “sensitive to the levels of spatial aggregation” (Chamlin et al., 1992, p. 379). Since at least 1973, Cousineau has warned that areal units used in ecological deterrence research are often too large to be homogenous social units and even smaller units of analysis are sometimes heterogeneous. These fixed boundaries may conflate or not capture the ecological distribution of homogenous social units, which he argued is desirable for ecological deterrence research. Kane (2006) adds “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” (p. 190) is paramount to structural deterrence research. Also, there could be multiple, overlapping,

related processes working at different levels, which might not be discovered in studies limited to fixed spatial and temporal units.

Chamlin (1992) goes on to argue that large, often heterogeneous units are inappropriate for testing the efficiency of police to deter crime. The transmission of information concerning police activity to potential offenders is most likely to be conveyed within neighborhoods versus larger areal aggregations (Bursik, Grasmick, and Chamlin 1990). For example, localized processes in different neighborhoods may significantly influence the ability of law enforcement to detect illegally carried firearms and the effectiveness of seizures on reducing firearm violence. A neighborhood resident's willingness to notify law enforcement about suspicious people might lead to a greater number of confiscated firearms. Additionally, certain neighborhood dynamics may encourage the sharing of information via secondary informal social networks; residents in these neighborhoods may be more likely to become aware of the police presence (and the potential/likely punishment associated arrests and convictions) than neighborhoods characterized by less interaction among neighbors. In sum, different neighborhood social dynamics might moderate the effects of police actions. Although the proposed project has no information on specific dynamics, the relevant temporal and spatial parameters identified in this project will have implications for future work specifying those dynamics. More particularly, the dynamics operative must be able to "cycle" (cause must be able to lead to effect) within these temporal and spatial limits identified here.

Despite the recognition that smaller spatial aggregation units are more desirable, research on the ability of police to reduce illegal carrying of firearms and firearms crime has focused on patrol beats varying in size: 80 square blocks, or about 0.65 square miles in Kansas City (Sherman and Rogan, 1995); two patrol beats 2.79 square miles in the North District

Indianapolis; two patrol beats 1.69 square miles in the East District Indianapolis (McGarrell et al., 2001); Patrol Zone One 8.9 square miles in Pittsburgh; Patrol Zone Five 9.4 square miles in Pittsburgh (Cohen and Ludwig, 2003); entire City of Bogota, Columbia; and entire City of Cali, Columbia (Villaveces et al., 2000). Yet according to Sherman (2001a):

Taking firearms off the streets, deterring firearm carrying, or deterring crime in general – all might require additional police in firearm crime hot spots. (Incidentally, hot spots are very localized. It is not just a matter of saying ‘this precinct has a high rate.’ Within that precinct, crime mapping can tell you that 1 to 3 percent of the addresses in that precinct have the majority of the firearm crime) (p. 90).

Clearly, work in this area has not been as focused as Sherman (2001a) suggests it needs to be.

In addition to using large administrative spatial units that may not accurately capture local social dynamics as well as dynamics linking police and offenders, prior work has been geographically binary, comparing one or two precincts or patrol beats to others. Displacement of firearm crimes or a diffusion of benefits have not been examined in some cases or might have been missed comparing one area to surrounding areas. For example, Lawton, Taylor, and Luongo’s (2005) evaluation of a geographically focused police intervention to curb drug activity and related violence used circular buffer spatial units as small as 0.1 miles, approximately one city block, found some evidence of both spatial diffusion of benefits and displacement. Larger spatial units might have conflated the localized intervention impacts.

To better understand not only the limits and effectiveness of localized firearm enforcement efforts, but also to clarify parameters of the relevant processes, research might best focus on smaller ecologically areas instead of patrol beats or entire cities. Smaller spatial units

might help better gauge the upper limit of the ability of law enforcement to elevate real and/or perceived apprehension threats (Koper and Mayo-Wilson, 2006). The studies reviewed above range from as few as 4,500 people (Kansas City) to millions in the case of the Columbian studies. If information about police tactics and behavior is in part transmitted via informal social networks and events witnessed, as well the existence of other highly localized processes, smaller areas than police districts or entire cities would appear appropriate.

Second, research using smaller and varying temporal units also seems warranted. Cousineau (1973) argued that ecological deterrence research has inadequately measured time lags between sanctions and effects. Large temporal units might not adequately capture the transmission of sanction-related information. A review of the deterrence approach to controlling drinking and driving by Ross (1982) led him to conclude that short-term deterrence is often attained but deterrence is not enduring. Ross (1982) posited that people might be initially deterred due to an overestimation of the likelihood of apprehension and punishment. Later experiences, however, may convince them that the risk of apprehension and punishment is negligible, and so they are not deterred.

Also, Koper and Mayo-Evan (2006) suggest that a relatively short study period muddles one's ability to confidently draw substantial inferences and that differences in the areas examined might be due to "regression artifacts and floor effects" (Koper and Mayo-Wilson, 2006, p. 244). The effect of variables may extend for a significant time period before and after an intervention (Ross, 1982) and therefore, deterrence-based research is improved by increasing the number of observation points for numerous time intervals before and after the intervention. Without definitive knowledge regarding the amount of time required to pass before effects of

legal sanction appear (Cousineau, 1973); a better understanding of the short and long-term effects of police action on later crime seems warranted.

Third, the spatial analyses used thus far have been susceptible to the MAUP and edge effects as comparisons have generally been made across police patrol beats. Results were dependent on the construction of the boundaries and vulnerable to clustering near the edge of these boundaries.

Next, none of these studies detailed has described those arrested for illegally carrying firearms. McGarrell et al. (2001) mention the potential importance of keeping firearms out the hands of “high-risk individuals,” or what Wright and Rossi (1986) termed “handgun predators.” No data, however, were presented in the police crackdown literature on characteristics of those who were arrested.

Aspects of firearm control policies assume that certain people, e.g. felons or the mentally ill, pose an unacceptably high risk of misusing firearms. Laws forbid members of these groups to own firearms (Jacobs and Potter, 1995). Studies examining the efficacy of a police presence and/or arrest of those illegally carrying a firearm to reduce illegal firearms crimes, however, have only reported the number of firearms confiscated and changes in certain types of crimes without spotlighting who was arrested for illegally carrying a firearm. Did those arrested for illegally carrying have criminal histories? We don't know.

Individuals with extensive and/or serious criminal histories might be more prone to using weapons in their possession. Removing firearms from them will reduce firearm violence more than removing firearms from those without extensive and/or serious criminal histories. The latter group may include many who illegally carry firearms but for otherwise non-criminal purposes. If police identify and arrest these individuals, firearm crimes may not decline much (Kleck and

Gertz, 1998), but it may be that crime would decline. Kleck (1987) pointed out “very few homicides are committed by people who have no prior history of violence” (p. 40) (Sherman, 2001b cites work to the contrary that preventing felons from possessing firearms is an effective strategy to reduce firearm violence). Arresting high-risk individuals and confiscating their firearms might not only halt an immediate threat, but that arrest news might also travel through criminal networks, thus deterring others. Alternatively, arresting a person illegally carrying a firearm but who is at a low risk for violence might have less effect on total violence, as he or she was not an immediate threat to commit violence. Whether the arrest resonates to others with a tendency for violence will depend on the local crime networks he or she was connected to.

Along these lines, prior research examining the ability of police to curb firearm violence has not measured whether reductions in firearm violence is due to incapacitation. Increased arrests of those illegally carrying firearms might have resulted in the incapacitation of particularly dangerous individuals, thus generating the decline in firearm crime (McGarrell et al., 2001). If particularly dangerous people are temporarily locked-up, reductions in firearm violence may occur while they incapacitated but once they are released firearm violence should return.

Lastly, research on the effect of the ability of law enforcement to reduce illegal carrying of firearms and reduce firearm crime has focused exclusively on patrol beats with exceptionally high rates of firearm crimes. Koper and Mayo-Wilson (2006) indicated that all the studies to date “were conducted in high-crime urban areas and at high-crime times,” making it unclear if firearm crime would be reduced “in places or at times with lower levels of crime” (p. 248). Since police make most arrests for illegal carrying of firearms as part of other investigations or random encounters with citizens (Brill, 1977; Moore, 1980), research should test the efficacy of these non-sustained, general patrol efforts that result in the detection and subsequent arrests of those

illegally carrying firearms. Although intensive patrols might be beneficial, they are expensive; a better understanding of cheaper, non-sustained specific police efforts seems warranted.<sup>1</sup>

In sum, while some research on structural deterrence and approximately a half-dozen quasi-experimental evaluations have strongly suggested that arrests and confiscation of firearms can be an effective strategy to combat firearm crime, a review of the literature reveals gaps in knowledge that should be addressed. The current study will examine four years of data with the ability to aggregate and disaggregate both temporal periods and spatial units. The observed patterns should help better gauge whether, and/or to what extent, arrests for illegal firearm carrying suppress shooting incidents at these various levels.

Based on prior research on ecological deterrence, incapacitation, and more specifically arrests and confiscation of firearms to reduce firearm violence, the following is anticipated:

### **Hypothesis # 1**

Holding constant ecological factors, it is anticipated that areas experiencing at least one arrest for an illegally carried firearm will experience fewer shootings incidents nearby and in the period immediately following (nearby and time period defined below), than would be expected based on chance.

Not only will arrestees be unable to commit later firearm violence, but an increase in the awareness of the arrests for illegally carrying firearms also might dissuade others from illegally carrying firearms.

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<sup>1</sup> There are numerous hypothesized dynamics that link arrests for illegal firearm carrying and firearm violence that have yet to be tested. Although testing these dynamics are beyond the scope of the current study results may have implications for future research by specifying the temporal and spatial parameters that these hypothesized dynamics operate within.

Focusing first on the spatial dimension, the Philadelphia streetscape supports using bandwidths of 400 feet, as many city blocks are approximately 400 feet. Street blocks serve as important settings for both crime (Taylor, Gottfredson, and Bower, 1984) and reactions to crime (Taylor, 1997). Street blocks can be important planning or deployment units for local law enforcement, thus providing more strategic guidance for prevention and deployment decisions than other arbitrary distances which neglect the local geographies (Messner and Anselin, 2004; Ratcliffe and Rengert, 2008).

Turning attention to the temporal dimension, ecological deterrence may ensue promptly and/or slowly. D'Alessio and Stolzenberg (1998) examined daily variations in reported crimes, arrests, and pretrial jailings in Orange County, Florida during the last half of 1991. They found an inverse relationship between arrests and reported index crimes only a day later. Arrests made by police almost immediately affected criminal activity. Criticizing the use of longer lags – yearly, quarterly, monthly – when testing for deterrence, the authors argued that “it took only one day for a deterrent effect to manifest itself” as news of arrests quickly disseminated through informal networks of interaction (p. 754). The use of somewhat longer lags, such as a month (Chamlin et al., 1992) or a quarter (Chamlin et al., 1992), can show deterrence effects of arrests on later crimes or delinquency (Taylor et al., unpublished manuscript).

In sum, the ecological deterrence literature shows police actions such as arrests can drive down later crime and maybe delinquencies. There is confusion, however, because the relevant ecological or group-based dynamics have not yet been fully specified. There may be multiple dynamics and they may operate on different temporal cycles depending in part on local area characteristics and on the type of crime in question. Although some is known about how far deterrence impacts extend spatially, and the lag before which first impacts materialize, duration

and strength are far less clear, and numerous key relevant ecological dynamics remain unidentified.

This study will use one-week time increments, with the expectation that smaller scale deterrent effects are generally short term and may not last more than a month. If and as these data permit, lags of up to a couple of months or a quarter will be examined. Arguably, a 400-foot radius spatial parameter – and perhaps multiples thereof – and a one-week time lag – and perhaps multiples thereof – take into account the underlying geography of Philadelphia, and attend to the possibility that deterrent effects may be short lived.

### **Informed and responsive police**

The preceding question took police actions as initiating events, and shooting as the relevant class of subsequent events. A second key question pursued here reverses this order of events. Do areas with high or increasing numbers of shootings, or locations nearby, experience more arrests for illegal firearms soon after? After a shooting incident, police may seek to increase the number of contacts with citizens via car and pedestrian stops, hoping to detect more illegal firearm carrying and resulting arrests. This section begins by reviewing empirical evidence suggesting that arrest and crime levels are positively associated. Attention is given both to the limitations of past research and to the ways the current research may fill some of those gaps.

### **Deterrence research and the use of ratio variables**

The negative association between current crime rates and prior lagged measures of police performance (arrest ratios, clearance rates, expenditures, etc.) has commonly been interpreted as a deterrence effect, but questions have been raised about the causal direction of this relationship (Jacob and Rich, 1980; Kohfeld, 1983). First, finding that more arrests lead to less crime may be

inherently artifactual, since the variables being correlated have a common term – the number of crimes. When the number of crimes at time one covaries closely with the number of crimes at time two, there is the possibility for the correlation of a variable (the numerator of the crime rates is the denominator of the arrest ratio), potentially creating a negative correlation (Jacob and Rich, 1980; Kohfeld, 1983). Second, instead of proposing that offenders are keenly aware about law enforcement behavior, specifically the number of arrests, it is possible that associations between arrests and crime levels are a result of informed and responsive police administrators and patrol (Decker and Kohfeld, 1985; Jacob and Rich, 1980; Kohfeld, 1983; Kohfeld and Sprague, 1990). Assuming police are aware of changes in criminal activity and police administrators react to more crime by allocating more resources (more officers) and/or emphasizing intensive patrolling in these areas, there may be a greater number of arrests.

In a seminal cross-sectional study of 35 large cities in the United States, Wilson and Boland (1978) using 1975 data, found that as the percentage of robberies leading to arrests increased, the rate of robberies committed decreased. Their finding seemed to support a deterrence doctrine since, as legal punishments in the form of arrests increased, crime decreased. Jacob and Rich (1980) performed a partial replication of Wilson and Boland's 1978 study and found a positive relationship between arrest rates and crime rates. As part of a larger initiative examining governmental responses to crime, Jacob and Rich (1980) had the necessary data for nine cities originally tested by Wilson and Boland. Using time-series data between 1948 and 1978 and one and two-year lags, they reexamined of the effects of police on crime. In six of nine cities, as the number of arrests increased, so did robbery rates, a strong and positive correlation.

Jacob and Rich (1980) argued that the divergent findings were in part due to their belief that the inclusion of common terms in the ratio variables (robberies/population and

arrests/robberies) employed by Wilson and Boland was inappropriate (see Wilson and Boland, 1981 for a rejoinder to Jacob and Rich). When a common component such as number of robberies is used in the numerator of one variable and the denominator of another, the results have a built-in tendency towards negative association (Long, 1979). Kohfeld (1983) described the same phenomenon to explain the results of her 1983 analysis of robbery rates and time-lagged robbery arrests in St. Louis between 1948 and 1978.

### **Evidence that police respond to changes in crime**

Beyond the potential issue of using an improperly specified model, there is a logical reason to believe that a positive association exists between level of crime and number of arrests. Jacob and Rich (1980) posit that as police respond to increasing crime conditions they may make more arrests, recording more crime, thereby generating a positive correlation between crime rates and arrest rates. Jacob and Rich (1980) noted that they have “no direct evidence,” but the direction of the relationship between arrests and crime suggests that citizens recognize changes in offending and may be more likely to call the police, therefore increase recorded crime rates (Jacob and Rich, 1980, p. 121).

Likewise, Kohfeld (1983) proposed that robbers were neither sensitive to nor aware of information concerning police clearance rates from the prior year, but that police did have information about the location and trends of robberies. Law enforcement personnel, therefore, were likely to respond to shifting robbery patterns by allocating additional resources to areas where they observed robberies going up. If law enforcement responded to these changing robbery patterns, the relationship between arrest levels and lagged (earlier) crime levels would be positive (Kohfeld, 1983). Above it was noted that Kohfeld (1983) discovered a negative correlation between robbery rates and time lagged (earlier) robbery arrests in St. Louis between

1948 and 1978. A reexamination of the same data, reversing the temporal relationships between the two variables – assuming increased arrests followed increases in crimes – revealed a strong positive correlation. She further argued that robbery and other violent crimes, the crime categories with the largest correlation, were the types that get the most publicity, and therefore placed additional pressure on the police to make arrests (Kohfeld, 1983).

Decker and Kohfeld (1985) drew a similar conclusion after comparing regression results of homicide, robbery, and burglary arrests in rate versus raw form. They contended that arrest ratios were inappropriate deterrence measures since criminals were unaware of subtle changes in the proportions of arrests but might be cognizant of an increase in the sheer number of arrests. Again using St. Louis data from 1948 to 1978, and a generalized least-squares procedure, they found a negative association when using robbery and burglary arrest rates, which would be predicted by deterrence, but the results were non-significant. The association between homicide and arrests was non-significant and in the opposite direction predicted by deterrence.

Conversely, using lagged raw numbers of arrests – arrests after crime – Decker and Kohfeld (1985) found significant positive relationships in most models. The authors noted the extremely high positive first-order correlations for raw numbers of crimes and number of arrests for each offense type. With arrests as the outcome, the effect of crime on arrest was significant and positive (Decker and Kohfeld, 1985). In sum, using annual data from a single city, Decker and Kohfeld (1985) concluded their analyses of arrests and crime levels in general did not support a deterrence interpretation, but instead suggested “arrests are a response to criminal behavior” (p. 448). A police department “undoubtedly responds to criminal behavior, and one therefore ought to expect that when the number of crimes increases, so do the number of arrests”

(p. 439). They go on to state that if “police are moderately good at their job,” then as crime increases so should the number of arrests (Decker and Kohfeld, 1985, p. 439).

Lastly, using official police records from the city of St. Louis, Kohfeld and Sprague (1990) modeled criminal responsiveness to police behavior and police responsiveness to criminal behavior. Disaggregating burglaries by weeks and census tracts, the authors estimated the deterrent effects of police arrest on criminal behavior and the degree to which police responded to changes in criminal activity. Additionally, the authors tested criminal responses to arrests and police responses to criminal activity under varying demographic conditions. Kohfeld and Sprague (1990) pointed out that neighborhood social status, residential stability, age, and family structure all covary with reported crime. Perhaps different neighborhood conditions shape the interactions between police and criminals. The social organization of a neighborhood (measured using demographic proxies) such as its cohesiveness or homogeneity might limit or increase crime opportunities and the causes of criminality, increase or decrease the speed of a police response, and assist or hamper in the communication of information about police activity to criminals. In sum, police and offender interactions might be moderated by various neighborhood social dynamics.

Over a ten-week period in the summer of 1982, Kohfeld and Sprague (1990) pooled and compared weekly frequency changes in census tracts for all arrests and for the crime of burglary. The authors posited that police would respond almost instantaneously (less than one week) to criminal behavior whereas criminal responses will generally take more time (one week or more). Under varying demographic conditions, the police response to criminal activity (more arrests) and the criminal response to police activity (fewer burglaries) can be enhanced or attenuated. For example, Kohfeld and Sprague (1990) found that in low-income areas, arrests are more likely to

be followed by fewer burglaries when compared to other areas. Conversely, in higher income areas, the effects of arrests in deterring burglaries are attenuated. The authors speculated that in low-income areas arrests by police result in a decline in burglary due to the existence of a criminal infrastructure that can facilitate communication about police activity that might not exist in higher income areas.<sup>2</sup>

### **Key remaining questions**

It appears there are only a handful of studies explicitly stating police rationally respond to criminal activity resulting in more arrests (Decker and Kohfeld, 1985; Jacob and Rich, 1980; Kohfeld, 1983; Kohfeld and Sprague, 1990). The current research hopes to build on and extend research on the association between offender and police behavior in the following ways:

First, the current research will use the Knox close pair method (described in detail in Chapter Three) to test for associations between a type of crime and arrests across space and time. Unlike prior research that has examined the relationship between robbery incidents and robbery arrests (Jacob and Rich, 1980) or burglary events and all arrests (Kohfeld and Sprague, 1990), the current study tests for an association between two theoretically closely related but different crimes. Instead of supposing that police respond to shooting incidents by increasing the number of shooting arrests, a plausible but untested assumption is that police shift attention towards detecting and confiscating illegally carried firearms as a means to reduce firearm violence. Changes in the number of arrests that involved the illegal carrying of a firearm might be a more appropriate measure of informed and responsive police administrators and patrol than arrests for shooting incidents. Arguably, firearm violations arrests are a more discretionary police activity.

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<sup>2</sup> The exact dynamics that underlie these connections are obviously less clear and beyond the scope of this study. Additionally, if it is discovered that illegal firearm arrests and shootings are linked future research should seek to test if these links are strengthened or weakened under different neighborhood conditions.

Second, the majority of studies that hypothesize police personnel respond to changing crime patterns and that have resulted in a positive correlation between crime and arrests have used time aggregations and time lags of one year (e.g. Decker and Kohfeld, 1985; Jacob and Rich, 1980; Kohfeld, 1983). Kohfeld and Sprague (1990) argued that data analyzed yearly, quarterly, or monthly insufficiently identify the differential response patterns occurring between police and criminals, and vice versa.

Further, not only do the majority of studies determining if police personnel respond to changes in crime by making more arrests use large temporal units, they also examine changes across entire cities (e.g. Decker and Kohfeld, 1985; Jacob and Rich, 1980; Kohfeld, 1983). These may be so large they mask or swamp dynamics which may be ecologically linked to more delimited spatial arenas (Sherman, Gartin, and Buerger, 1989; Taylor, 1997).

It appears that only one study (Kohfeld and Sprague, 1990) used units of analysis smaller than the city (census tracts) and smaller time aggregation units than one year (weeks). Despite their use of finer temporal and spatial units, questions still remain. Although census tracts were likely an improvement over the use of a city as the unit of analysis, research has suggested that crime may be concentrated within very small spatial units, even smaller than census blocks, which are subdivisions of census tracts (Weisburd, Morris, and Ready, 2008). Generally, crime conditions that may lead to an increase in police presence and more recorded crime may be very localized (Sherman, Gartin, and Buerger, 1989). Police responding to serious crime may canvass specific locations as they set up a perimeter of one block in each direction to search for suspicious people, and this may lead to arrests (Herbert, 1997). Thus, studies spatially disaggregating the considered connections may find different links.

Third, turning attention to time aggregation, Kohfeld and Sprague (1990) assumed police respond immediately to criminal behavior, but criminals' response to police behavior is delayed. Some have questioned, however, if the police respond to criminal behavior immediately and efficiently. For example, Famega, Frank, and Mazerolle (2005) in their study of how Baltimore patrol officers used their discretionary time, found that supervisors often provided little input or only vague directives regarding where to implement proactive strategies to target crime, ones that presumably should lead to arrests.

In short, although there is reason to believe that police respond faster to criminal behavior than criminals respond to police behavior, this needs further examination. Various works have suggested police respond to crime as swiftly as one week or all the way up to a year. These findings are worthwhile if they untangle law enforcement's ability to suppress crime and their ability to react to crime. Complicating this is that various studies have used either the city or, in the case of one study, census tracts as the units of analysis.

Kohfeld and Sprague (1990) argued criminal and police activity are "not simultaneously interactive if measured on sufficiently fine temporal and spatial scales" (p. 112). Nevertheless, the question persists: was their analysis with one-week temporal units and census tract spatial units over only a ten-week period adequate enough to detect the consequences of police activity on criminal activity and/or criminal activity on police behavior? Specifically, the limited 10-week period may not be a long enough period to allow for sufficient variation in the distribution of criminal offenses and police activity. Analyzing arrest data of illegal firearm carrying and confirmed shooting data from Philadelphia over a four year period (2004 to 2007) may help clarify associations between criminal activity and arrests. Areas with more arrests soon after one or more shootings may indicate a concerted police response. The current research's use of a

spatio-temporal clustering method will allow for varying and smaller temporal and spatial units than previous research to help test for police responsiveness. Based on prior research on police behavior, and more specifically the assumption that police respond to criminal behavior (Decker and Kohfeld, 1985), the following is anticipated:

### **Hypothesis # 2**

Holding constant ecological factors, areas experiencing at least one shooting incident, will experience a greater number of arrests for illegally carrying firearms nearby and in the period immediately following (nearby and time period defined below) compared to what would be expected based on a random distribution.

For example, the Philadelphia Police Department, like other police departments, assigns priority numbers to incidents, with the first priority incident being dispatched and responded to first. Calls to assist other officers and then crimes in progress (such as shootings, and homicides in particular) are considered more serious incidents, and thus treated as priorities requiring immediate action by the police (Philadelphia Police Department, 2008). Following a shooting incident, police are likely to not only respond within a short temporal period but spatially they will canvass a specific area to search for a suspect(s). In a qualitative study of police officers in Los Angeles, California, Herbert (1997) observed that police respond to a shooting by forming a perimeter on each of the four streets forming the block surrounding the scene to apprehend a fleeing suspect. In addition to erecting a perimeter to seal a square block, officers will circle “at a distance of two or three blocks” to the last reported location of the incident (1997, p. 105).

Although the exact amount of time is not specified, research suggests that police respond in time to changes in criminal activity with “immediacy” (Kohfeld and Sprague, 1990: 112). Others (see, D’Alessio and Stolzenberg, 1998) have drawn similar conclusions that “criminal

activity has a relatively immediate impact on arrest levels” (p. 753). In sum, criminal activity should prompt a fast and highly localized response from police.

The space parameter again will be 400-foot increments, as that distance reflects the average length of a city block in Philadelphia. The temporal parameter will be one-week increments. In short, an increase in the number of arrests for illegal firearm carrying after a shooting is expected within one week and within/up to a three block radius (1200 feet), and the likelihood of arrests should decay over space and time.<sup>3</sup>

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<sup>3</sup> One might expect shootings and VUFAs to covary, that is illegal firearm arrests and shootings may increase and decrease in tandem spatially and temporally. Considerable research has found that assaultive violence and firearms spread together in human populations (Blumstein, 1995, Blumstein and Cork, 1996; Boyum and Kleiman, 1995; Cork, 1999; Loftin 1986; Van Kammen and Loeber, 1994). The current study acknowledges this potential but testing for simultaneous occurrences may confound the two separate trends; therefore, shooting-arrest links are tested separately.

## CHAPTER 3: DATA AND METHODOLOGY

### Data

Confirmed shootings during which victims were struck and Violations of the Uniform Firearms Act (VUFAs) occurring within the City of Philadelphia from January 1, 2004 to December 31, 2007, comprise the data that will be used in this study. Shootings were collected from the Philadelphia Police Department's record management system (RMS), which, in part, receives and catalogs incidents of crimes in Philadelphia including their specific locations. The shooting data extracted from the RMS are maintained in the Philadelphia Police Department's Research and Planning Unit, based at Police Headquarters by a corporal who confirms daily the crime events and updates a separate database focused exclusively on shootings (Ratcliffe and Rengert, 2008). The shooting database that will be used in this study consists of only confirmed shootings; therefore, reports of "shots fired" or "man with a gun" were not included. On the rare occasion when there were multiple victims at a single shooting incident, classified as repeat shootings, these incidents also were included in the database. The shooting database includes records of shooting that resulted in death (homicide) and those that did not (aggravated assault) (Ratcliffe and Rengert, 2008).

In addition to confirmed shootings incidents in Philadelphia, the current research will also examine arrests for carrying firearms without a license in Philadelphia. The Pennsylvania Uniform Firearms Act (UFA) introduced in the early 1990s, and subsequently passed in 1995, detailed who may not possess, use, manufacture, control, sell or transfer firearms (Title 18, Chapter 61). More specifically, the Pennsylvania UFA at Section 6106 provides that no person can carry a firearm in any vehicle or concealed on or about his person without a valid and lawfully issued license. In addition to prohibiting those who have been involuntarily committed

to a mental institution and those unlawfully in the United States, the Act enumerates criminal offenses where a conviction precludes an individual from obtaining a license to possess and carry a firearm (Rules and Regulation, 2001).

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. An individual caught carrying a firearm in a vehicle, or concealed on or about his/her person without a valid and lawfully issued license has committed a felony of the third degree. A person caught possessing a firearm in a vehicle or concealed on or about his/her person who otherwise would be eligible to possess a valid license under chapter 18, and has not committed any other criminal violation, however, commits only a misdemeanor of the first degree (PA UFA Title 18 § 6106 (1) & (2)) (Rules and Regulation, 2001).

Data about cases in which defendants were charged with a VUFA as the most serious charge by the District Attorney's Office were acquired from Philadelphia's Adult Parole and Probation Department (APPD), where data about those who are charged with VUFAs are maintained. The APPD is responsible for the supervision of all probation and/or adults sentenced to a Philadelphia county prison or jail who are released under parole conditions. Overall, the APPD has a caseload of approximately 49,000 offenders. In addition to its supervisory role the APPD maintains and analyses crime data particularly related to recidivism (Philadelphia Adult Probation and Parole Department, 2008).

During the years 2004 to 2007 there were 7,236 total records of confirmed shooting that resulted in death (homicide) and those that did not (aggravated assault). During this time period, the greatest number of shooting occurred in 2006 with 2,004, followed by 2005 with 1,793, 2007

with 1,734, and 2004 with 1,705 respectively (Ahlman, Kurtz, and Manning, 2008). Similar calculations will be reported regarding the number of VUFAs during the same four year period. According to the 2007 census estimates, slightly less than 1,500,000 people reside in Philadelphia (U.S. Census Bureau, 2007). Females slightly outnumber males (53.2% vs. 46.8%) and blacks accounted for 45% of the population, whites (non-Hispanic) approximately 39% and Hispanic/Latinos almost 11%. Turning attention to age and poverty, approximately one-fourth of the population reported being younger than 18 and almost 24% of the population indicated they were living below the poverty line (U.S. Census Bureau, 2007). Like many other large cities in the United States, Philadelphia experienced an overall population decline of almost 5% from 2000 to 2007. Additionally, while Philadelphia's population declined, the percentage of people reporting their ethnicity as Hispanic/Latino increased from 8.5% to almost 11%. Other key descriptors outlined above changed only slightly from 2000 to 2007 (U.S. Census Bureau, 2000c; U.S. Census Bureau, 2007) (see table 1).

Descriptive statistics for shooting victims and people arrested with a lead charge for carrying a firearm without a license in Philadelphia during the years 2004 to 2007 will be presented (see table 2).

Table 3 will show the results of a sample population proportion test. This test will compare the proportions of Philadelphia residents age 18 and older generated from the 2007 census, first with shooting victims and then with arrestees with a lead charge of a VUFA by race, sex, and age. The test will demonstrate if the demographic differences observed between shooting victims and those charged with a lead charge of a VUFA versus the general or expected population of Philadelphia are statistically significant.

## **Police districts and violent crime in Philadelphia**

As of 2007 there are more than 6,000 officers subdivided across Philadelphia into 25 patrol districts of varying size but two patrol districts, 77 and 92, cover Philadelphia International Airport and Fairmount Park, a large urban park/green space and therefore differ significantly from the patrol districts (Philadelphia Police Department, 2007).

There is a considerable amount of variation in the total land area of each police district as well as the amount of crime and the socio-demographic characteristics within each district. Focusing first on size of police districts, in Philadelphia they have a mean size of 5.81 square miles, with the smallest police district encompassing only 1.29 squares miles versus the largest police district encompassing 16.33 square miles (Greene, Piquero, Hickman, and Lawton, 2004). On average, smaller police districts are found near the center of the city, which tend to be more densely populated, with larger police districts in the less densely populated areas with the city limits.

Next, violent crime is clearly not randomly distributed throughout Philadelphia. Overall, nine districts in particular were recently identified by the Philadelphia Police Department as being the most violent (measured by the number of homicides, shootings, robberies, and aggravated assaults) in 2007, the 12<sup>th</sup>, 18<sup>th</sup>, 19<sup>th</sup>, 14<sup>th</sup>, 35<sup>th</sup>, 39<sup>th</sup>, 15<sup>th</sup>, 22<sup>nd</sup>, and 25<sup>th</sup>. Six of the nine districts identified as extremely violent were in the Southwest and Northwest Police Divisions (Philadelphia Police Department's Crime Fighting Strategy, 2008). These districts surround the core of the city, whereas districts within the core or center of the city as well as those in the Northeast, had far less violence relative to the districts identified by the Philadelphia Police Department (see figure 1).

## **Describing shootings and VUFAs spatially**

In addition to recording the incidents and dates of shootings and VUFAs, both crime events will be geocoded. Geocoding is the process of assigning geographic identifiers in the form of x- latitude and y- longitude coordinates to events, and then plotting those coordinates on a map (Chainey and Ratcliffe, 2005). For the purposes of the current study, the events are all shootings, geocoded to the location of the shooting and VUFAs, geocoded to the address of the arrest, not the arrestee. The geocoding hit rate (successfully geocoded) for shootings and VUFAs should both be above the 85% threshold suggested by Ratcliffe (2004) as a first estimate of a minimum reliable geocoding rate.

The number and rates of shootings and VUFAs by police districts will be presented (see figure 2). Additionally, a Moran's I, a measure of global spatial dependence, will be calculated to test separately whether shooting and VUFAs clustered across police districts (see figure 3).

## **Analytic method**

A spatio-temporal clustering technique will be used to determine whether the number of VUFAs and shootings are associated, or if VUFAs and shootings are independent of each other. Stated differently, the current investigative method is a new approach to determine whether arrests for illegal firearm carrying link to shooting incidents. The data required for the current study will consist of the date and location (x/y coordinates) of both shootings and VUFAs. Using the standard projected coordinated 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 (Ratcliffe and Rengert, 2008). Manhattan distances most precisely reflect the actual distance traveled by urban residents by taking into account the traditional grid layout of most streets, whereas Euclidean distances (also

known as “crow flies” distances) simply measure the shortest distance between two points (Chainey and Ratcliffe, 2005).

### **Knox method**

To reiterate, the analytic method proposed here draws from the Knox close pair method originally used to study the communicability of disease. When used to study crime, researchers (e.g. Johnson and Bowers, 2004a, 2004b; Ratcliffe and Rengert, 2008, Townsley, Homel, and Chaseling, 2003) have noted the primary benefit of using the Knox method is its ability to test for clustering of events in both space *and* time. Crime may occur close spatially reflecting the spatial concentration of crime, but not temporally since the incidents could be spread out over time reflecting enduring crime levels (Townsley, Homel, & Chaseling, 2003). Similarly, certain periods might exhibit a rise in crime, thereby resulting in an excess of crime incidents compared to what is normally witnessed by chance. Although a concentration of crime incidents in time might generate a spike in crime, if the incidents are unrelated reflecting the temporal but not spatial concentration of crime, the incidents will be spread out over all distances. In sum, the number of crime incidents must be significantly different from what is expected by chance in space *and* time to suggest they are in some way related, otherwise, concentrations in time *or* space may suggest high levels of crime in small areas or changes in crime levels produced by a variety of reasons but it is unclear if they are related. The Knox method identifies whether an excess of observed events occur more closely in space and time than one would anticipate based on chance (Townsley, Homel, and Chaseling, 2003).

The Knox approach was first used to identify space-time clusters of childhood leukemia. Knox (1964), in order to identify these interactions between space and time, paired each childhood leukemia case with every other childhood leukemia thereby  $N$  cases produce  $N(N -$

1)/2 distinct pairs (Townsville, Homel, and Chaseling, 2003). Spatial and temporal distances between all possible pairs were aggregated into a 2 by 2 contingency table that listed distance and temporal bands outlining distances and temporal intervals between each case of childhood leukemia. Examining 185 cases of childhood leukemia in the North of England over a 10-year period, Knox concluded cases in a pair were close in space if the two events were less than one km apart. Cases in a pair were considered close in time when they occurred within 60 days of each other (Knox, 1964). Distance and time values considered close were set by Knox.

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. Overall, Knox (1964) determined that the observed spatio-temporal concentration of 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).

Originally the Knox method called for a comparison of the observed values, from the contingency table with ones calculated by an adjusted residual value from the expected values based on marginal row and column totals. However, Ratcliffe and Rengert (2008) pointed out 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. Since each crime event is measured in terms of space and time from every other crime event, each event pair is not independent of other event pairs. To combat the potential issue of a lack of independence, researchers (see, Johnson and Bowers, 2004a, 2004b; Ratcliffe and Rengert, 2008; Townsville, Homel, & Chaseling, 2003) built on the work of Besag and Diggle (1977) who examined colonies of Kittiwakes, a coastal breeding bird.

While maintaining the values of the event location for their study (warehouse window ledges), Besag and Diggle (1977) used a Monte Carlo simulation to shuffle the date on which each event occurred. They randomly shuffled the dates repeatedly to create a number of contingency tables with expected values thus creating a projected distribution of incidents that could be compared to the observed values.

To better illustrate a contingency table and the incorporation of the Monte Carlo simulation, imagine over a one-year time period a small city has recorded 84 residential burglaries along with the date and location of each of those burglaries. Although Knox studied the transmission of disease, the same principles in constructing a contingency table can and have been applied in the field of criminal justice. For example, a researcher might hypothesize that burglaries will cluster in space and time since offenders after a successful burglary may soon return to houses near their initial burglary incident since they may have scrutinized surrounding dwellings and feel confident they will be successful again (Townesley, Homel, and Chaseling, 2003). Using the aforementioned formula  $N(N - 1)/2$ , 84 residential burglaries would produce 3,486 distinct pairs. The geographic distance and the amount of time elapsed between each pair of events is calculated and populated into the contingency table.

The contingency table will summarize how many pairs of residential burglaries occurred within various spatial and temporal bandwidths. To examine all pairs closer than 5,000 feet (almost one mile) and one year apart a researcher might select spatial increments of 500 feet and temporal increments of 60 days (approximately two months). Ultimately the temporal and spatial bandwidths are at the researchers' discretion (Ratcliffe and Rengert, 2008; Townesley, Homel, and Chaseling, 2003). Using a space dimension of 500 feet and 60-day time intervals would

result in a contingency table with six columns and 10 rows. The range of spatial and temporal increments used will allow for a sensitive analysis of the hypothesis investigated.

Once the contingency is populated the pairs of residential burglaries are compared to the number that would be expected under the null-hypothesis. To reiterate, the null-hypothesis is what is expected if the location and timing of the burglaries were distributed randomly. To generate a contingency table where the location and timing of burglaries are independent, the date on which the burglaries occurred is randomized across events.

To randomize the timing of burglaries a Monte Carlo approach is used. Leaving the space distribution in place, the Monte Carlo simulation will generate a new random distribution of times for the burglaries. Stated differently, the dates on which burglaries occurred are randomly rearranged. Each simulation will regenerate the geographic distance and the amount of time elapsed between each pair of burglaries. This process creates a new expected contingency table. These expected values are ones where the temporal relationships appear as they would if there was no spatio-temporal association. This process, one in which the burglary times are randomly shuffled is repeated a number of times, the exact number of times is at the researchers' discretion but 999 permutations are common. By conducting 999 simulations where the dates on which the residential burglaries occurred are randomly rearranged while preserving the distance distribution across event pairs, 999 new contingency tables with only expected values are created.

While preserving the distance distribution across burglary pairs, the dates on which the burglaries occurred are randomly rearranged 999 times creating 999 new contingency tables with expected values in each space-time cell. The distribution of the 999 expected values in each cell should roughly follow a random distribution. Next, the newly created expected values in each

space-time cell are compared to the values in each space-time cell from original observed contingency table to determine where the observed value for each cell fits on that random distribution. Specifically, if the number of observed event pairs in a specific space-time cell exceeds the expected (N of event pairs) across the entire spatial and temporal ranges.

Based on the number of times that the actual number of burglaries exceeds the expected number of burglaries for each specific space-time dimension an estimate of statistical significance can be calculated. The number of times that the observed number of burglaries surpasses the numbers generated by the Monte Carlo simulation can be calculated into a pseudo *P*-value. For example, if the observed number of burglaries was 189 in the 0 to < 500 feet and less than 60 days cell and 950 of the 999 permutations resulting in a value below 189 (the observed value) one could conclude that observed frequency for this space-time cell exceeded the values generated by the Monte Carlo simulation 95% of the time creating a pseudo *P*-value of 0.05. If none of the expected values generated from the 999 permutations exceeded 189 (the observed value) the result would be a pseudo *P*-value of 0.001. In both example the observed value exceeded the expected values at least 95% of the time. Such a result suggests the frequencies observed were not likely to occur under the null hypothesis of no spatio-temporal clustering (Johnson, Summers, and Pease, 2008). Additionally, statistical significance of the observed value for each spatio-temporal dimension can be calculated as  $P = 1 - n_e / (n_s + 1)$ , where  $n_e$  represents the number of times that the expected values were greater than the observed and  $n_s$  represents the number of permutations (Ratcliffe and Rengert, 2008).

Lastly, an effect size can be calculated by dividing the observed value from a space-time cell by the mean of the expected values from that same space-time cell. For example, the observed value of 189 from the 0 to < 500 feet and 60 days and less cell is dividing by the mean

of the expected values derived from the 999 permutations. A mean expected value of 110 would indicate that 1.7 times as many events occurred in the 0 to < 500 feet and less than 60 days cell that was expected under random distribution.

### **Analysis plan**

Using much of the same logic and methods described above, the current research attempts to determine whether there is evidence of space-time clustering of shooting incidents and VUFAs. Although many of the methods will be similar, the current research differs significantly from past work on disease transmission or repeat/near repeat victimization by focusing on two different phenomena, shootings and VUFAs, instead of a single type of event such as cases of childhood leukemia or residential burglaries.

The data will be analyzed using a C#.NET program originally written by Jerry H. Ratcliffe to specifically compute multiple simulations of the expected values. Using C# programming language to create an executable program for Windows, the program created to examine space-time relationships between a single type of phenomenon will be modified to read the data and create an observed matrix of space-time associations among two different types of phenomena, in this case shootings and VUFAs.

The spatial and temporal distances between the cases for each pair will be recorded. The matrix will be aggregated into pair counts based on the distance bands and temporal bands resulting in a table displaying the counts of event pairs observed (Ratcliffe and Rengert, 2008). Based on the underlying geography of the area under study and theory outlined above during the discussion of the hypotheses, the spatial increments will be 400 feet (approximately one city block in Philadelphia) and temporal increments of one-week periods.

All events pairs will be aggregated into a 2 by 2 contingency. Using 400 feet and one-week increments space-time cells will be created for event pairs closer than 5,200 feet (approximately one-mile) and 91 days (approximately three-months) apart. Additionally, the remaining event pairs with distance and temporal periods greater than 5,200 feet and 91 days will be calculated and aggregated in space-time cells resulting in a contingency table with 14 columns and 14 rows (see tables 4 and 5 for examples). Additional spatial and temporal increments (e.g., 200 feet and one day intervals) may be used to offer a sensitivity analysis of the various hypothesis outlined above (assuming these finer increments do not result in cell frequencies that are too small).

Once the contingency table has been developed and populated, the cell counts will be contrasted versus a null-hypothesis condition (the expected values based on a random distribution). The current study will use the same Monte Carlo approach described above to perform repeated simulations of the actual study data. Again, the Monte Carlo simulation will keep the event location fixed to generate tables that have the same marginal distance totals for pairs as the table under consideration to create an expected distribution in the absence of space-time clustering (Ratcliffe and Rengert, 2008).

Each hypothesis will be concentrating on different subsets of the data. To organize and analyze temporal and spatial clusters, two 2 by 2 contingency tables will be generated, one related to each hypothesis (see tables 4 and 5 for examples).

To test each hypothesis a different set of event pairs will be produced. First, to test whether or not firearm arrests are associated with fewer shootings in the period soon after, and in nearby locations, each shooting incident will be paired with each VUFA, with arrests preceding shooting incidents making arrests the initiating event (see figure 4). The distance and the amount of time elapsed will be calculated from only those shooting incidents that occurred after an

arrest. Theoretically, since it is expected that arrests influence the likelihood of later shootings it is not necessary to calculate the distance and time of prior shootings incidents, ones that occurred prior to arrests. In sum, these event pairs will consist of the spatial and temporal distance of shootings from each prior arrest. If more firearm arrests are associated with fewer shootings in the period immediately following, and in nearby locations one may discover the observed number of shootings are lower than the expected values. Although those examining the near repeat phenomenon were primarily interested in cases where the observed values exceed the expected values the current hypothesis predicts the observed values of shootings will be lower than the expected.

Second, to test whether or not shooting increases are associated with more subsequent firearm arrests in the period immediately following, and in nearby locations, each arrest will be paired with each shooting incident, with shootings preceding arrests making shootings the initiating event (see figure 4). Conversely, the distance and the amount of time elapsed will be calculated from only those firearms arrests that occurred after a shooting incident. These event pairs will consist of the spatial and temporal distance of arrests from each prior shooting incident. If observed firearm arrests in a particular space-time cell exceed the expected value at least 95% of the time the effect size will be calculated to determine how much more likely firearms arrests occurred than would be expected by chance.

The principles described above still apply. The dates will be randomized a total of 999 times and a finding that the observed number of shootings is less than the expected count every time would result in a pseudo *P*-value of 0.001. The effect size created by dividing the observed value from a space-time cell by the mean of the expected values from that same space-time cell

will be below one indicating that observed shootings incidents less likely to occur than expected by the null-hypothesis.

## **CHAPTER 4: RESULTS**

## CHAPTER 5: IMPLICATIONS

The current research may considerably enhance criminological theory, future research on firearm violence, and provide potentially useful strategic information to law enforcement agencies.

Theoretically, the proposed research may improve our understanding of ecological deterrence and police responsiveness to crime. The disaggregate examinations of spatio-temporal links among carried firearms, police arrests for illegally carried firearms, and shooting incidents may help to clarify conceptual views about these connections. Investigating these links in a more fine-grained manner may align the examination more closely with the corresponding offender and police dynamics. Further, varying the spatial and temporal increments may help provide a sensitivity analysis on pertinent dynamics working at different space and time scales. Overall, exploring shooting-arrest links in a more disaggregated and integrated view should refine our knowledge of offender and police dynamics and clarify existing theory.

In addition to contributing to criminological theory, results from the current research may provide potentially important strategic information to police departments. Results from the first model may be a valuable addition to literature on police efforts to discourage illegal firearm carrying in public places as a means to reduce firearm violence. Unlike prior studies that focused specifically on intensive patrols in high crime areas, the current research may provide support that law enforcement may reduce firearm related violence through street searches and arrests of people illegally carrying firearms via non-sustained, general patrol efforts. Considering the cost of intensive or directed patrols, a better understanding of cheaper, non-sustained specific police efforts seems warranted.

Next, the second model may demonstrate that arrests increase after shootings. Considering that recent research in Philadelphia suggested that a shooting incident is often followed soon after and in close proximity by a subsequent shooting likely due to retaliation or escalation (Ratcliffe and Rengert, 2008) an emphasis on targeting police and other resources to specific areas after shootings may be advantageous to limit retaliatory firearm violence. Deploying and maintaining an officer presence for a short time in an area after a shooting may be an effective enforcement strategy used by police to halt retaliatory firearm violence. In sum, the proposed research may make a considerable contribution to criminological theory as well as provide results that could inform law enforcement crime reduction tactics.

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Table 1: Key demographic characteristics: Philadelphia residents 2000 and 2007

	2000	2007
Population	1,517,550	1,449,634
Female	53.5%	53.2%
Male	46.5%	46.8%
Black	43.2%	45.0%
Hispanic/Latino	8.5%	10.7%
White	45.0%	47.6%
White/Non-Hispanic	42.5%	39.4%
Persons under age 18	25.3%	25.1%
% High school graduate	71.2%*	NA
% College graduate	17.9%*	NA
Median household income	\$30,746**	\$35,461
% Below poverty line	22.9%**	23.5%

Source: 2000 and 2007 United States Census Bureau

\* percent of persons age 25+

\*\* based on 1999 estimates

Table 2: Race/ethnicity, sex, and age distribution of shooting victims and illegal firearm arrestees in Philadelphia, 2004 to 2007

	Shooting victims (number/%)	Firearm arrestees (number/%)
Total	XX	XX
Black	XX(xx%)	XX(xx%)
Hispanic/Latino	XX(xx%)	XX(xx%)
White	XX(xx%)	XX(xx%)
Other race/ethnicity	XX(xx%)	XX(xx%)
Male	XX(xx%)	XX(xx%)
Female	XX(xx%)	XX(xx%)
Age (mean)	XX	XX

Table 3: Sample population proportion test: Race/ethnicity, sex, and age

	Overall population	Shooting victims (2007)	Firearm arrestees (2007)
Black	XX	XX	XX
	XX	XX	XX
Male	XX	XX	XX
	XX	XX	XX
<25	XX	XX	XX
	XX	XX	XX

Overall population based on U.S. Census data 2007. Philadelphia residents 18 years and older  
 Two-tailed test: \* = significant

Table 4: Observed values: Arrests and later shootings

Distance between events (feet)	Days between events (number of days)														Totals
	0 to < 7	7 to < 14	14 to < 21	21 to < 28	28 to < 35	35 to < 42	42 to < 49	49 to < 56	56 to < 63	63 to < 70	70 to < 77	77 to < 84	84 to < 91	91 +	
0-400															
401-800															
801-1200															
1201-1600															
1601-2000															
2001-2400															
2401-2800															
2801-3200															
3201-3600															
3601-4000															
4001-4400															
4401-4800															
4801-5200															
5201 +															
Totals															
Arrests n = XX; Shootings n = XX; Event pairs = XX															

Table 5: Observed values: Shootings and later arrests

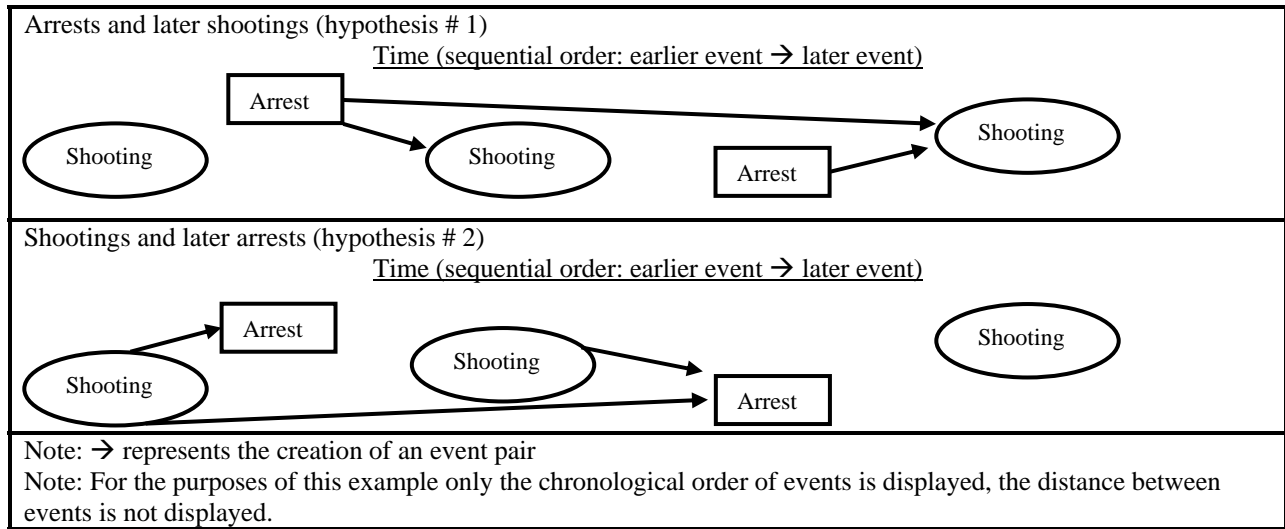
Distance between events (feet)	Days between events (number of days)														Totals
	0 to < 7	7 to < 14	14 to < 21	21 to < 28	28 to < 35	35 to < 42	42 to < 49	49 to < 56	56 to < 63	63 to < 70	70 to < 77	77 to < 84	84 to < 91	91 +	
0-400															
401-800															
801-1200															
1201-1600															
1601-2000															
2001-2400															
2401-2800															
2801-3200															
3201-3600															
3601-4000															
4001-4400															
4401-4800															
4801-5200															
5201 +															
Totals															
Shootings n = XX; Arrests n = XX; Event pairs = XX															

Figure 1: Philadelphia violent crime, 2007 (Not shown)

Figure 2: Confirmed shootings and VUFAs in Philadelphia (Not shown)

Figure 3: Moran's I for Shootings/VUFAs (Not shown)

Figure 4: Initiating event



## APPENDICES