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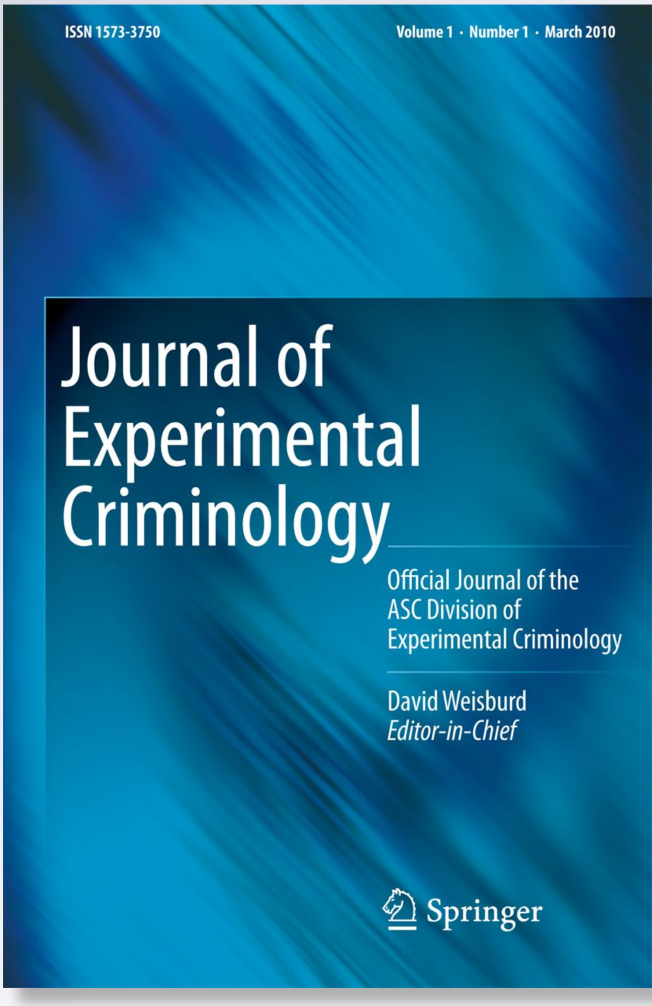

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Police-monitored CCTV cameras in Newark, NJ: A quasi-experimental test of crime deterrence

Joel M. Caplan · Leslie W. Kennedy · Gohar Petrossian

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Abstract We present a test of the crime-deterrent effect of police-monitored street-viewing CCTV cameras using viewsheds of areas that were visible by cameras via direct line-of-sight and that were digitized using easily replicable methods, Google Maps, and standard GIS tools. A quasi-experimental research design, using camera installation sites and randomly selected control sites, assessed the impact of CCTV on the crimes of shootings, auto thefts, and thefts from autos in Newark, NJ, for 13 months before and after camera installation dates. Strategically-placed cameras were not any different from randomly-placed cameras at deterring crime within their viewsheds; there were statistically significant reductions in auto thefts within viewsheds after camera installations; there were significant improvements to location quotient values for shootings and auto thefts after camera installations. There was no significant displacement and there was a small diffusion of benefits, which was greater for auto thefts than shootings. The system of cameras in Newark is not as efficient as it could be at deterring certain street crimes; some camera locations are significantly more effective than others. Results of a system-wide evaluation of CCTV cameras should not be the only basis for endorsing or contesting the use of CCTV cameras for crime control or prevention within a city. Future research should test whether the effectiveness of CCTV cameras are dependent upon the micro-level attributes of environments within which they are installed.

Keywords Camera · CCTV · Crime · Deterrence · Police · Public surveillance · Viewshed

Introduction

There is a widespread and growing use of closed-circuit television (CCTV) cameras by law enforcement officials to identify and control crime in public places. This has

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led to a rather intensive debate about CCTV cameras and surveillance strategies centering on the unease in the community concerning their effectiveness (Akers and Sellers 2009). Advocates of CCTV claim that cameras deter criminal activity because people believe that their behavior is being monitored. It is expected, then, that CCTV monitoring, and the swift and certain punishment that cameras signify, is enough to deter criminal activity in places where cameras are present. This explanation and the installation of CCTV cameras for deterrent effects is consistent with more traditional (albeit less technological) policy reactions to crime problems, such as hiring more police and increasing street patrols, that aim to increase the certainty of apprehension and conviction of criminals (Akers and Sellers 2009). However, empirical research about the effectiveness of street-level public CCTV cameras at deterring crime has shown mixed results (see, in particular, Welsh and Farrington 2002; Gill and Spriggs 2005; Gill et al. 2006; Harris et al. 1998). Some studies suggest CCTV cameras have no effect on crime (e.g., Ditton and Short 1999; Gill et al. 2006; Phillips 1999; Brown 1995) while others find small to modest reductions (e.g., Armitage, et al. 1999; Short and Ditton 1996; Farrington et al. 2007).

The quasi-experimental study presented here was guided by the following three objectives to improve upon the limitations of prior research: (1) test the crime deterrent effects of "strategic" versus "non-strategic" placements of CCTV cameras; (2) demonstrate a new technique for creating more realistic target areas, or viewsheds, for empirical testing; and (3) evaluate the overall effectiveness of CCTV cameras in Newark according to their local place-based impacts on crime. Geographic information system (GIS) mapping and analytical techniques including descriptive and inferential statistics were used to meet these objectives. We sought to maximize the reliability and validity of our results by using viewshed areas that were visible by the cameras via direct line-of-sight; by assessing the impact of CCTV cameras only on crimes that could conceivably be deterred from street-viewing cameras; and by limiting our dependent variables to crimes that are mostly always reported and known to police and that occur mostly in public places that cameras could monitor. We begin with a presentation of the theoretical framework and existing literature that guided and informed the study—specifically, crime at places and research on CCTV. A "Methodology" section follows that discusses in detail the research setting of Newark, NJ, and the data and tasks performed to carry out the statistical analyses. "Results" follow and then a "Discussion and conclusion" section ends the paper with interpretations of the findings and suggestions for policies, practices, and future research endeavors.

Crime at places

That crime concentrates at specific, select places or "hotspots" is well supported by research (Weisburd et al. 2004; Sherman et al. 1989; Harries 1999; Eck 2001; Eck et al. 2005; Ratcliffe and Rengert 2008) and comports with the daily experiences of crime analysts in law enforcement agencies across the nation (Weisburd 2008). Brantingham and Brantingham (1981) initially provided important conceptual tools for understanding relationships between space and crime, such as with the term "environmental backcloth". Groff (2007a, b) points out that there remain definite tendencies for crime to concentrate and congregate in certain areas according to the structure and features of the underlying study areas. This observation provides support for the notion that the presence or absence of criminal activity in particular areas is enabled by the unique combination of certain factors that make these places opportune or inopportune locations for crime (Eck 1995; Mazerolle et al. 2004); that is, where the potential for crime comes as a result of all the characteristics found at these places. CCTV cameras are features of certain places and are, therefore, part of the environmental contexts that could affect nearby crime occurrence (Ratcliffe and Rengert 2008). This could be one reason why opportunities for crime are not equally distributed across places, or "small micro units of analysis" (Weisburd, 2008: 2), and why the choice of the level of aggregation plays a critical role in the reliability and validity of CCTV evaluation studies (Weisburd et al. 2009a).

We considered the effects of CCTV cameras on crime from the perspective of (potential) criminals and whether they could see cameras or should be concerned about cameras from the places where they are going to commit the crime. This contextual approach to considering places that are least conducive to crime occurrence is consistent with ideas that were popular among ecologists, repeated by environmental criminologists when Brantingham and Brantingham (1995) talked about “environmental backcloths”, and are now studied by crime and place scholars (e.g., Weisburd et al. 2008, 2009b; Weisburd and Eck 2004) and are appearing in terms of risk terrains (Caplan et al. 2010; Kennedy et al. 2010) or opportunity structures (Groff and La Vigne 2001). Environmental context is also a theme in situational prevention with regard to opportunity reduction, particularly with regard to CCTV as a measure of formal surveillance (Clarke 1997; Cornish and Clarke 1986; Clarke and Eck 2003a). In a way, the concept of cognitive mapping (Zurawski 2007), as introduced by psychologists and behavioral geographers, was reformulated here to consider CCTV camera viewsheds as “risky places” to commit crime due to the greater potential of being seen and recorded by police. From this conceptualization of camera target areas, and by using crime data consistent with this framework, we more directly measure the deterrent effect of police-monitored CCTV cameras on street crimes in Newark, NJ. Individual risk factors are important, such as those owned by motivated offenders or potential victims (Cohen and Felson 1979), but micro-level places such as CCTV viewsheds are particularly important for measuring the direct impact of cameras on crime in a way that maximizes the validity and reliability of results.

Review of CCTV research and its limitations

Much of the empirical research about the effectiveness of street-level public CCTV cameras at deterring crime has shown mixed results (see, in particular, Welsh and Farrington 2002; Gill and Spriggs 2005; Gill et al. 2006; Harris et al. 1998). Part of this uncertainty about the impact of cameras derives from difficulties that have been faced in developing research techniques that reliably measure the effects of cameras and provide convincing evidence for or against the use of CCTV cameras as a means of crime control through deterrence. Improvements to research designs have come from adding control areas to compare effects across project interventions (Welsh and

Farrington 2002), measuring camera saturation (Wells et al. 2006; Sivarajasingam et al. 2003; Bowers and Johnson 2003), expanding the analytical scope of a camera's impact on the public psyche (in particular, surveying the general public and victims of crime to measure fears of crime in monitored areas and overall support for CCTV, e.g., Farrington et al. 2007), and the application of new statistical tests, such as hierarchical linear modeling (HLM) or weighted displacement quotients (WDQ), to assess the reach of deterrence caused by CCTV cameras (Ratcliffe et al. 2009; Bowers and Johnson 2003). However, in spite of these innovations, the most common limitations of past research designs have not been overcome. These limitations pertain to the operational definitions of "target" areas and the types of crimes that are used for statistical testing.

CCTV camera viewsheds

Most target areas are defined by researchers as entire regions of a jurisdiction where one or more cameras were installed, such as whole towns/cities within a country, or as whole districts such as "downtowns" or "town centers" within a municipality (Sivarajasingam et al. 2003; Squires 1998, 2000; Brown, 1995; Ditton and Short 1999). Other researchers designate target areas as 360-degree circular buffers around a camera's installation location (e.g., Mazerolle et al. 2002; Williamson and McLafferty 2000; Gill and Spriggs 2005). These target, or experimental, areas are then used for before-and-after analyses of crime occurrence. There has been little theoretical consideration of appropriate buffer diameters, as evidenced by the arbitrary selection and much variation of distances used in previous research. A 360-degree "buffering" approach measures crime incidents within a specified distance of a camera, but it does not take into account the camera's actual unobstructed viewing area. Neither does the regional target area approach consider this. Regions, whether they be entire towns or districts within towns, are rarely completely visible by cameras (even the best cellular phone networks have some areas with dead zones). Cameras can only see via direct-line-of-sight, up to certain distances. And for deterrence purposes, offenders are only likely to be aware of them if they are within a certain distance, regardless of the camera's actual visible horizon.

If, in fact, the cameras are actively used as intelligence gathering tools and instruments for documenting the circumstances of crimes that occur and then dispatching police accordingly (Brown 1995; Goold 2003), then researchers who use either of these techniques are not actually measuring deterrence—as they intend to measure—because cameras will only be effective if potential offenders believe that they are in places that will be seen (Farrington et al. 2007; Phillips 1999). This is an important measurement validity issue that can over- or under-state the impact of CCTV cameras on crime and is consistent with insights gleaned from recent research on "crime and place" in that the study of crime should be at the relatively local geographic level (Weisburd et al. 2004, 2008, 2009b; Weisburd and Eck 2004). Consistent with what we would expect theoretically about a camera's effect, potential offenders will not be deterred if the coverage is low "…since people can then choose to offend in places that are not covered by the cameras" (Farrington et al. 2007: 22). Offenders surveyed by Phillips (1999), for example, reported that limits to cameras' range of vision and their ability to dodge cameras made CCTV ineffective at deterring crime because they did not always increase the (real or perceived) risk of apprehension in all places, all the time.

Research designs that recognize that some places within a camera's target area may be visibly obstructed due to natural or human-made barriers, such as buildings, has been nearly absent or at least greatly under-appreciated. A study conducted by Ratcliffe et al. (2009) is a notable exception. They proposed using true-to-life viewsheds of cameras as the experimental area for testing, addressing the limitations that we discussed above concerning the detectability of activities obstructed from the cameras point of view. They identified and drew viewsheds using the tools available in the police department's camera control room (i.e. by panning and zooming each camera about its pedestal). Although this seems like a valid and appropriate method, it is limited in two ways. The first is the ability of the researcher to interpret and subjectively transplant visible distances observed in two dimensions on a CCTV monitor to a finite map feature within a Geographic Information System (GIS). The process is certainly possible and the acceptable margins for error are at least moderate, but the qualification is still noteworthy. A second, and more important, limitation of this method is replicability. Many researchers and crime analysts do not have access to camera control rooms for a number of legitimate reasons and, therefore, would not be able to replicate Ratcliffe et al.'s viewshed production method. The methodology used by Gill et al. (2006) included "extensive periods of observation in three police areas" in the UK to assess the impact of CCTV on drug crimes. Similarly, Wells et al. (2006) conducted an observational study of an Australian security camera network control room, and Mazerolle et al. (2002) analyzed video footage to assess levels of pro- and anti-social behavioral adaptations to CCTV cameras in Cincinnati. Live monitoring of cameras certainly increases the likelihood of identifying both reported crimes and unreported illegal behavior within a camera's viewshed, but it is very time consuming and still not easily replicable by the average crime analyst or researcher.

Crime types and deterrence

A systematic review and meta-analysis by Welsh and Farrington (2009) supports the idea that CCTV can be most effective at preventing certain types of crime at certain types of places. Crimes that occur in public on the street should be subject to any deterrent effects of CCTV cameras. Most evaluations of CCTV cameras use administrative police data of previously reported crimes that do not discriminate between crimes that could have occurred on the street—within a camera's viewshed—and crimes that could not have been seen by cameras. For example, theft or assault may occur within a dwelling where walls block visibility to a camera. These incident locations would nonetheless be recorded as the dwelling's street address in police administrative datasets. This nuance, though common practice for most police departments, poses issues of construct validity and could produce misleading results if not addressed.

The dependent variable of prior empirical research on CCTV tends to be "all crimes" (e.g., Ditton and Short 1999; Squires 1998; warned against by Phillips 1999) or specific types of crimes such as drug selling (Gill et al. 2006), burglary, robbery, violence (King et al. 2008; Brown 1995), shoplifting (Squires 2000), or police misconduct (Goold 2003) that could conceivably occur out of camera view. Without knowledge of the exact incident locations, the use of certain types of crimes to statistically test the deterrent effect of CCTV cameras can produce suspect results because the proportion of incidents that actually occurred within a camera's viewshed could be low. One can not always justifiably assume that most incidents of certain types of crimes occurred in public view. Isnard (2001: 2) gives a case in point: "A shop owner was upset that people were climbing onto the roof of his premises and vandalising it as well as committing anti-social offences. This had been happening over a period of 2 months…." There was a camera that could be operated to take in a view of his premises, but it was aimed at the street, "as most people would expect them to be." For the purpose of modeling and testing the deterrent effect of CCTV cameras in a theoretically consistent way, only crimes that more often than not occur on streets, sidewalks, or other unobstructed public areas should be used for study. At the very least, the rigorous but conservative approach taken in this study provides a more reliable and valid baseline measure of CCTV deterrent effects. At best, certain street crimes are in fact the only crimes affected at places with cameras, and so, this study provides a uniquely realistic empirical evaluation of the impact of CCTV cameras on nearby crimes.

Methodology

Study background and setting

Newark is the largest city in the State of New Jersey, covering 26 square miles, with an estimated 2009 population of over 280,000 persons (U.S. Census Bureau). The Newark Police Department is the largest municipal police force in the state, with more than 1,300 sworn officers as of 2008. Mayor Cory Booker took office in 2006 and swiftly began to invest in cutting-edge technologies to boost the police department's ability to monitor and control crime in the city. One initiative was the installation of street-level police-monitored closed circuit television (CCTV) cameras; more than 100 are located throughout Newark to date providing live video footage to operators in a control room at police headquarters. Two groups of CCTV cameras were installed on two separate dates in March and July 2008 using two different placement strategies, respectively. The placement of "March" cameras was dictated by the sponsors who paid for this first wave of cameras and who required that they be placed in Newark's Business District. "July" cameras were placed in consultation with Newark police department personnel and were subsequently located in known higher-crime areas.

The types of cameras installed throughout Newark are rooftop (n=9), street-level dome (n=79), and bullet resistant (n=23). Rooftop cameras are mounted on roofs of buildings and are mostly inconspicuous to people on the ground. Dome and bullet-resistant cameras are generally mounted on telephone or light poles at street intersections and are within plain view. They have the ability to zoom, pan 360 degrees and tilt 180 degrees. That is, these cameras can focus on all areas around and below their mounting point. Dome cameras have a tinted hemisphere glass cover that bars knowledge of the camera's actual viewing direction and angle. Bullet resistant cameras are encased in a glass and steel housing that protects it from projectiles, but the direction of the camera's lens is quite obvious to the street-level pedestrian.

Viewshed production and data preparation

Dome cameras were the only type used for this study because, consistent with the theoretical framework, they are within plain view of pedestrians, they have the greatest range of motion, and their opaque housing is the most likely to produce a sense of omnipresent monitoring of the viewshed at all times.[1] The calculation of the extent or distal limit of viewsheds around a camera's location was based upon empirical research suggesting that crime-prone places typically comprise just one or two street blocks, which qualify as behavior settings (e.g., Felson 1995; Taylo, 1997; Taylor and Harrell 1996) that are "regularly occurring, temporally and spatially bounded person-environment units" (Taylor 1988). Behavior settings of CCTV cameras was operationalized to be twice the median length of Newark block faces, or 582 feet. Viewsheds were then created within this distance using aerial photographs from Google Earth and standard ArcGIS editing tools and procedures to digitize viewshed polygons that took into account buildings and other permanent barriers to a camera's visibility. As shown in Fig. 1, not all the areas within a buffer (i.e.behavior setting) were visible to the camera—a reality that has been largely overlooked or ignored by many other researchers.

Out of concern for a viewshed production method that was generally accessible and replicable, we used Google Earth aerial photographs to guide the drawing of polygons around cameras whose exact locations were geocoded to a Newark street centerline map. The distance calculator tool in Google Earth was used to ensure that the extent of the acquired photographs would cover at least 582 feet from each camera. These images were then downloaded and georectified in ArcGIS using a Newark street centerline shapefile as the reference layer. As exemplified in Fig. 1, viewsheds were drawn within the 582-foot buffer and excluded areas that were blocked by major permanent fixtures, such as buildings, via direct line-of-sight from the camera. This process was repeated 73[2] times so that every camera had a respective viewshed feature about its location on a map.

Tools in the Newark Police Department's CCTV control room were used only to ground-truth the viewsheds already digitized using the Google Earth method. First, several experimental cameras were randomly selected for inclusion in the ground-truthing process. Second, a new viewshed polygon feature was drawn in ArcGIS using the pan, tilt and zoom features of the CCTV cameras in the control room as a guide. Third, the viewsheds' shape, size and extent were compared to the viewshed of the same camera that was created via the Google Earth method. Viewshed polygons drawn using tools in the control room were nearly identical to those drawn using the Google Earth method. The only deviation between each viewshed

[1] Other than press releases and media reports, there was no official advertising, such as signage, associated with the installation of cameras that were aimed at aiding deterrence.

[2] Six cameras were physically damaged or otherwise broken and out of commission for long periods of time and, therefore, excluded from this study.

Fig. 1 Shaded region within the circular buffer exemplifies a viewshed drawn using a Google Aerial Photograph

production method was their distal extents: viewsheds drawn using the control room tools extended farther from the camera mount than the ones drawn using Google Earth images. This was expected due to the fact that we limited viewsheds to a radius of 582 feet from their respective cameras, even though cameras can actually focus and zoom farther. This ground-truthing endeavor adds credence to the method of using viewsheds devised by Ratcliffe et al. (2009) but, importantly, validates this alternative method that is just as robust and less time consuming but much more accessible to researchers in the US and around the world.

Two criteria were considered before creating 73 control viewsheds. First, only areas patrolled by Newark Police Department were considered. Locations that fell under the Newark Port Authority Police or Airport Police jurisdictions were excluded because crime data, which was provided by the Newark Police Department (NPD), did not include incidents that were recorded by these other agencies. Additionally, the CCTV cameras under study were within the jurisdiction of, and solely monitored by, the Newark Police Department. Restricting our analysis to areas under the jurisdiction of NPD and using only NPD administrative data controlled for any variations that might exist among different law enforcement agencies regarding CCTV monitoring operations, incident reporting, and record-keeping.

Control cameras (which were artificially defined) were operationalized as random points that served as hypothetical camera locations.[3] The permissible placement area of these points was street segments within the NPD jurisdiction but outside the 582-foot radius from an experimental camera. Control camera locations were identified on street segments due to the fact that this same limitation existed for experimental cameras. It is a fact that some experimental camera locations were selected because they were problematic areas. Other (a-theoretically) "desired" locations were chosen by the cameras' funders. However, it would be impractical to select control camera locations in the exact opposite ways of either strategy. Instead, we sought to test the deterrent effects of "strategic" verse "non-strategic" placements of cameras. For research purposes, a meaningful and operationalizable opposite of "strategic" is random—no forethought at all was given to what environment would be best for camera placement. It is generally unlikely, due to the time and expenses of installing, maintaining and monitoring, that CCTV cameras would be installed in places with low or no crime counts (e.g., the opposite of high crime). So, matching control cameras to such places seemed unreasonable and unlikely to produce meaningful results for the purposes of this study.[4] Furthermore, crimes were the dependent variable. Low crime places would make statistical testing difficult due to the limited frequency of crimes, which could systematically bias results. Once the control camera points were randomly placed, their XY coordinates were obtained and used to locate and then download aerial images of these places from Google Earth. Viewsheds of these putative control cameras were then digitized in the same manner as the experimental camera viewsheds.

Counts of crimes were recorded within the experimental and control viewsheds that occurred 13 months before and 13 months after the March and July camera installations, respectfully. The 13-month time period was selected after carefully considering the wisdom of several published reports that warned against using lengths of time that are too short or too long (e.g., Phillips 1999; Isnard 2001; Brown 1995; Squires 2000; Ditton and Short 1999) for adequate testing of direct and sustained deterrent effects. We were after a short time frame to measure the immediate impact of CCTV on crime as well as a reasonably longer follow-up period to assess if (potential) benefits persisted. Each viewshed had ten attributes: the numbers of shootings, auto thefts, and thefts from auto that occurred within them (before and after installation dates); whether the viewshed was experimental or control; the viewshed's area; the camera's installation date; and the rate of crimes per viewshed area.

[3] One might argue that control sites should be places with similar problems to the experimental sites. Though a simple statement, this would require a complex methodological endeavor. As discussed in the "Discussion and conclusion" section, and consistent with place-based criminological theories, "places" are defined by more than the problems that emerge there. Crime problems, for instance, are only one of many attributes of places that could influence the effectiveness of CCTV cameras. Identifying all other environmental, social, and/or criminogenic attributes of places where cameras are installed can be a separate study in itself—to typify these places and quantify the significant similarities and differences they have with respect to all other places in Newark. Future research can look at these siting typologies and the characteristics and qualities of the CCTV viewshed places of each experimental camera (such as for the purposes of statistically commensurate matching), but that task was beyond the scope of this project. The next best option was to select random locations as control sites, as we did here.

[4] Control viewsheds are systematically comparable to experimental viewsheds only with regard to the methods and parameters used to create them.

The deterrent effect of CCTV was studied on three types of crimes: shootings, auto theft, and theft from auto. Crime data were obtained from the Newark Police Department for years 2007 through 2009. The police wisely included an attribute in their crime data files that noted the specific location of each incident—e.g. “street” or “dwelling”. Some types of crimes other than those that were included in the study had too few cases that occurred on the street (e.g., robbery, which often occurred inside retail stores). Other crimes, such as disorder crimes, had many incidents but were excluded because they did not address the study's theoretical framework—the primary reason for crime types to be excluded. We also wanted to include crimes for which a majority of incidents tended to be reported or known to police. Crimes such as burglary that were used in other empirical studies were omitted because we did not believe them to be a valid measure of a CCTV camera’s deterrent effect since many burglaries could occur out of a camera’s view. The same can be said of other crimes such as murder or rape. According to crime attribute data, more than three-quarters of the crime incidents tested here were known to have occurred on the street: 81% of shooting incidents; 95% of auto thefts; and 90% of thefts from auto. In addition to their street-level incident locations, these crimes were unique from other types of crimes in that they were the most reliably reported and known to the police.

Results

The principal objective of this investigation was to evaluate the deterrent effects of CCTV cameras on three types of crimes—shootings, auto thefts, and thefts from autos. The results, however, are presented in a way that permits this final test to be grounded in findings of sub-analyses that were necessary to validate the ultimate methodology and statistical procedures. This stepwise analytical process maintained the rigor of the entire study and maximized the reliability of results pertaining to the principal research objective.

Experimental control comparison

The 73 experimental viewsheds cover 268,000 square feet, or 0.04% of the total area of the city. An ANOVA test was performed to examine whether the two sets of strategically placed cameras (the ‘July’ or “March” cameras) had any deterrent effect (i.e., crime reduction within the viewsheds) compared to randomly placed cameras. That is, was either placement strategy employed by the City of Newark any better or worse than random placement? The hypothesis was that viewsheds of strategically placed cameras will have meaningfully less numbers of crime incidents within them, compared to randomly-placed cameras—since crimes were known to be an above average problem at these places compared to elsewhere. Table 1 compares means and standard deviations of crimes occurring within each viewshed area. As shown in Table 2, results failed to reach statistical significance for auto theft and theft from auto, while results for shootings were statistically significant. The effect sizes for March/Control, July/Control, and March/July viewshed areas were 0.06, 0.62, and 0.69, respectively. However, looking at the mean number of shootings in each area—0.17, 0.15, 0.46—it seems that the statistical significance and two out of three relatively large effect sizes

Table 1 Means and standard deviations comparing the three areas

	Auto theft		Theft from auto		Shooting	
Viewshed Area	M	SD	M	SD	M	SD
March	2.65	1.63	1.68	0.91	0.17	0.22
July	2.29	1.42	1.40	1.47	0.46	0.61
Control	2.00	2.23	1.44	1.64	0.15	0.3

are less important because these numbers are not contextually substantive in raw form. There cannot be 17/100ths of a shooting in real settings. Rounded up or down to a whole number, these values would also be the same as either zero (0) or one (1). Salkind (2008: 163) explains, "statistical significance cannot be interpreted independently of the context within which it occurs." The difference may be statistically significant, but it may not be meaningful (Salkind 2008). These numbers are substantively similar and, therefore, we considered the difference between these groups as unimportant (Taylor and Frideres 1972; Fern and Monroe 1996). Consequently, the results suggest that groups of strategically-placed cameras were not meaningfully different than the group of randomly-placed ones for auto theft, theft from auto, or shootings.

In addition to the implications for CCTV camera placement, as will be discussed in a later section, a decision was made to include March and July camera installation groups together, without differentiation, in subsequent statistical analyses. An initial concern about our research design was that March and July viewsheds would have to be studied separately because their placement strategies differed. This is apparently not so and no further group distinction was deemed necessary for subsequent analyses.

Table 2 One-way analysis of variance (ANOVA) summary table comparing experimental and control viewsheds on crime occurence per viewshed area

Source	*df*	SS	MS	*F*	*p*
Auto theft					
Between groups	2	7.90	3.95	1.10	.337
Within groups	143	514.67	3.60		
Total	145	522.57			
Theft from auto					
Between groups	2	1.44	.72	.32	.726
Within groups	143	319.27	2.23		
Total	145	320.71			
Shootings					
Between groups	2	3.07	1.53	7.35	.001
Within groups	143	29.86	.21		
Total	145	32.93			

Pre- to post-installation effects of experimental cameras

An independent samples *t* test was conducted using all 73 experimental street-level dome working cameras to examine the relationship between crime rates before and after CCTV installation. It was hypothesized that installations of CCTV cameras in Newark would result in a significant drop in crime incidents within all cameras' viewsheds compared to pre-installation figures. As shown in Table 3 below, *t* tests did not reach any statistical significance for either theft from auto ($p =< .86$) or shootings ($p =< .34$). That is, when all CCTV cameras are considered to be equally qualified crime deterrents, they do not have a statistically significant impact on city-wide reductions of theft from auto or shootings within their viewsheds. The results for auto theft were statistically significant ($p < .01$). The mean number of auto thefts within the experimental viewsheds was 7.66 before CCTV and 5.85 after CCTV; an effect size of 4.02 indicates a strong effect.

Differential effects of cameras by location

A location quotient was calculated for each of the 73 experimental viewsheds to identify the cameras, if any, which were expected to be most effective at deterring crime at their locations. In accordance with ecological theories of crime (e.g., Miethe and Meier 1994; Shaw and McKay 1969; Brantingham and Brantingham 1995; Weisburd 2008), some places are likely to be more crime prone than others—regardless of any police interventions, including CCTV cameras. Therefore, the effect of police-monitored CCTV cameras on crime deterrence could be very minimal in some places while other places yield better results. Location quotients permitted us to identify and assess the impact of CCTV cameras on these different camera locations in Newark.

The location quotient (LQ) is an index for comparing an area's share of a particular activity with the area's share of some basic or aggregate phenomenon. Here, the LQ is a measure of the relative significance of crime incidents within experimental viewsheds compared to their significance in the larger City of Newark. Put another way, LQ is a ratio of the proportional share of crimes at the local level

Table 3 Comparison of 73 experimental cameras pre- to post-installation

Variable	M	SD	*t*	*df*	*p*
Auto theft			2.87	144	.005
Before	7.66	4.12			
After	5.85	3.47			
Theft from auto			−0.18	144	.859
Before	3.71	4.03			
After	3.82	3.38			
Shootings			0.95	144	.343
Before	1.01	1.30			
After	0.82	1.14			

(i.e., experimental viewsheds) to the ratio of the total area covered (Newark). Location quotients were calculated for each viewshed as:

$$LQ = (x_i/t_i) / (X/T)$$

where x_i represents the number of crimes of type x (e.g., shootings, auto thefts, thefts from auto) in viewshed i; t_i represents the total area of viewshed i; and X and T represent the city-wide numbers of crimes of type x and area, respectively. Location quotients are interpreted as "the likelihood of certain crimes occurring in a viewshed, given the other attribute about that place." In effect, the location quotient formula controls for area, which is important since viewshed sizes of different cameras differ greatly according to environmental conditions of their camera's placement. The use of location quotients to identify unique characteristics of certain places has a proven track record in the criminal justice literature (e.g., Brantingham and Brantingham 1998; Ratcliffe and Rengert 2008; Robinson 2008; Andresen 2009). LQ values greater than 1 indicate a relative concentration of crimes in the viewshed, compared to the city as a whole; LQ values below 1 indicate the viewshed has less of a share of the crimes than is more generally found city-wide; LQ values equal to one indicates the viewshed has a share of crimes in accordance with its share of the rest of the city. Three LQ values were calculated for each viewshed—one for each type of crime. Thirty-nine out of 73 experimental cameras had location quotient values below 1 for shootings after their installation; 40 cameras for auto theft and 43 for theft from auto.

Independent samples t tests of viewsheds with LQs below 1 showed that CCTV camera installation was associated with a significant decrease in the numbers of shootings and auto theft in these places (see Table 4). Inspection of the means of the numbers of shootings before (M=0.77) and after (M=0.10) camera installation indicates that shooting incidents are substantially lower in the time periods examined. The effect size is approximately .50, indicating a strong effect. Similar results were found for auto thefts. The mean number of auto theft before cameras were installed (M=7.35) was significantly different from the mean number of auto thefts after installations (M=4.10). The effect size is 5.75, indicating a very strong effect. No significant differences were found in the number of "thefts from auto" crimes in the 43 camera viewshed locations studied. As expected, t-tests for viewsheds with location quotients above 1 yielded statistically insignificant results for all three crime types (Theft from auto, $n=30$, $p=.385$; Auto theft, $n=33$, $p=.944$; Shootings, $n=34$, p=.286), thereby supporting our hypothesis that some places are more conducive to deterrent effects of CCTV cameras than other places.

Results from regression analyses suggest that the linear distance from a camera within the camera's viewshed has no significant bearing on the likelihood of crime occurring [Shooting: $F(1,760)=1.179$, $p = .278$; Auto theft: $F(1,760)=2.12$, $p = .146$; Theft from auto: $F(1,760)=0.648$, $p = .421$]. The mere presence of a camera with an unobstructed view is enough to deter certain types of crimes in certain places of the city, regardless of how far away the camera is from the perpetrator. This makes intuitive sense since cameras are expected to be able to zoom and focus over long distances from their fixed locations.

Although some viewsheds did not reach LQ values below 1 after camera installation, many viewsheds did improve pre- and post-installation. Out of the 73

Table 4 T-test results of shootings, auto theft and theft from auto in areas with a location quotient below 1

Variable	Mean	SD	Min	Max	*n*
Shooting					
Before CCTV	0.77	1.04	0	4	30
After CCTV	0.10	0.31	0	1	4
Auto theft					
Before CCTV	7.35	4.27	1	20	294
After CCTV	4.10	2.88	1	12	164
Theft from auto					
Before CCTV	2.51	1.55	0	6	108
After CCTV	1.95	1.53	0	6	84

Variable	M	SD	*t*	*df*	*p*
Shooting			3.85[a]	45[a]	.001
Before CCTV	0.77	1.04			
After CCTV	0.10	0.31			
Auto theft			3.99[a]	68[a]	.001
Before CCTV	7.35	4.27			
After CCTV	4.10	2.88			
Theft from auto			1.68[a]	84[a]	.096
Before CCTV	2.51	1.55			
After CCTV	1.95	1.53			

[a] The *t* and *df* were adjusted because variances were not equal

experimental cameras' viewsheds, 58 showed a change in LQ toward or below 1 for shootings; 34 and 41 viewsheds had improved LQ values for auto theft and theft from auto crimes, respectively. If viewshed A, for example, had a LQ equal to 1.7 for shootings before a camera was installed and then the LQ value was 1.0 after installation, then this could suggest a meaningful decrease in the likelihood of shootings in viewshed A as a result of the camera. Unlike the first approach that tested significance at the group level and assumed all cameras to be equal crime deterrents, calculating LQ-change permitted the identification (and anecdotal evidence) of specific places that produced the significant deterrent effects from cameras. This highlights the importance of conducting place-based assessments of individual CCTV cameras, a practice advocated for by Gill et al. (2006), but, to our knowledge, was rarely pursued by researchers to date. Our own future research will certainly aim to fill this void and we encourage others to do the same.

Displacement and diffusion of benefits

A displacement analysis was conducted to measure the effects of CCTV cameras in viewsheds with LQ values below 1 (post-intervention) for shootings or auto theft, respectively. Thirty-nine viewsheds met this criteria for shootings and 40 viewsheds did so for auto theft; thus, equal numbers of the 73 control viewsheds were used in the displacement analyses. One set of 39 control viewsheds (for shootings) and another set of 40 viewsheds (for auto thefts) were randomly selected. Several steps were then taken to measure the displacement effect of CCTV cameras in these areas. Clarke and Eck (2003b) suggested the following to measure the effectiveness of any intervention: (1) measure if the problem has changed before to after the intervention is implemented (by calculating gross effect), (2) measure whether the intervention was the likely cause of any change (by calculating net effect), and (3) measure the relative size of possible displacement or diffusion of benefits (by calculating the weighted displacement quotient). The first step was already completed in the previous sections of this paper; That is, CCTV cameras reduced incidents of shootings and auto theft within their viewsheds. So, we continue with testing the net effects and displacement effects of CCTV cameras on these two crime types.

Rates of the number of crimes per experimental viewshed area, control viewshed area, and viewshed buffer area were each calculated to produce standard measures to use in statistical tests because these areas differed greatly in size. For example, buffer areas were defined as the spaces within the 582-foot radius from the camera mount location minus the respective viewshed area, and were often nearly four times the size of a camera's viewshed. If we used these large buffer areas without standardizing the measure for crimes within them, we would have risked calculating 'displacement by default.' Using the net effect formula provided by Clarke and Eck (2003a, b),[5] net effects of CCTV cameras were 2.37 for shootings and 0.53 for auto thefts. These results are positive values, which indicate an improvement on the reduction of these crimes within CCTV viewsheds. The weighted displacement quotient (WDQ; Bowers and Johnson 2003) was 0.23 for shootings and 0.78 for auto theft. This indicates that there was no displacement for either crime type and there was a small diffusion of benefits from CCTV cameras for the crime of shootings and a greater diffusion of benefits for auto thefts.

Discussion and conclusion

Research on the ability of CCTV cameras to impact crime is not new, so this quasi-experimental study is not innovative or unique because of its topic area. Its practical and scholarly value lies in its approach, which overcomes two major limitations of previous studies. The first was to utilize crime incidents that mostly occurred in public view on the street, and the second was to digitize camera viewsheds using accessible and easily replicable methods that can be generalized to most other U.S. or worldwide jurisdictions, using standard tools in ArcGIS. Importantly, both of these novelties were consistent with a theoretical framework that supported a study to strictly assess the crime-deterrent effect of police-monitored CCTV cameras in public places. A further contribution of this study was the attention paid to the fact that valid and reliable evaluations of CCTV cameras must assess the impact of the whole system within the jurisdiction (i.e., the macro-level) as well as the individual cameras' viewsheds that comprise the system (i.e., the micro-level). Like many other police responses to crime (Weisburd 2008), the effectiveness of CCTV cameras are

[5] The net effect (NE) formula is (Response Before/Control Before) Minus (Response After/Control After).

dependent upon the micro-level environments within which they are installed. This reality is supported by the results presented here and should qualify broad conclusions to endorse or contest the use of CCTV cameras for crime control or prevention within a city.

Recall the pre- and post-installation effects of all experimental cameras for which significant reductions were found for auto theft but not for theft from auto. Both crimes have a starting location—where the car is parked—which may or may not be within a camera's viewshed. Offenders likely consider the camera and other risks of apprehension (Cornish and Clarke 1986) before perpetrating either crime. Yet the real or perceived effects of cameras on successful (i.e., un-apprehended) getaways differ in a very meaningful way, which could explain the study's findings. Small items such as GPS units, money, or cell phones are relatively easy to hide after theft from autos and, thus, make the offender less conspicuous very shortly after committing the crime. If the offender were to walk along the street through another camera's viewshed, the stolen items could not be seen in a bag or pocket and would not trigger cause for suspicion by police, even if the items were reported and known by police to be stolen. But a stolen car can be recognized much more readily across different camera viewsheds. This would create a longer period of time (or risk) in which the offender could be noticed and apprehended while getting away from the scene of his/her crime. A city-wide system of CCTV cameras are perhaps more effective at deterring auto thefts than thefts from autos for this reason. Overall, the system of cameras in Newark is not as efficient as it could be at deterring certain crimes. Some camera places are more effective than others.

Researchers need to be concerned about the generalizability of CCTV evaluations with regard to geopolitical jurisdictions and settings. Social, political, and cultural characteristics of London, for example, are arguably different from Newark so the conclusions drawn from research in London are certainly subject to scholarly debate about their applicability to Newark and other settings. Results of this study also warn of the ecological fallacy inherent in prior CCTV research. The ecological fallacy refers to an error in the interpretation of results whereby assumptions about specific cameras are based solely upon aggregate statistics for the group to which those individual cameras belong. To state that every camera in a city is or is not effective at deterring crime based upon aggregate data and global analyses may not be accurate. Rather, local variations in crime concentrations and, presumably, the criminogenic characteristics of these locales can differentially impact the ability of police-monitored CCTV cameras to deter street crimes. For example, the system of cameras in Newark significantly deters auto theft city-wide. However, shootings and thefts from autos are only deterred by cameras installed in certain places within the city. Similar cameras do not have similar benefits everywhere and, therefore, should be evaluated at both the micro and macro levels so that effects on crime are not only measured by an average across all cameras in the system.

Findings also noted that linear distances from a camera within its viewshed had no bearing on the likelihood of crime occurring. The impact of distances from cameras was important to test: when distance from a camera is found to be significant and it is not controlled for, it can discredit CCTV evaluation methods that aggregate crimes into arbitrary 360-degree buffer zones or entire geopolitical "districts" or "downtowns". This is because when distance (significantly) matters within a bounded area, that unit of analysis is not a good representation of the camera's spatial influence. Related to the modifiable aerial unit problem, this realization is particularly important when evaluating deterrent effects of CCTV cameras and was a strength of this study that served to maximize construct validity of the viewsheds and the overall validity of its results. Cameras do have an extent to which they can be most effective at deterring crime, and their viewsheds up to two blocks or 584 feet away appears to be the zone of their spatial influence. So, while environmental context matters for strategically locating CCTV cameras in a city, distances between cameras should also be carefully considered—regardless of the pan, tilt, or zoom capabilities—to achieve full deterrence coverage throughout the selected environments. Research to-date suggests an overall shortcoming with CCTV technology in terms of broad and measurable crime reductions. Given the large amount of financial, political, and human capital dedicated to CCTV systems, police and the public deserve much larger effects on crime than what has so far been received or empirically shown to be possible. We now propose that the fault lies not with CCTV technology itself but rather with the lack of innovation in CCTV camera placement strategies.

It was beyond the scope of this study to contextualize the places where cameras deterred crime better than others. If future research identifies environmental conditions under which cameras would be most effective, then police can more strategically allocate CCTV resources to achieve positive outcomes—with techniques such as risk terrain modeling (Caplan et al. 2010; Kennedy et al. 2010). Some may choose to install fewer cameras in certain places to achieve maximum impact, while others may achieve greater impact by reallocating existing cameras to strategically selected places. Especially in the context of shootings, which run a high risk of fatality, the deterrent effect of fewer cameras mounted in certain locations could have a significant dividend. Further research is needed to inform officials where to place each camera at the micro-level so that all cameras produce an efficient CCTV deterrence system at the macro-level. Interventions in the social sciences are commonly developed to target specific groups or to operate in particular settings in accordance with certain political, cultural, or other considerations. Similarly, the impact of CCTV cameras should be considered modest in scope and, depending on where they are used and how they are operated, should only be targeted to specific crimes under certain conditions.

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