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Evaluation of Durham's ShotSpotter Installation:

Results of a 12-Month Pilot Project

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Executive Summary

The City of Durham contracted with SoundThinking for a 12-month pilot program with ShotSpotter, a gunfire detection system. The system was installed in a three-square-mile area of Durham that was selected based on having a relatively high rate of gun violence. The pilot operated from December 15, 2022 through December 14, 2023.

This evaluation offers information on both the costs and the relevant impacts of the ShotSpotter pilot installation, but it does not offer a suggestion on whether the City should use ShotSpotter in the future. It is intended to inform the decisionmakers, but not to advise them.

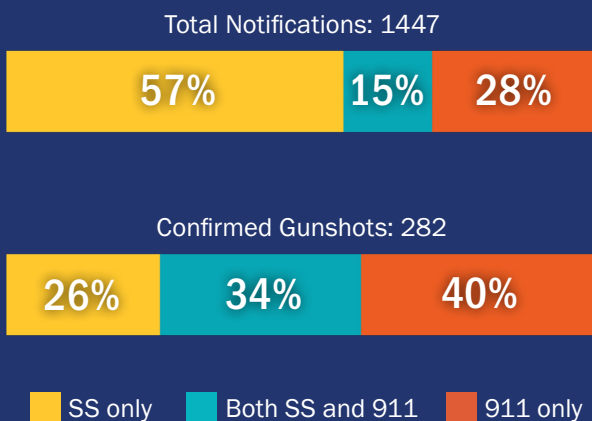
Notifications and Deployments

The ShotSpotter (SS) installation operated as a supplement to the 911 system, whereby residents are

encouraged to contact the Durham Police Department (DPD) if they hear or witness a shooting. During the pilot period, DPD received 1,447 notifications of gunfire in the target area in which ShotSpotter was installed: 57% of these were SS alerts with no 911 call, 28% were 911 calls with no SS alert, and 15% had both 911 and SS notifications. Thus SS more than doubled the number of gunshot notifications compared with what DPD would have received (from 911) in its absence.

DPD implemented a response protocol for the entire city on December 15, 2022 that any gunshot notification would be treated as a Priority 2 incident, requiring the immediate deployment of two patrol cars to the scene without sirens and flashers. In the target area, the effect of the “extra” SS alerts was to add an average of 2.3 Priority 2 deployments daily to the target area, approximately a 2% increase citywide.

Gunshot Notifications in Pilot Area



Serious gunshot incidents

In incidents where someone was wounded or killed, SS alerts were published for **26** of 52 known incidents
911 calls were received in **50** of 52 known incidents

Median response time

Median response time during the pilot period declined by **1.2 minutes** in the target area compared with the rest of the city.

The SS installation was designed to detect gunfire that occurred outdoors, with a few exceptions (such as if the firearm was equipped with a silencer). For the 52 known gunshot incidents during the pilot period in which victims were wounded or killed, SS alerts were published for 26 and 911 calls received for 50 of these 52. Eight of the incidents (accounting for 14 gunshot victims) that were missed by SS were due to system failure or human error. In addition to these false negatives, there were likely some false positives, but we have no way to estimate how frequent.

SS alerts include information on the time and precise location of the incident, and the number of shots fired. They were transmitted directly to DPD's CAD system in each patrol car, almost always within 60 seconds. For incidents in which there is both a SS alert and a 911 call, the SS alert typically was first, and often provided a more

precise location. Our analysis finds that in 2023, the median response time (from alert to arrival at the scene) was 5.5 minutes, which reflected a decline by 1.2 minutes in the target area compared with the rest of the city. There was a still greater improvement in the 90th percentile of response times, which declined by 3.6 minutes.

In sum, SS had the effect of more than doubling the number of gunshot notifications received by DPD for the target area, and notably improving response times by patrol officers.

Productivity of Deployments/ Investigations

SS increased the number of gunshots for which DPD was notified and reduced the response time by patrol officers. The expanded coverage contributed to the number of confirmed gunshot incidents, the number of arrests, and the collection of evidence at the scene (such as shell casings). For the incidents known to the police only because of a SS alert (no 911 call), there were 7 incidents with an arrest (out of 29 total), 6 of which were directly related to the shooting, and 71 incidents in which evidence was collected (of 145 total).

We also conducted an extensive analysis of the target-area incidents in which there was a 911 call (with or without a SS alert). We found no evidence that the productivity of investigations in these incidents was affected by SS. That conclusion is somewhat surprising given the reduction in response times.

Rapid response to the scene where gunfire has been detected may in some cases improve the chance of saving the life of a gunshot victim. There was one incident (of the 26 SS alerts involving an incident with a wounded victim) where that quite plausibly was the case.



Other evaluations of SS installations have offered conclusions about whether they reduced gun violence. It is not possible to make that determination based on the data from the Durham pilot. The best-known published study of this outcome is also indeterminant.

Budgetary Cost, Opportunity Costs, and Other Possible Problems

The budgeted costs of the one-year contract included the payment of \$197,500 to SoundThinking and \$27,925 to the CAD vendor.

In addition, police deployments triggered by SS alerts utilized patrol resources that had other valuable uses – responding to other calls for service or conducting routine patrol. However, the magnitude of this opportunity cost is not large in a proportional sense:

Priority 2 deployments increased by only about 2% citywide.

The cost of deployments could be reduced by adopting a more nuanced protocol for deployments. Only 9% of SS-only alerts resulted in confirmation of a shooting, and the percentage was still lower for alerts with just one or two shots. These incidents could be “demoted” to a single-car deployment with only a small loss of investigative productivity.

In some other cities with longer experience with SS, some residents have expressed concern about over-policing. In Chicago, for example, officers have been accused of using SS alerts as justification for aggressive tactics in the field that are unrelated to the shooting. The SS pilot in Durham did not generate any resident complaints, in part perhaps due to the restrictive protocol covering deployments.



A. Introduction

ShotSpotter, a private product owned by SoundThinking, Inc., is a gunfire-detection service. ShotSpotter installations consist of an array of acoustic sensors positioned throughout a target area and a system for identifying which noises that are detected by these sensors are gunshots. When a gunshot is detected and confirmed, an alert is sent to the police along with its geographic coordinates. SoundThinking/ShotSpotter has been selling its services to cities and police departments since 1997 and has been utilized by more than 150 cities and law enforcement agencies in the U.S., including large installations in Chicago and New York City.ⁱ

Concerned about a growing rate of gun violence, the City of Durham, NC, contracted with ShotSpotter (SS) in 2022 to pilot the technology in a three-square-mile area of the city. The SS installation was in operation for 12 months beginning December 15, 2022. The Durham

Based on our analysis, we conclude that SS more than doubled the number of gunshot notifications received by DPD for the target area and reduced the police response time between the alert and first arrival at the scene.

Police Department (DPD) arranged with Duke University's Wilson Center for Science and Justice at Duke Law to provide an arms-length evaluation, and Professor Cook agreed to head up this effort, together with Professor Adam Soliman. This report presents our results based on data from the full 12 months of operation.

In our evaluation, we view the 12 months of SS as a pilot project or quasi-experiment. The “treatment” is the services provided by SS in the target area during the 12 months, and the “control” for this experiment is the rest of the city during the same time period. Both treatment and control areas are compared with a baseline period. Other logical comparisons are also utilized in the effort to estimate the effects of the SS installation.

Based on our analysis, we conclude that SS more than doubled the number of gunshot notifications received by DPD for the target area and reduced the police response time between the alert and first arrival at the scene. In most cases, officers deployed in response to an SS alert did not find evidence of a criminal incident or make an arrest, which was also true for 911 calls about gunfire. That said, there were 73 SS alerts for which there was no other notification that officers did confirm as shootings. Those incidents constituted 26% of total confirmed shootings in the target area.

It is plausible that a quicker and more comprehensive deployment of officers increases the chances of saving the life of a gunshot victim,ⁱⁱ arresting the shooter, and interviewing witnesses at the scene. There have been several cases during the Durham pilot project that

illustrate the potential contributions of ShotSpotter.¹ A shooting on the evening of May 6, 2023, near the intersection of Fayetteville Street and E. Umstead Street resulted in a ShotSpotter alert. Police arrived at the scene and stopped a private vehicle that was transporting a gunshot victim. (He was ultimately treated at Duke ER and survived.) The shooting had not otherwise been reported. Multiple shell casings were found at the scene, and an analysis of these shell casings assisted the police in arresting a suspect the following week. He was charged with felony assault with a deadly weapon inflicting serious injury and discharging a firearm within the city.ⁱⁱⁱ

A second incident suggests the potential of ShotSpotter to save lives. On July 25, a shooting in the target area (Colfax and Linwood) resulted in several SS notifications. Officers arrived at the scene less than four minutes after the shooting, and found a victim with life-threatening injuries. They administered first aid to stop the bleeding, and the victim survived. In this case there was a 911 call received 47 seconds after the first SS alert. It is plausible, though uncertain, that the quicker response enabled by ShotSpotter saved the victim's life.

But in our analysis, we find no evidence that quicker police response enabled by ShotSpotter increased the productivity of shooting investigations with respect to the likelihood of making an arrest, interviewing witnesses, or gathering evidence. Where SS did make a measurable contribution was by notifying the police of some shootings for which there was no 911 call. Some of those investigations resulted in positive outcomes (arrests, evidence, witnesses) that are directly attributable to SS.

In this report we consider the costs as well as the impacts of SS services, to the extent that the data permit.^{iv} The cost to the City for the pilot project included the \$197,500 payment to ShotSpotter for installation and one year of service.² In addition, \$27,925 was paid to the 911 computer-aided dispatch (CAD) vendor (CentralSquare) for the ShotSpotter interface that allowed the alerts to automatically generate a call for service, rather than dispatchers having to enter them manually. There is also an opportunity cost associated with the increased number of deployments of patrol officers resulting from SS alerts, which added an average of 2.3 per day in the target area. These “extra” deployments increase the total number of priority 2 calls for service of all sorts by about 2% citywide, so the cost is real but not proportionately large. Still, the time spent in these deployments could have been used for other patrol activities. The increase in deployments may also have affected police-community relations, for better or worse.³

The Durham Police Department was committed to responding to SS alerts just as it does to 911 calls about gunshots, which is to say that it treated them as priority 2 and dispatched two patrol cars to the scene. But it is possible that a more nuanced protocol would have been more cost-effective. During the pilot period, SS alerts for which there was no 911 call had a low “yield” with respect to finding victims, witnesses, or other evidence at the scene. Given the possibility of renewing the contract with SS, we consider other possible protocols, such as one that reduces the priority for responding to SS alerts for which only one “shot” is recorded.

¹ These are recounted in DPD's Third Quarter Report.

² Technically, the contract with ShotSpotter indicates that three months are free and that the fee covers the remaining 9 months.

³ An analysis of community sentiment about ShotSpotter was conducted in parallel to this study, utilizing focus groups of residents (Kelly, Gammell, and Bass-Patel, 2024).

One potential consequence of the SS installation was to undermine residents' motivation to call 911 when they heard gunfire.³ If true, that would have impaired gunshot investigations, since 911 calls about gunshots remained essential – many gunshots were not detected by SS, including half of all gunshots resulting in injury during the pilot period.⁴ In any event, the data suggest that residents of the target area called 911 for gunshots at a rate that did not change much from 2022.

We begin by describing the SS system, choice of target area, and standard operating procedures adopted by the Durham Police Department (DPD) in responding to SS

alerts. Section C documents the SS contribution to the flow of gunshot notifications in the target area. Section D presents our estimate of the reduction in response time, while Section E provides estimates of the effects of SS on arrests, evidence collection, and witness contact. Ultimately, we would also like to know the effect of the pilot installation on the volume of gun violence, but as explained in Section F, that is not statistically feasible. Section G considers several possibilities for reducing the opportunity cost of SS deployments without much affecting the productivity of these deployments. The final section, Section H, lists our main conclusions.



⁴ ShotSpotter is not intended to capture all gunfire in the target area, only unsuppressed, outdoor gunfire incidents using standard, commercially available rounds greater than .25 caliber.

B. Design and Purpose of the ShotSpotter Installation

Residents often contact DPD when they hear (or think they hear) gunshots. ShotSpotter alerts are intended to serve as a supplement to these 911 calls for gunshots fired outdoors. Even if a resident has contacted the police, an SS alert may make the police deployment more productive, since it is transmitted more quickly and often provides a more precise location than a resident call.

For the installation in Durham, SS mounted outdoor acoustic sensors and positioned them strategically throughout the contracted target area. SS installations automatically filter out noises deemed unlikely to be gunshots and transmit the remainder to the ShotSpotter Incident Review Center where they are reviewed by trained staff. The staff alert the police if they determine that the sound was indeed gunfire. The lag between gunshot detection and alert is usually less than one minute. The alert includes the geographic coordinates, based on triangulation from several sensors. This system generates some false positives, since there are a variety of percussive sounds that are similar to a gunshot. It also has certain limitations regarding which gunshots it can reliably detect; it is unlikely to detect the sound of gunfire within a building or vehicle, or a gunshot from a gun equipped with a silencer. Thus, SS serves as a supplement rather than a substitute for the existing 911 system.

Our evaluation finds that SS detected 60% of confirmed gunfire incidents in the Durham target area. Even within its admitted design limitations, the system was less than perfect. As a result of human error or malfunction of the equipment, there was no SS alert for eight shooting incidents in the target area (in which a total of 14 people were wounded or killed).

Target Area

The City of Durham contracted for SS service in the relatively small area shown in the map (Figure 1), located in east and southeast Durham covered by Police Districts 1, 4, and 5.^{vi} That area was selected due to a relatively high rate of gun violence during the years leading up to the installation. While covering only 2.7% of the landmass, this area experienced 29% of all shootings resulting in gunshot wounds (fatal or nonfatal) between 2019 and 2022, and a similar percentage (26%) of other criminal incidents involving gunfire (Table 1). It borders the NCCU campus, and includes the Hayti neighborhood and McDougald Terrace public housing community.⁵



⁵ Other neighborhoods include Albright, Cleveland Holloway, East Durham, Franklin Village, Golden Belt, NCCU area, Old 5 points, Southside/St. Theresa, and Wellon's Village

Figure 1: Map of Durham and ShotSpotter Treatment Area (via the City of Durham) ⁶

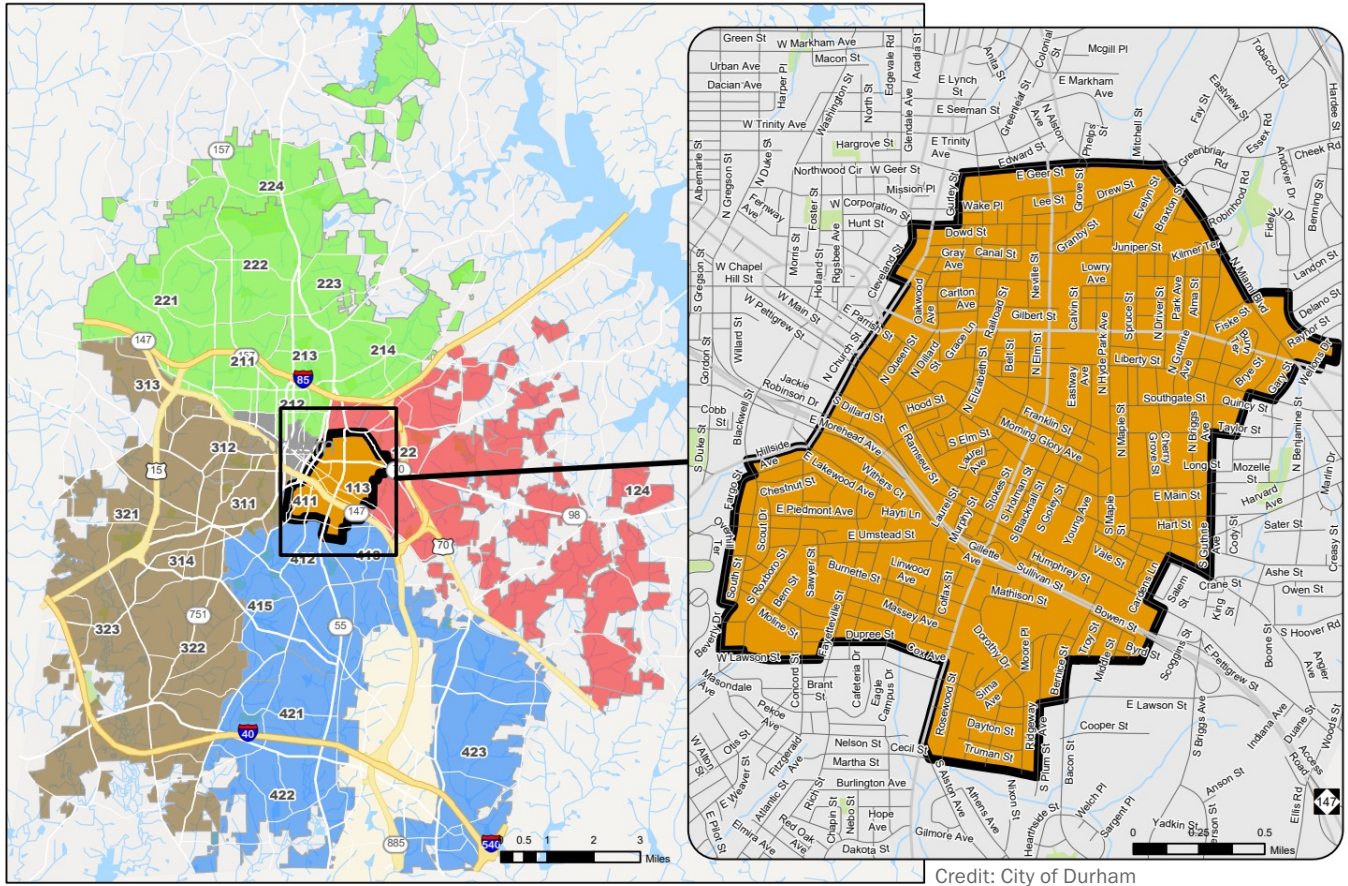


Table 1: Shootings in Durham by area prior to SS installation, 2019-2022

	Confirmed Shootings		Unconfirmed Shootings
	With Gunshot Wound	With No Gunshot Wound	
Target area	247 (29%)	624 (26%)	2269 (24%)
Rest of City	608 (71%)	1739 (74%)	7260 (76%)
Total	855	2363	9529

Note: For most (83%) of these incidents, the notification was by a resident using the 911 system

⁶ This map is courtesy of the City of Durham and available online: [City-and-Callout-ShotSpotter-Map \(durhamnc.gov\)](https://www.durhamnc.gov/city-and-callout-shotspotter-map)

Operations

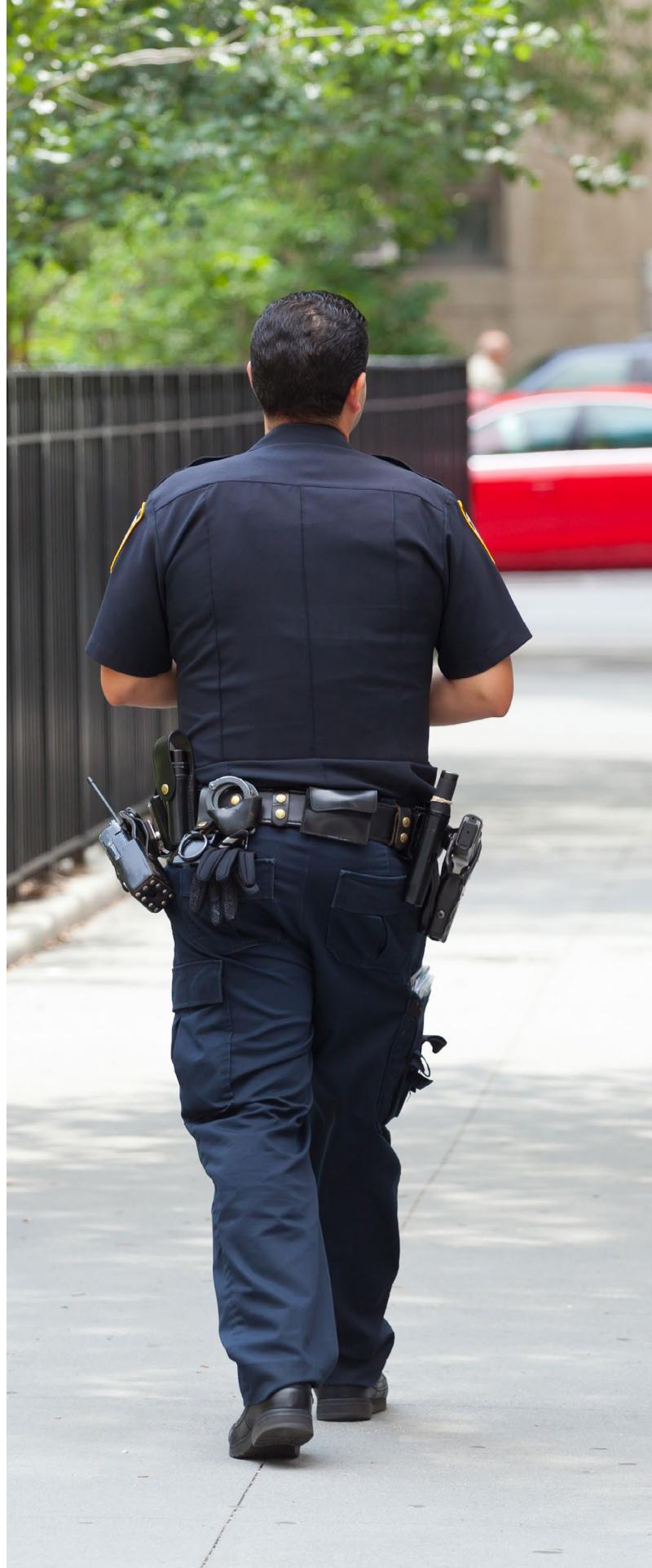
DPD established a set of protocols for responding to SS alerts.⁷ Coincident with the SS installation going “live,” DPD upgraded the priority for responding to gunshot notifications, regardless of source or area of the city, from priority 3 to priority 2. Ordinarily, a level 2 response involves dispatch of two patrol cars, as opposed to just one vehicle for a level 3 response, though there is some discretion on the part of the police supervisor in this respect. Officers do not turn on their lights or sirens in the typical level 2 response.

SS notifications were integrated into the CAD system and went directly to the nearest patrol cars. Responding officers were instructed that “Members shall not detain or arrest based solely on a ShotSpotter notification. As it is a lead only, any possible connection or involvement of any subject to the ShotSpotter notification must be based upon the totality of the circumstances.”⁸ To keep the public informed, DPD created a data dashboard that provided up-to-date documentation of SS-related activities and outcomes.

There were no complaints filed against the DPD in connection with SS deployments during the 12 months of operation.

[7 ShotSpotter General Order 4086](#)

⁸ See Shotspotter General Order 6, cited above. The Chicago Office of the Inspector General (2021) found some cases in which officers were using the high level of SS alerts in a neighborhood as one justification for an investigatory stop of a resident. These and related misuses of SS data were the basis of a lawsuit filed by the Northwestern University MacArthur Center. It should be noted that in Durham, there have been no civilian complaints to DPD that relate to SS deployments.



C. The Contribution of ShotSpotter to Gunshot Notifications

Before and since the SS pilot, the DPD is routinely notified of gunfire incidents through 911 calls from residents and sometimes officers who witness gunfire while in the field. Based on the subsequent investigation, DPD determines whether there was a criminal incident in which a gun was fired, and if so whether anyone was shot and wounded (fatally or nonfatally). In practice, most notifications are not confirmed and no criminal incident report is created. While some of the unconfirmed incidents are likely false positives, the others may be accurate — a gun was in fact fired (which is almost always a crime within city limits), but the officer was not able to find an eyewitness or other evidence to that effect.

In what follows, counts of shooting notifications are grouped into three categories regardless of their source (911 or SS):

- Confirmed shootings that wounded or killed the victim
- Confirmed shootings with no gunshot wound, and
- Unconfirmed shootings,

The difference between a confirmed and an unconfirmed shooting is whether the investigating officers found evidence of a shooting and filed a criminal incident report.



Table 2 indicates that for the most serious incidents where someone has been shot, so there is a gunshot wound (GSW), 50 of 52 incidents generated 911 calls,⁸ but only 26 (half) generated SS alerts. The 26 GSW incidents in which there was no SS alert illustrate a limitation of the system. SS is not expected to detect shots fired indoors or in vehicles, which explains part of the discrepancy. Moreover, eight of the “SS missing” GSW incidents were malfunctions of the SS system. Three of these were human error, where the agent at the SS Incident Review Center mistakenly concluded that the detected sound was not a gunshot.^{vii} The other errors were attributable to a malfunction of the technology; in four of these there was no signal, and in the remaining incident the alert mislocated the gunshot.

⁸ We use the term “911 calls” somewhat loosely, to include not only a standard 911 telephone call, but also other resident calls (using the non-emergency DPD number) and notifications using the online version of 911

Table 2: Sources of shooting notifications, by type for target area: 12/15/2022 to 12/14/2023

Source of notification	Confirmed % (N)		Unconfirmed % (N)	Total % (N)
	Gunshot Wound	No Gunshot Wound		
Both SS and 911	46.1% (24)	31.3% (72)	10.1% (118)	14.8% (214)
SS only	3.9% (2)	30.8 (71)	64.5% (752)	57% (825)
911 only	50% (26)	37.8% (87)	25.3% (295)	28.2% (408)
Total	100% (52)	100% (230)	100% (1165)	100% (1447)

For the 230 confirmed shootings with no GSW, there was a 911 notification in 69% of all cases, while SS alerts were received in 62%. The two systems overlap: notifications were received from both 911 and SS in 31% of confirmed shootings with no wound. For the 1,165 unconfirmed cases, resident 911 calls accounted for 35% and SS for 75%, including just 10% of cases with both sources.

Looking at the last column of Table 2, we see that a majority (57%) of all gunshot notifications in the target area were “SS only” alerts. Thus, SS more than doubled the number of notifications and hence deployments during the pilot period. That conclusion rests on the assumption that the SS installation did not reduce the number of 911 calls by residents – an assumption we explore below.

Focusing just on the “SS only” cases, it appears that there were 73 confirmed shootings and 752 unconfirmed shootings not reported by a 911 call. In effect, there were 825 “extra” notifications and deployments due to SS, of which 9% were confirmed as crimes and just 2 (0.2%) a GSW.

Here is a complete tabulation of the “yield” of different types of notifications, based on the data in Table 2:

Notification	GSW	Confirmed (GSW or not)
SS and 911 (15% of total)	11.2%	44.9%
SS only (57% of total)	0.2%	8.8%
911 only (28% of total)	6.4%	27.7%
911 (all) (45% of total)	8.0%	33.6%
SS (all) (72% of total)	2.5%	16.3%

Thus, 911 calls tend to have higher “yield” than SS notifications. In all, 34% of 911 calls yield a confirmed shooting, as opposed to just 16% of SS alerts. Most productive are incidents in which there are both SS and 911 notifications, for which 45% are confirmed as gunshot incidents. Least productive are SS alerts for which there is no 911 call, for which only 9% are confirmed.

In sum, SS more than doubled the total number of gunshot notifications during 2023, with 2.3 “extra” deployments per day on average. While the investigating officers did not find evidence of gunfire in 91% of the “extra” instances, there were two such extra instances in which there was a gunshot victim, and 71 others in which the officers did confirm a shooting. As we will document below, some of those instances proved productive in terms of gathering evidence and making arrests.



D. Response Time and Time on Scene

ShotSpotter is designed not only to increase the likelihood that a shooting will be known to the police, but also to reduce the time elapsed from the shooting until an officer arrives at the scene. In that respect the Durham SS pilot was successful.

SS alerts are generated following review by a staff person at the SS Incident Review Center. For the Durham installation, the elapsed time from when the first shot was detected until the SS alert was published was almost always less than 60 seconds (93% of incidents) and usually less than 45 seconds. While we have no direct measure of the comparable delays with respect to 911 calls, we know that SS alerts almost always come first when there are both types of gunfire notification.

Figure 2 depicts two measures of the timing of police response: the elapsed times from notification to deployment and from notification to arrival at the scene.

(Note that the second measure incorporates the first.)

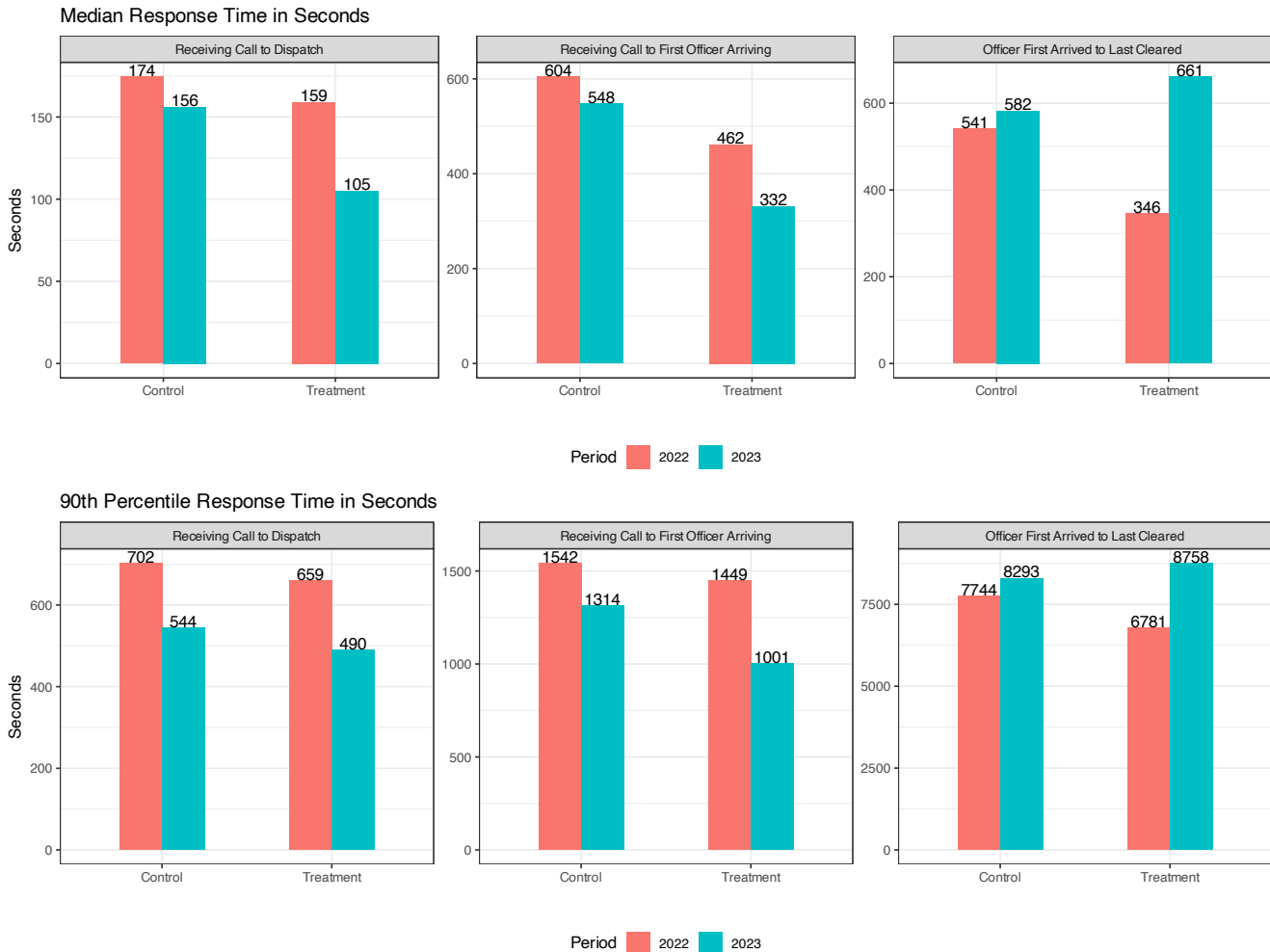
A third measure is also included, namely the amount of time officers spend on the scene once they arrive.

The first row of panels depicts the median values, while the second row depicts the 90th percentile values.

(The mean is an unsatisfactory measure because of its sensitivity to extreme values.) In each case we compare the “before and after” change for the target area and the control area (rest of the city). “After” in this case means the four “operational” quarters of 2023, while “before” is the corresponding quarters of 2022. The analysis is limited to confirmed shooting incidents.

Note that Figure 2 is based on a tabulation of all incidents in which there was a 911 call. That definition includes all notifications except the SS-only incidents in 2023 in the target area. The purpose of excluding SS-only incidents is to make the results for the pilot directly comparable to the target area in 2022 and to the rest of the city.

Figure 2: Sources of shooting notifications, by type for target area: 12/15/2022 to 12/14/2023



Note: The sample includes all 911 shooting events that were not solely SS notifications and capture the operational year. Numbers above each bar capture the number of seconds for a given response time measure by area and time period.

The first two panels in both rows depict a notable reduction in response times for both the target area and the rest of the city, reflecting the city-wide change in priority for gunshot notifications. The reductions are larger in the target area than in the rest of the city, which is directly attributable to SS. For the target area, the median dispatch time dropped 54 seconds while the response time (dispatch plus travel to the scene) dropped by 130 seconds – compared with a 56 second drop in the control area. If the control is a reliable guide to what would have happened in the target area in the absence of SS, then we conclude that the median

response time to the scene improved by 74 seconds due to SS in the treatment area. The observed 2023 median was 332 seconds (5.5 minutes), and it would have been 406 seconds (6.8 minutes) if it had followed the “control” pattern.

The results for the corresponding 90th percentile values were much larger. The 90th percentile response times (from alert to arrival at the scene) declined by 448 seconds in the target area, compared to 230 seconds in the rest of the city. The difference, arguably due to SS, was 218 seconds (3.6 minutes).

This analysis provides clear evidence that following the SS installation, officers responded more quickly to gunshot notifications in the target area in 2023 than 2022, and that gain is greater than what occurred in the control area. These patterns provide compelling evidence that SS services caused a notable reduction in response times, with whatever benefits that may have entailed.

Finally, the third panels depict the time the investigating officers spend on the scene, which ranged up to several hours but typically was just a matter of ten minutes or so. Time on scene increased between 2022 and 2023 in both the control area and especially in the target area. The median increase in the target area was from 5.8 minutes to 11.0 minutes, compared with a negligible increase in the control area. The addition of information from the SS alerts in some of these cases may have extended the police investigation.

To interpret the magnitudes in Figure 2 properly, note that all 911 calls are included in the analysis. For the “after” period in the target area, just 34% of these incidents also had a SS alert¹⁰ – which means that in 2/3 of these cases without SS notification, response time was not affected by the SS installation. In other words, if the improved response times in the treatment

area were solely due to the advantages associated with SS alerts over 911 calls, then the magnitudes of those effects were diluted in this analysis by the inclusion of many incidents in which there was no SS alert. The implication is that SS accelerated response times by somewhat more than suggested by our analysis.

Other Calls for Service

DPD increased the priority for responding to gunshot notifications on December 15, 2022, the same day that the SS installation was activated in the target area. Both actions may come at the cost of slowing DPD deployments for other calls for service. Our particular interest is with respect to the opportunity cost of the increased volume of gunshot notifications in the target area.¹¹ There have been 825 SS-only gunshot notifications in the target area since activation, which works out to 2.3 “extra” notifications per day on average, and some days considerably more. In some cases the response to the SS alert (by two patrol cars) may have slowed the response to other calls for service. But in Durham, that effect is likely to be small. Without SS, gunshot notifications constitute only about 4.5% of all priority 2 calls for service; when installed, SS increased priority 2 calls citywide by about 2%.¹²

¹⁰ This calculation is based on the counts in Table 2. Of the 622 calls for service from 911, just 214 also had a SS alert during the pilot.

¹¹ We note that this issue has been investigated for Chicago in Topper and Ferrazares (2023). We do not endorse their findings.

¹² In 2023 there were 40,415 priority 2 calls for service, excluding SS, for the entire city. The addition of SS in the target area increased the total number of gunshot notifications by 825 during 2023 or 2%. The leading source of Priority 2 calls citywide are alarms (30.8%) and disturbances and domestic cases that require a co-response with the HEART team (27.9%). There were also about 9,861 Priority 1 calls for service in 2023.

E. Evaluation Results on Arrests, Evidence, and Witness Interviews

The SS installation in the pilot area would be expected to increase the number of instances in which officers arrived at the scene of the shooting in time to locate witnesses, shell casings and other gun related evidence, thus increasing the chance of a subsequent arrest.

We estimate the frequency of such positive outcomes, or “yield,” in two parts. The first part focuses on the “SS only” shooting alerts, on the assumption that any arrest or other outcome in these incidents would not have occurred in the absence of the SS installation. This method is simple, since no control group is required, but incomplete, since it does not take into account any effect of a SS alert in cases where there was a 911 notification.

The second part is a quasi-experimental evaluation of the productivity of 911 notifications. For 2023 in the target area, those notifications include many cases in which there was a SS alert as well as a 911 call.

ShotSpotter-Only Notifications

There were 73 incidents of confirmed shootings that were only known to the police as a result of a SS alert. As shown in Table 3, these cases resulted in 7 arrests (24% of the 29 total incidents with arrests) and 71 cases in which evidence was collected on scene, such as shell casings and other gun-related evidence (49% of total).

Table 3: Confirmed shooting cases, Target Area, 2023

	# confirmed shooting cases	# cases with arrests	# cases with evidence collection
911 (SS or not)	209	22	74
SS only	73	7	71
Total	282	29	145

Data: Target area, pilot period only (2023), confirmed shootings

The seven arrests due to SS only are of particular interest. All seven were “on-view,” meaning they occurred during the original response to the ShotSpotter alert and not through follow-up investigation. Six of these

seven arrests were directly tied to the shooting. A total of five firearms were confiscated, some of which have been connected via the National Integrated Ballistic Information Network (NIBIN) to other past shootings.

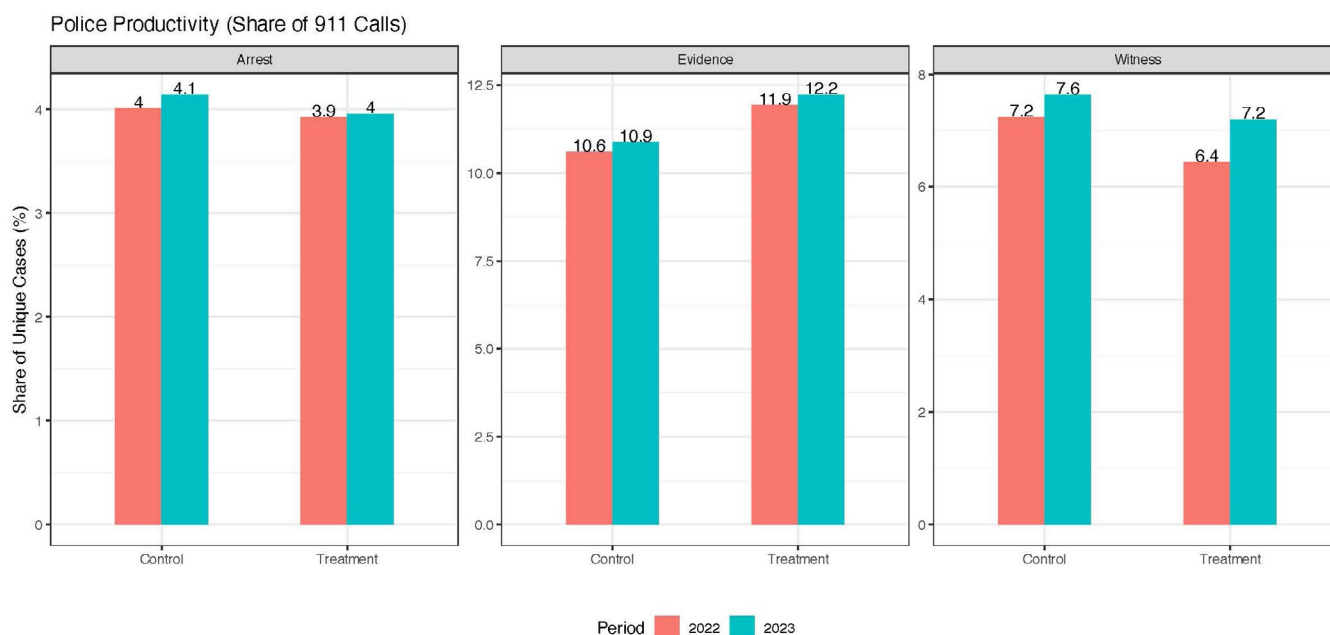
In two of the incidents, the individual was charged with firing the gun in city limits, but in the others, there was insufficient evidence to include a firearm charge in the arrest despite indications that the individual was involved in the shooting. The seventh case was a traffic citation that was unrelated to the gunfire incident.

Quasi-Experimental Analysis of 911 Calls

The counts of arrests and other productive outcomes in Table 3 omit any gains in productivity due to SS for cases in which there was a 911 call. In instances

where 911 calls are accompanied by SS alerts, the reduced response time may increase the likelihood of an arrest on scene or the ability to locate witnesses and physical evidence. Unlike in , there is no absolutely reliable method for estimating how productive those 911 calls would have been in the absence of SS (which is the relevant comparison). Here we adopt a quasi-experimental method, executed in two ways. In the text, we present the results of a simple analysis similar to the analysis we conducted on response times. In the Appendix, we present a more sophisticated statistical regression analysis, the results of which are referenced in the text. The two methods reach similar conclusions.

Figure 3: Confirmed shooting cases, Target Area, 2023



Note: The sample includes all 911 shooting notifications. Numbers above each bar capture the share of 911 calls for the productivity measure by area and time period.

Figure 3 depicts patterns in the likelihood that a 911 call results in an arrest, in collection of evidence, and interviews with one or more witnesses. In every case there is a small increase in these likelihoods between 2022 and 2023 in both the target and control areas.

The similarity in these patterns suggest that the SS pilot installation did not notably enhance the productivity of police investigations (if at all) for these incidents. What is also clear from this figure is that the overwhelming majority of responses to 911 calls were unproductive.

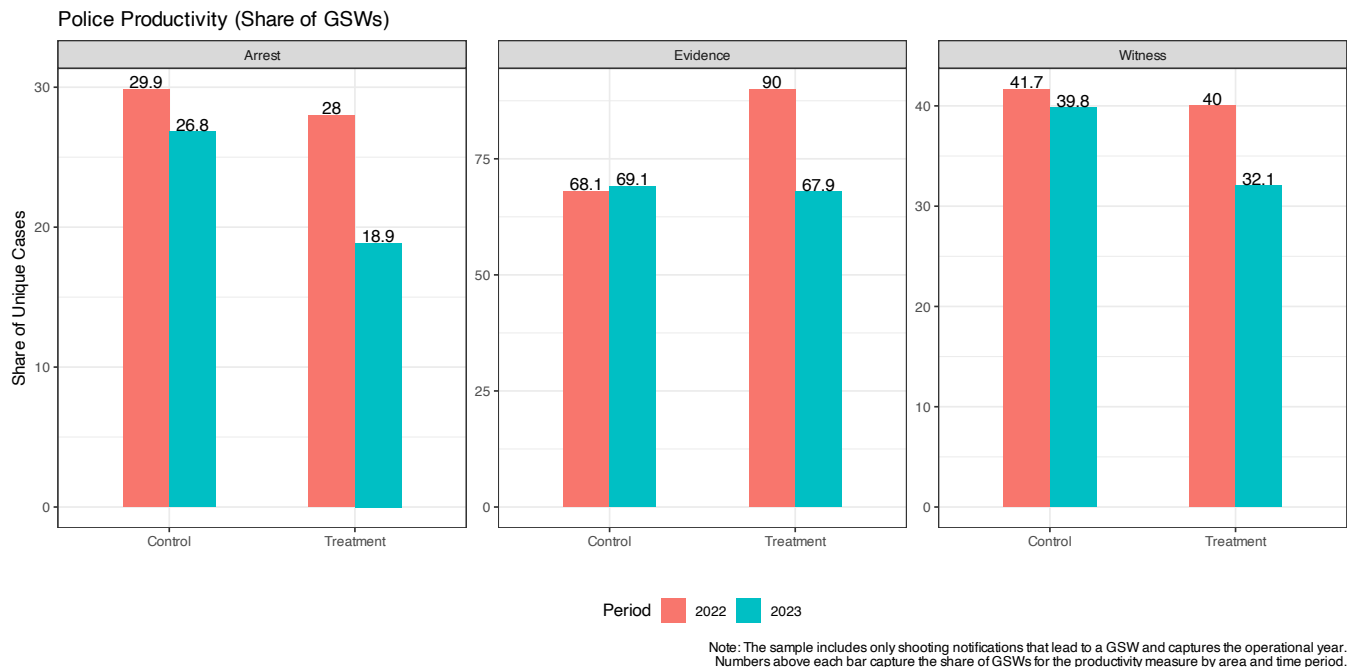
Roughly speaking, 4% resulted in an arrest, 11% resulted in collection of evidence, and 7% in witness interviews. Those results align with finding (above) that the typical time on scene for responding officers is around ten minutes. SS does not change that baseline reality by much.

The patterns evident in Figure 3 are confirmed by the results of a regression analysis, reported in some detail in an appendix to this report. The advantage of the regression analysis is that it allows us to statistically adjust for changes in the mix of cases, providing an estimate of the effect of the SS pilot without the potential confounding from other changes. In particular, we include in the regression specification indicators of whether the incident resulted in a gunshot wound.

(Shootings that result in injury or death tend to be investigated more thoroughly than other cases, and have a much higher arrest rate.) In summary, the key results of the regression are negative – there is no indication that the pilot intervention increased the productivity of investigations of incidents with 911 gunfire calls.

To dig deeper into the productivity effect, we re-did our analysis for just those incidents in which at least one victim was wounded or killed. Since all but two of these incidents included a 911 call, we include all such cases in the analysis – in effect, we combine the two-part analysis into a single calculation. Figure 4 presents results of our simpler analysis, which the appendix again reports the results of the corresponding regression analyses.

Figure 4: SS’s contribution to productivity of police investigations: Incidents in which a victim was shot. 2022-2023





For this sample, consisting of the most serious incidents, the measures are much higher overall. They generally decline for the arrest rate and rate of securing witnesses; for evidence collection, the rate is stable for the target area but increases in the control area. Generally speaking, it appears that the control area outperformed the target area. For example, for arrest, the control area was 3.1 percentage points ahead of the target area in 2022, and that advantage increased to 9.1 percentage points in 2023.

Since the incident counts are quite small, these patterns may be due to chance variation. The regression analysis serves as a check on this possibility by generating not only a point estimate of the key effect, but also a 95% confidence interval for that effect. As shown in the appendix, the point estimates for the effect of the pilot intervention are all negative, but those estimates are not precise enough to rule out the possibility that the underlying effect was null or even positive.

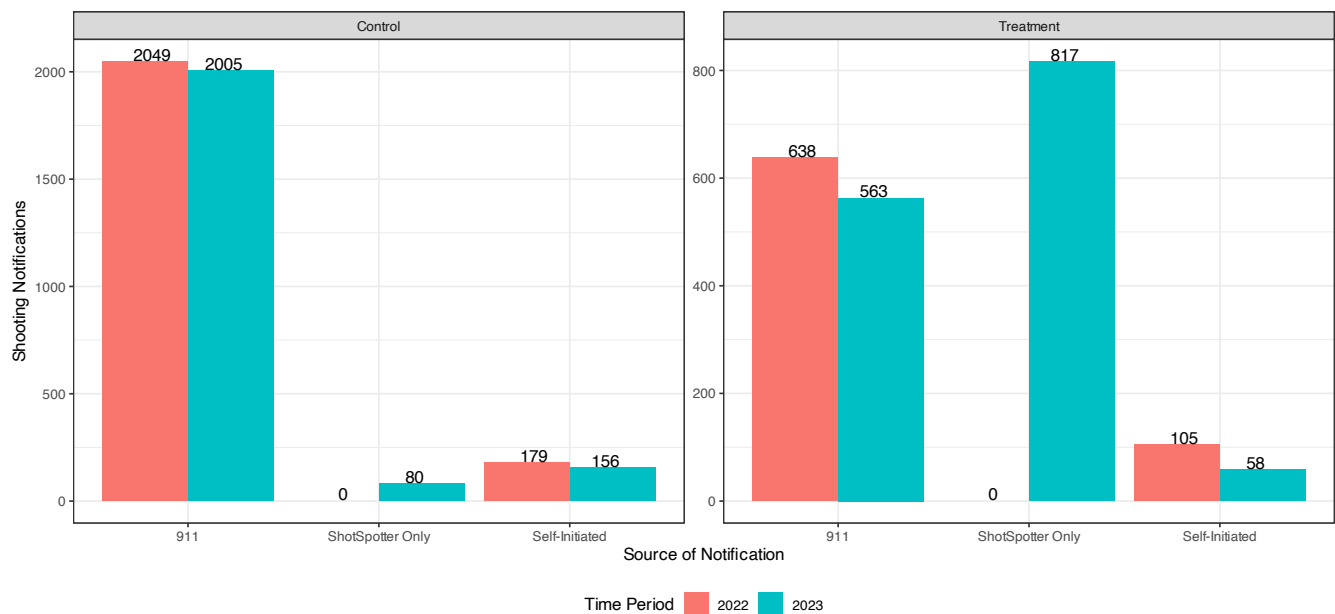
Our overall conclusion from the analysis of how the SS pilot affected the productivity of investigations is twofold. First, the incidents that were only known to the police due to a SS alert did sometimes have productive results. Those arrests can be credited to the SS installation. Second, for incidents that included a 911 notification, there is no evidence that SS increased investigation productivity. Generally speaking, it appears that the key contribution of SS was to provide the police with prompt notice of shootings that they otherwise would not have known about. Investigations of incidents that did include a 911 call were not enhanced by the SS pilot.

Does ShotSpotter Affect Residents' Propensity to Call 911?

One possible unintended consequence of a SS installation is that it would undermine residents' motivation to contact the police when they hear a gunshot. While plausible, we see no clear indication that that has happened in the target area in Durham. The number of 911 gunshot calls declined between 2022 and 2023, both in the target area (-11.8%) and the rest of the city (-2.1%). While that difference may be due to a decline in the propensity of residents of the target area

to call 911, it is also possible that it reflects somewhat different trends in the underlying reality of the volume of gunshot incidents.¹³ A definitive conclusion requires an independent estimate of the number of incidents with gunfire. While that is generally lacking, for the most serious incidents (GSWs) we do have confidence that most cases are known to the police one way or another; the fact that fully 50 of the 52 known GSWs in the target area generated a 911 call in 2023 suggests that residents continue to reliably contact the police in these cases.

Figure 5: Counts of gunshot notifications by source, target area and rest of city: 2022 vs. 2023



Note: Sample consists of all known shooting notifications in the target and control areas for the associated four operational quarters. 911 consists of any notification initiated by the public and includes SS notifications.

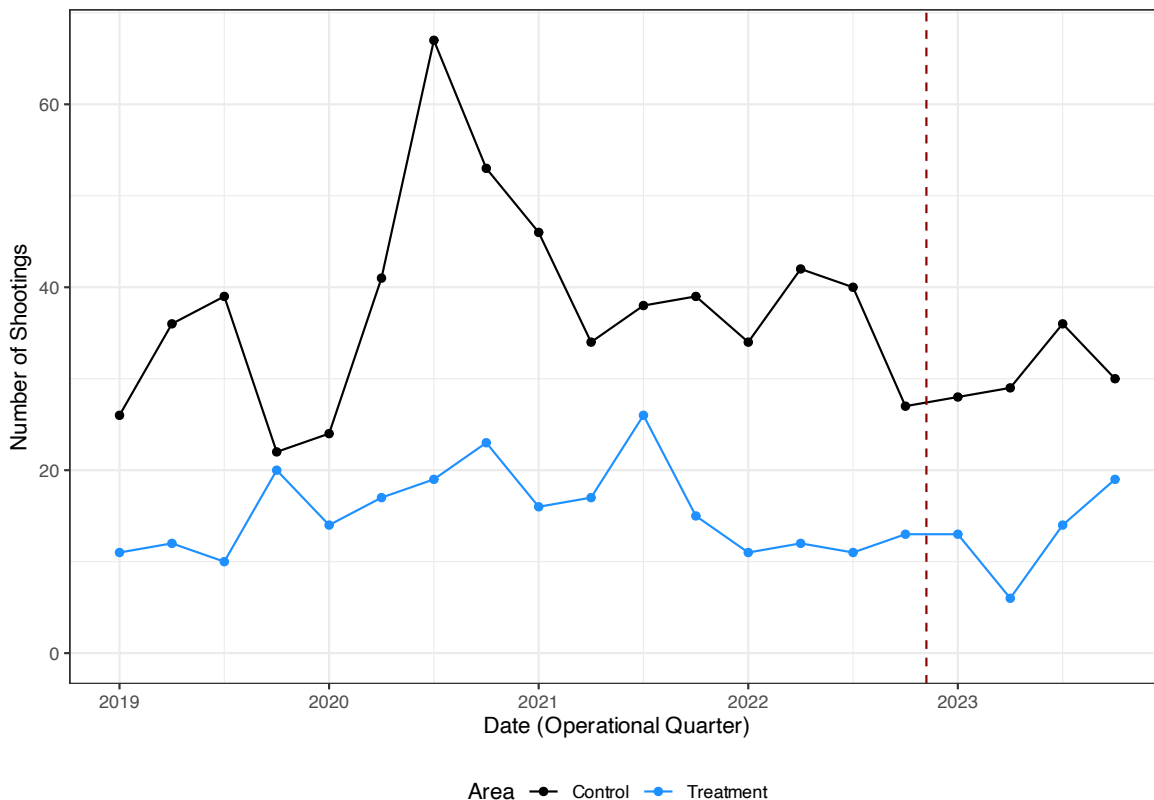
¹³ A puzzling result evident in this figure is that there were 80 SS alerts in the “control” area during 2023. Occasionally the SS sensors do pick up gunshots that occur outside the boundaries of the target area, but that is relatively rare. Note that the self-initiated notifications (mostly from police officers in the field) declined by 45% in the target area, presumably because SS alerts preempted the need for these in many cases.

F. Did the ShotSpotter Pilot Reduce Gun Violence?

One justification for investing in SS is that it might help to prevent gun violence. With SS in place, the police are more likely to know about and investigate gunfire incidents and to arrive at the scene more quickly, than if they were relying on 911 calls alone. To the extent that SS increases the productivity of shooting investigations, the traditional preventive effects of punishment — deterrence and incapacitation — would suggest a reduction in subsequent gun violence.

Figure 6 depicts the quarterly counts of GSWs in the target and control areas beginning in 2019. The two trajectories have considerable quarter-to-quarter variation and are not closely linked. Given that reality, it is not possible to reach a conclusion about the preventive effect of the SS installation. For example, if the true effect were to reduce gun violence by 10% (a valuable achievement), that effect would be swamped by the normal variation in this series.

Figure 6. Quarterly shooting counts by category and by area, 2019 - 2023



Notes: Each dot represents the count of quarterly shootings. The sample includes all known shooting events that led to a GSW from 2019 through the first year of ShotSpotters implementation.

Particularly notable in these time series is the unprecedented spike, especially for the control area, in all three counts in the year beginning in the second quarter of 2020 – the period associated with the onset of the pandemic and, shortly thereafter, the George Floyd-related demonstrations and their political consequences. (Interestingly the corresponding spike in the target area was much more muted than for the rest of the city.) This variability precedes and is unrelated to the SS installation, but it is relevant to our current purposes because it helps illustrate the challenge of estimating the effect of any one innovation, such as SS, on a relatively rare event. Variation in the time series due to other events may overshadow the effect of the specific innovation. The control group provides an indication of what would have occurred in the target area in the absence of SS, but it is far from perfect in that respect.

There have been a couple of published studies that have attempted to estimate the effect of SS on rates of gun violence in other cities.¹⁴ Most notable is Doucette et al.'s analysis of homicide rates in large metropolitan counties for the period 1999 – 2016.^{viii} Jurisdictions in some of these counties adopted SS during this period, which provides the basis for a sort of quasi-experimental evaluation. The authors' preferred estimate of the impact of SS on homicide rates is not precise, and includes a range of possibilities, both negative and positive, in the 95% confidence interval. It is statistically plausible that the “true” effect of SS on homicide in

these counties was a reduction of 5% or 10%, which would be a very valuable accomplishment. But from the same estimate we conclude that it is plausible that SS actually increased the homicide rate by that amount or more. The point is that this analysis leaves us uncertain about the true effect on homicide rates. It is not correct to conclude that SS had no effect, or that the study was able to rule out a meaningful change in homicide, either positive or negative.

Medical Intervention

Quicker and more comprehensive response creates the possibility that officers may arrive in time to save the life of a gunshot victim who would otherwise expire for want of medical assistance. Given that GSW cases are quite rare, there are few opportunities in which a minute or two difference in response time would spell the difference between life and death. Nonetheless, the possibility remains important.¹⁵ In the introduction to this report, we mention one instance in which a victim was found at the scene with life-threatening gunshot wounds, and kept from bleeding out by the officers' administration of first aid. The response was expedited by a SS alert which arrived sooner than any 911 call, and that 43-second difference may have spelled the difference between life and death, but that speculation cannot be confirmed. It should be noted that in any estimation of benefit, saving just one life every year or two is likely to justify the expenditure and other costs of SS at its current level.¹⁶

¹⁴ Piza et al. (2023), which analyzes the effect of SS on gun violence in Kansas City, is the most recent. It does not find a statistically discernible impact on homicide rates, but is subject to the same critique as provided in the text.

¹⁵ The recent evaluation of SS in Winston-Salem identified one incident in which SS provided the only notification, and in which the police response was deemed to save the life of the victim (Center for Crime Science and Violence Prevention 2023).

¹⁶ Standard practice for a cost-benefit analysis of a government program that affects health and safety is to value each life saved at several million dollars. For example, the US Environmental Protection Agency utilizes a value of \$11.4 million for a “statistical” life saved. <https://www.epa.gov/environmental-economics/mortality-risk-valuation#whatvalue>. But it should be noted that budget and other limitations often place limitations on life-saving activities, and it is appropriate to evaluate a program by a different standard. The question then is not just whether the program is worthwhile based on a cost-benefit assessment, but whether the program provides the greatest benefit that can be achieved for the given cost.



G. Reducing the Costs of Deployments

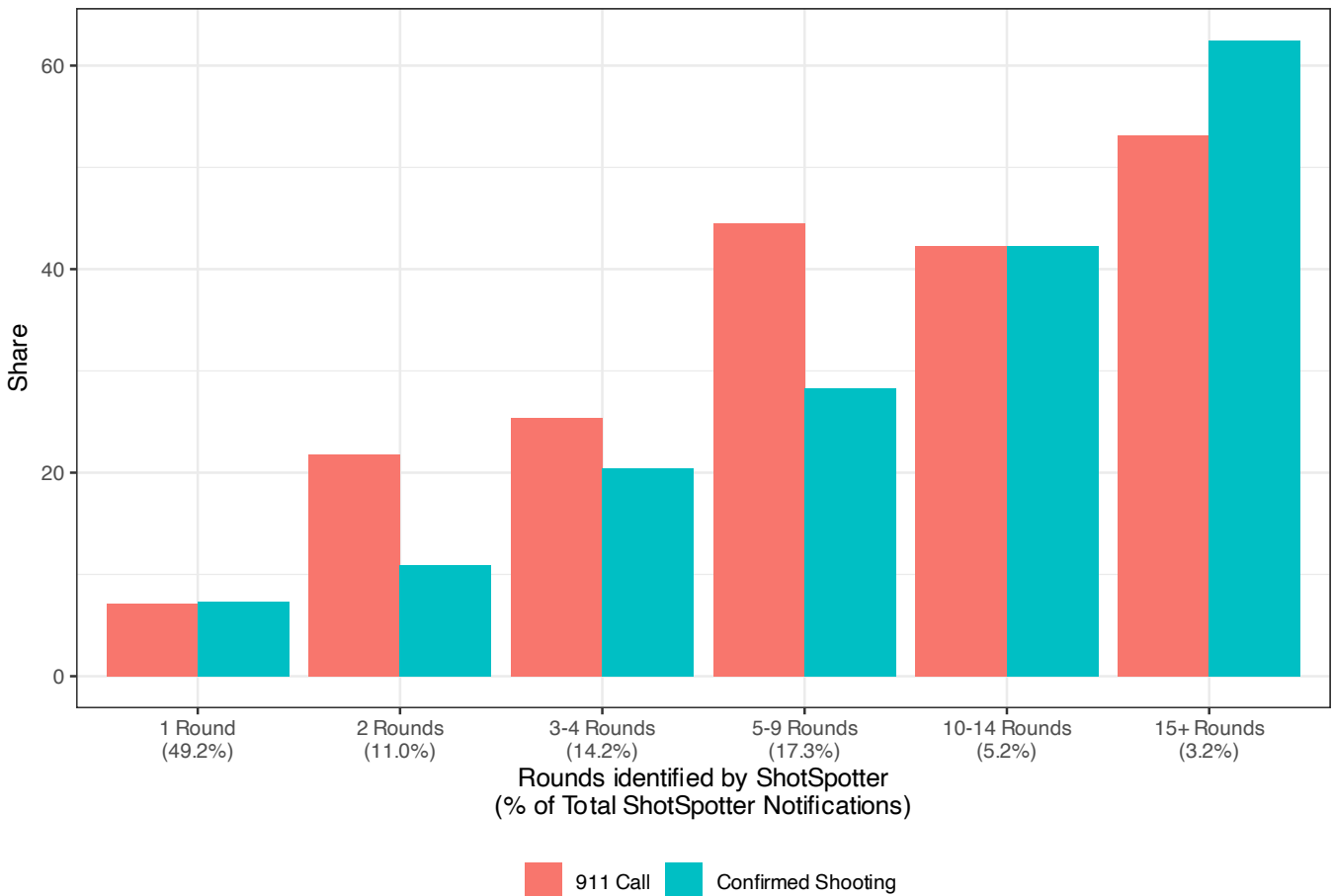
To recap, over half of all gunshot notifications in the target area in 2023 were SS alerts in which there was no 911 call, and in 91% of those alerts the responding officers did not find evidence of a crime in which a gun was fired. The DPD protocol required a priority 2 response to every gunshot notification, including the “low yield” SS-only notifications. But in the interest of reducing the costs of deployments should the SS contract be extended, a more nuanced protocol could be considered. One intriguing possibility is to take account of the number of shots recorded in the SS alert. While a majority of SS alerts record only one or two shots,

the most productive alerts are those with multiple shots. Here we present the evidence in support of this statement, and do some sample calculations of savings and losses resulting from screening SS alerts based on the number of shots recorded.

Figure 7 plots the likelihood that an SS alert resulted in a crime report, and also the likelihood of a 911 call, both as a function of the number of shots recorded. The clear pattern is a strong positive relationship between number of shots and likelihood of confirmed shooting; the same pattern is clear for the likelihood of a 911 call. These visual patterns are confirmed by linear regression analysis.¹⁷

¹⁷ The regression coefficients are 0.034 (confirmed shooting likelihood) and 0.059 (911 call likelihood) for a sample truncated at 10 shots. The interpretation is that each additional shot adds 3.4 percentage points to the likelihood the shooting will be confirmed, and 5.9 percentage points to the likelihood that a 911 notification will be received. Both estimates are quite precise.

Figure 7. Share of SS alerts with confirmed shooting and/or 911 call, target area: 12/15/2022 to 12/14/2023



Note: Sample consists of all SS notifications during first year of SS implementation in target area. Vertical axis share represents percent of all SS notifications conditional on the number of rounds. Horizontal axis share in parenthesis represents percent of total SS notifications.

Based on the percentages marked below the X-axis in Figure 7, we see that only one or two shots are recorded in 60% of incidents. While alerts with multiple shots are less usual, those multiple-shot alerts are the most productive.

These statistics provide a basis for predicting the consequences of a more nuanced protocol for responding to a SS alert. For example, suppose that

alerts with only one or two shots were “demoted” to lower priority for officer deployment. That would have affected 60% of SS alerts, but only 30% of confirmed shootings resulting from such alerts (39/130). Note that the protocol could be further modified if a 911 call was received along with the SS alert, restoring the case to Priority 2 (albeit with some possible delay if the 911 call was slow in coming).



H. Conclusions

The findings reported above are based on a 12-month pilot project in a three-square-mile area of Durham that has relatively high rates of gun violence. Here are the main conclusions from this evaluation:

- 1. SS provided alerts to some incidents for which there was no other source of notification – including two cases involving a gunshot wound (out of 52).** In all, for 26% of confirmed shootings in the target area, there was a SS alert but no 911 call.
- 2. SS alerts were published in 60% of confirmed shootings overall, and in half of the shootings that caused injury or death.** SS is not designed to detect gunfire indoors or in vehicles, and the detection/recognition system is subject to both human and technological failings. Of note, there were eight incidents in which one or more people were shot that should have generated an SS alert but did not.
- 3. For most SS alerts, the subsequent police investigation did not find confirmation that a crime occurred. That was also true of 911 calls regarding gunfire, although a 911 call was twice as likely to be confirmed as a SS alert.** But the effect of adding SS to the mix was to more than double the number of gunshot notifications, at some opportunity cost to the department. Of the 825 SS alerts for which there was no 911 call, 91% were unconfirmed – which is to say, the police investigation did not result in a crime report.
- 4. The Durham ShotSpotter installation reduced response times to 911 calls for service for gunfire.** The median reduction in the time required for dispatch and travel to the scene was 74 seconds. At the 90th percentile the decline was 114 seconds. The true savings in time may be still greater, since the SS alerts often come more quickly following the shooting than the typical 911 call. Response time can be crucial in emergency medical response and crime scene investigation.
- 5. The SS-only notifications during the pilot period were sometimes productive from an investigation viewpoint.** In fact, 7/29 gunshot incidents resulting in arrest were only known to the police as a result of a SS alert. Of these seven arrests, six were directly tied to the shooting.
- 6. It appears that in the target area the response to 911 calls during the pilot period did not become more productive, despite the quicker response time.** An analysis limited to the most serious incidents, those with gunshot wounds, offered the same (null) finding.
- 7. The SS installation may have resulted in a small reduction in the propensity of residents to call 911 following a shooting.** For the most serious cases during the pilot period, where a victim was shot, residents almost always contacted the police (50 of 52).
- 8. It is plausible but uncertain that in one particular incident, rapid deployment made possible by a SS alert actually saved the life of a gunshot victim.** While lifesaving is bound to be a rare event, it should be noted that lives are precious, and even one lifesaving intervention due to SS might be enough to justify the annual budgetary cost by the standards applied in federal government cost-benefit analyses.¹⁸

9. **The budgeted costs of the one-year contract included the payment of \$197.5 thousand to SoundThinking and \$28 thousand to the CAD vendor. In addition, SS alerts redirected DPD resources: the DPD responded to about 69 additional notifications per month in the target area.** These “extra” deployments may in some cases have delayed response to other calls for service, or cut back on routine patrol. But the increase in the total volume of Priority 2 calls for service (most of which are not gunshots, but rather alarms, disturbances, and domestic cases) due to SS was small, approximately 2% citywide.
10. **Given the large natural variation in rates of gun violence, it is not possible to discern the effect of SS on gunshot injuries in Durham.** That does not mean that there was no effect – only that it cannot be determined from available data.
11. **There may also have been costs and benefits to the community that are not accounted for in DPD records.** The experience for residents of the target area included an increase in police presence resulting from two-plus extra deployments per day. Some residents may have welcomed the extra police presence, and felt safer and better served as a result. Other residents may have had the opposite response. And others may have been ambivalent or unaware.¹⁹ Public opinion would typically be influenced by specific events, including high profile cases in which officers save lives or, on the other hand, treat citizens badly while responding. But there were no complaints filed with DPD as a result of a deployment to a SS alert.
12. **DPD adopted a protocol for responding to SS alerts that in effect equated them with gunshot notifications by residents or other sources. A more nuanced approach could have reduced the opportunity cost of the “extra” deployments without much effect on the productivity of shooting investigations.** For example, it would have been possible to downgrade the response to SS alerts that indicate just one or two shots.
13. **We do not offer a conclusion on whether the benefits of the SS installation exceeded the costs.** It is clear that ShotSpotter helped the DPD to respond to more confirmed gunfire incidents, and respond more quickly, than it would have with 911 alone. The expanded response coverage was somewhat productive. The value of this improved service to the community must be weighed against the budgetary and opportunity costs.

¹⁸ See footnote 16 on the standards applied in federal government cost-benefit analyses.

¹⁹ Kelly et al. (2024) explored residents’ experience and opinions through structured conversations in focus groups.

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Disclosures & Endnotes

Disclosures

In February 2023 Cook published *Policing Gun Violence*, co-authored with Anthony Braga, a criminology professor at the University of Pennsylvania. Braga and Cook were subsequently invited to address the annual meeting of the SoundThinking staff about the conclusions and recommendations from this book. Braga had other commitments so Cook accepted the invitation, delivering the speech on January 23, 2024. SoundThinking paid his travel expenses, but he did not receive an honorarium or other consideration.

Endnotes

i See ShotSpotter Annual Report, 2023.

ii See, for example, Goldenberg et al., 2019, and Gontarz et al., 2021.

iii [Arrest made in Durham after ShotSpotter leads cops to man wounded in shooting, police say \(cbs17.com\)](#)

iv There have been a number of recent evaluations of ShotSpotter in other cities. Here are a few examples: Houston (Cheng 2023); Winston Salem (Center for Crime Science and Violence Prevention 2023); Kansas City, MO (Piza et al. 2023); St Louis (Mares and Blackburn 2021); Camden, NJ (Goldenberg et al. 2019); and Las Vegas (Koren 2018).

v Mares and Blackburn 2021; Huebner et al. 2020.

vi This map is courtesy of the City of Durham and available online: [City-and-Callout-ShotSpotter-Map \(durhamnc.gov\)](#)

vii See the DPD's 2023 [1st Quarter Crime Report – Page 24](#). https://cityordinances.durhamnc.gov/OnBaseAgendaOnline/Documents/ViewDocument/WS-Published%20Attachment%20-%2016236%20-%20REPORT%20-%203%20-%20Q1%202023%20CRIME%20REPORT%20-%206_.pdf?meetingId=584&documentType=Agenda&itemId=33429&publishId=186564&isSection=false

viii Doucette et al. 2021.



Appendix

The Effect of the ShotSpotter Pilot on the Productivity of Investigations: Regression Results

The SS “treatment” is limited to the target area, with the rest of the city serving as a “control.” The control area is potentially useful in the same way that a control group is in a true experiment. In particular, the control area is subject to the same city-wide events as the target area, which in recent years include the COVID epidemic, the civil unrest stemming from George Floyd’s murder in Minneapolis, the “Defund the Police” movement, a growing number of DPD vacancies, and the change in police leadership. Observed trends in the productivity of police deployments in the target area following SS are compared to the rest of the city – if they differ, it may be due to the effects of SS. It should be noted that with only one treatment and one control area, this experimental design is far from definitive in identifying and estimating a causal effect.

Table A1 presents the results of an OLS regression analysis of incidents for which there was a 911 call about gunfire. Separate analyses were conducted for four outcomes, each for the 5-year period 2019-2023:

- The investigation resulted in at least one arrest
- The investigation resulted in collection of gun-related evidence, including shell casings
- The investigation resulted in witnesses being identified and interviewed
- The initial crime-scene investigation confirmed that a gun had been discharged

The regression specification included the following variables:

- Year indicators
- Indicator for Target area (as opposed to the rest of the city)
- Indicator for Target area/ Pilot period (the intersection of 2023 and target area)
- Indicators for whether the victim was shot (either fatally or nonfatally). (These indicators are not included in the regression for “confirmed gunshot” since all cases in which a victim had been shot are confirmed.)

Table A1 reports the estimated coefficients and standard errors (in parentheses). The key independent variable in each regression is the indicator for the pilot period/area.

Table A1. SS's contribution to productivity of police investigations: Incidents with 911 gunshot notification, 2019-2023

	Arrest (1)	Evidence (2)	Witness (3)	Confirmed (4)
Target Area	0.001 (0.004)	0.016*** (0.006)	-0.001 (0.005)	0.039*** (0.010)
Fatal GSW	0.419*** (0.014)	0.893*** (0.021)	0.539*** (0.017)	
Non-Fatal GSW	0.164*** (0.007)	0.611*** (0.010)	0.234*** (0.008)	
Treatment: 2023 X Target Area	-0.008 (0.010)	-0.020 (0.015)	-0.011 (0.012)	0.036 (0.023)
Observations	13,629	13,629	13,629	13,629

Note: *p<0.1; **p<0.05; ***p<0.01

These regression results suggest several findings of interest. For example, the likelihood of arrest was much higher for incidents in which a victim sustained a gunshot wound than for all other cases: specifically, the arrest rate was 43.2 percentage points higher if the victim died, and 16.8 percentage points higher if the victim was shot but survived. The key findings on arrest are that the pilot “treatment” (SS installation) had no discernible effect on any of the four outcomes. The coefficients are close to zero, and given the degree of precision of these estimates (as indicated by the estimated standard errors) it is plausible that the true effect was positive, negative, or null.

We re-do this analysis for a sample restricted to incidents in which a victim was shot and wounded or killed – a much smaller sample, but one which includes all the most serious cases. The specification is the same, except that one of the injury indicators is

dropped; for this sample, all incidents are either fatal or nonfatal injury, so only one indicator is needed. Table A2 reports the results.

Table A2. SS's contribution to productivity of police investigations: Incidents in which victims are known to have been wounded or killed

	Arrest (1)	Evidence (2)	Witness (3)
Target Area	0.030 (0.031)	0.116*** (0.032)	0.048 (0.034)
Fatal GSW	0.266*** (0.033)	0.285*** (0.034)	0.303*** (0.036)
Treatment: 2023 X Target Area	-0.115 (0.075)	-0.134* (0.076)	-0.132 (0.082)
Observations	1,038	1,038	1,038

Note: *p<0.1; **p<0.05; ***p<0.01

As with the larger sample, the coefficient estimate for the treatment impact are negative for the three outcomes included here: arrest, evidence, collected, and witness interviewed. The absolute magnitudes of these coefficients are an order of magnitude larger, but none of them are statistically significantly different from zero at the usual standard ($p < .05$). These results make it very unlikely that there was an increase in productivity for investigations of gunshot wound incidents, and in fact are suggestive of a negative effect. That result is not a scientifically established finding by the usual standards, but should motivate more research with these data, as well as qualitative research with investigating officers.

About Us

The Wilson Center for Science and Justice at Duke Law seeks to advance criminal justice reform and equity through science and law. We engage with academics, policy makers, and community stakeholders to translate interdisciplinary research into effective and practical policy. Our work focuses on three key areas: improving the accuracy of the evidence used in criminal cases, promoting fair and equitable outcomes in the criminal legal system, and improving outcomes for persons with mental illness and substance use disorders who encounter, or are at risk for encountering, the criminal legal system. Learn more about the Center at wcsj.law.duke.edu.

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