Title:
A citywide cluster randomized trial to restore blighted vacant land and its effects on violence, crime and fear

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One Sentence Summary:
Standardized processes for the restoration of vacant urban land were experimentally tested on a citywide scale and found to significantly reduce persistent urban problems such as gun violence and fear.

Abstract
Vacant and abandoned urban land is a widespread and potentially risky environmental condition encountered by millions of people every day. As a citywide cluster randomized controlled trial, we investigated the effects of standardized, reproducible interventions that restore vacant land on the commission of violence and crime as well as perceptions of fear and safety. A total of 541 randomly sampled vacant lots were randomly allocated into three study arms; outcomes from police and 445 randomly sampled participants were analyzed over a 38-month study period. Participants living near treated vacant lots reported reduced safety concerns when going outside their homes (-57.8%, $p<0.05$) and increased use of outside spaces for relaxing and socializing (75.7%, $p<0.01$). Gun assaults were reduced in areas near treated vacant lots (-27.1%, $p<0.001$). Blighted and vacant urban land affects people's perceptions of safety and their actual, physical safety. Restoration of vacant urban land can be an effective and scalable intervention to significantly reduce persistent urban problems such as gun violence and fear.

Introduction

Blighted and vacant urban land is a widespread environmental condition encountered by millions of people on a daily basis. About 15% of the land in US cities is deemed vacant or abandoned, translating into an area roughly the size of Switzerland – over 9 million acres of otherwise beneficial spaces that remain neglected.[1,2] Urban residents, especially in low-income neighborhoods, point to these spaces as primary threats to their health and safety[3] while cities continue to seek meaningful, evidence-based interventions for their once vibrant but now vacant land.

Many cities have focused on complicated and expensive responses to their vacant land problem as part of larger, urban transformation initiatives.[4] These responses have typically been intended to drive economic development and have often resulted in the relocation of residents or the transformation of vacant spaces into luxury amenities or housing intended to economically buoy depopulating neighborhoods. While these strategies can change local economic conditions, they also can have the unintended consequence of displacing people who do not wish to move, create further entrenched neighborhood segregation[5], and may not adequately address the more widespread, often citywide nature of vacant land that chiefly affects low-resource and working class neighborhoods. These neighborhoods account for the majority of space in many cities and their residents are exposed to blighted and vacant spaces on a daily basis.

The widespread vacant land problem in US cities calls for more than economic development or relocation programs as these solutions can be expensive, may affect relatively few urban areas and people, and may not reflect residents' needs and preferences. A recent, landmark randomized controlled trial demonstrated that individuals who relocated out of low-income urban residences via a voucher system had significant health and safety benefits. Yet subsets of these individuals, such as adolescent boys, were also found to have been negatively affected by relocation and over half of the study's participants who were given relocation vouchers opted not to use them.[6, 7] This study clearly indicates the importance of neighborhood context, although the high costs of relocation and the demonstrated preferences against relocation suggest that perhaps less expensive, "in situ" approaches, that can be applied to entire cities and allow residents to remain in their home spaces, deserve consideration.[8, 9]

Inexpensive, in situ approaches, such as green infrastructure installations on vacant urban land in residential neighborhoods, have been shown to affect economic outcomes.[10] A developing recent literature has shown that such changes may also affect health and safety outcomes, such as violence and crime.[11] The literature on greening urban space and its association with violence and crime has produced mixed results.[12] Urban green space, low-lying trees and shrubs, and vegetation have on the one hand been associated with greater fear of crime. Residents may feel that such vegetative growth decreases their line of sight and hides potential attackers and illegal activity.[13, 14, 15, 16] On the other hand, residents living near newly greened vacant lots felt significantly safer[17] and green space in public housing was associated with enhanced feelings of personal safety[18]. Beyond perceptions of crime, dense vegetation has been associated with greater crime in some studies.[19, 20, 21, 22] But again the literature is mixed and other analyses link urban green space, street trees, and vegetation to reductions in violence and crimes.[23, 24, 25, 26, 27, 28, 29]

Urban context matters in terms of human behavior. A contagion of problems can spread from abandoned, dilapidated and trash-strewn spaces to other nearby spaces, possibly leading to violence and crime.[30, 31, 32] Green infrastructure installations are a potential solution to these problems yet mixed scientific findings on urban green space, perceptions of safety, and crime suggest that not all green space is the same and that controlled scientific testing of inexpensive, standardized, and reproducible greening interventions for vacant urban land would be of value.[33] To the best of our knowledge, no large randomized controlled trial has tested a greening intervention on a citywide scale and, in doing so, described the impact of a nature-based interventions in a large representative sample of low-income communities.

This paper presents findings from a citywide cluster randomized controlled trial of standardized, reproducible greening interventions to treat the problem of vacant lots in a major US city. These

interventions were designed to quickly, reliably, and inexpensively remediate large numbers of vacant lots in violation of city blight ordinances due to overgrown and neglected vegetation, illegal dumping of large trash items and debris, or proliferation of rodents and other vermin. The interventions specifically involved the "cleaning and greening" of vacant lots via standard, reproducible processes completed by teams of landscape contractors, many of whom come from local urban neighborhoods. Over the study's two-month intervention period, 375 vacant lots across the city were transformed by removing trash and debris, grading the land, planting grass using a hydroseeding method that can quickly cover large areas of land, planting a small number of trees to create a park-like setting, installing low wooden perimeter fences to show that the lot was cared for and to deter illegal dumping, and then regularly maintaining the newly treated lot throughout the post-intervention period. The overall costs of this intervention have been shown to be inexpensive and highly cost-effective[34] with initial expenses averaging about $1.50 per square foot and maintenance averaging $0.17 per square foot thereafter.[35] (Figure 1)

The objectives of this randomized controlled trial were to determine the effect of these interventions on the commission of violence and crime as well as perceptions of fear and safety among individual study participants. We also incorporated a qualitative ethnographic component into the trial itself to more fully test, corroborate, and explain ongoing hypotheses of reductions in these outcomes that could not be explained in prior non-experimental studies.[27, 36, 37, 38, 39, 40, 41]

Randomized Controlled Trial and Displacement Test Results

Baseline balance was evident in terms of multiple variables at the participant-level and the cluster-level between the three intervention conditions (Table 1). All 110 vacant lot clusters, and 445 participants within their clusters, initially received the intended intervention to which they were randomly assigned. This formed the basis of an intent-to-treat analysis that was completed for all primary study outcomes. Despite their initial random assignment, select numbers of vacant lots did not maintain their originally assigned condition in the post-period: some vacant lots that were randomly assigned to receive interventions deteriorated and some vacant lots that were randomly assigned to receive no intervention saw improvements in the post-period. (Figure 2)

Intention-to-treat (ITT) analyses demonstrated significant changes in participant-reported outcomes related to violence and fear for one's safety. Vacant lot intervention group A experienced significantly reduced perceptions of vandalism (-39.3%, $p<0.05$) and crime (-36.8%, $p<0.05$) across all neighborhoods. This intervention group also reported significantly reduced safety concerns tied to going outside their homes (-57.8%, $p<0.05$) and significantly increased use of outside spaces for relaxing and socializing (75.7%, $p<0.01$). (Table 2)

Intention-to-treat analyses also demonstrated significant changes in police-reported outcomes. Across all neighborhoods, gun assaults were significantly reduced after implementation of both vacant lot interventions (-2.7%, $p<0.05$ and -6.7%, $p<0.001$). Nongun assaults showed no significant reductions across all neighborhoods. In neighborhoods below the poverty line, gun assaults were significantly reduced to a larger degree after implementation of both vacant lot interventions (-9.1%, $p<0.001$ and -11.6%, $p<0.001$). Burglaries were significantly reduced after implementation of both vacant lot interventions (-7.7%, $p<0.001$ and -8.1%, $p<0.001$) in neighborhoods below the poverty line. Nuisances were significantly reduced after implementation of vacant lot intervention A across all neighborhoods (-12.8%, $p<0.01$) and neighborhoods below the poverty line (-15.7%, $p<0.01$). Illicit drug crimes were significantly reduced after implementation of vacant lot intervention B across all neighborhoods (-4.1%, $p<0.05$). (Table 3)

Contamination-adjusted intention-to-treat (CA-ITT) analyses of police-reported outcomes produced similar results to the ITT analyses. Across all neighborhoods, gun assaults were significantly reduced after implementation of both vacant lot interventions (-5.8%, $p<0.01$ and -27.1%, $p<0.001$). Nongun assaults showed no significant reductions across all neighborhoods. In neighborhoods below the poverty line, gun assaults were significantly reduced to a larger degree after implementation of both vacant lot interventions (-17.4%, $p<0.001$ and -63.5%, $p<0.001$). Burglaries were significantly

reduced after implementation of both vacant lot interventions (-14.6%, p<0.001 and -43.5%, p<0.001) in neighborhoods below the poverty line. Nuisances were significantly reduced after implementation of vacant lot intervention A across all neighborhoods (-27.5%, p<0.05) and neighborhoods below the poverty line (-28.1%, p<0.05). Illicit drug crimes were significantly reduced after implementation of vacant lot intervention B across all neighborhoods (-17.1%, p<0.01) and neighborhoods below the poverty line (-25.1%, p<0.05). All CA-ITT results had first stage F-statistics >100.0. (Table 4)

Displacement tests of the police-reported crime outcomes showed no significant spillover effects of the intervention. In none of the spatial scales studied was there a significant reduction in the central radius area around vacant lots that was coupled with significant increases in the ring surrounding this central area.

Interpretations and Implications for Prevention of Urban Fear and Violence

This is the first citywide randomized controlled trial of actual place-based changes to urban spaces as a structural intervention to reduce violence and fear among residents. We enrolled a random sample of spaces and residents across a major US city and randomly assigned these spaces to receive two types of interventions to restore blighted vacant land. Both types of place-based interventions significantly reduced police-reported gun violence as well as other police-reported problems such as burglaries and nuisances. Randomly sampled residents who lived near newly renovated spaces also reported experiencing significantly less crime and vandalism, independently corroborating findings from police-reported data.

A statistically significant -58% reduction in people's fear of going outside due to safety concerns and as much as a -27% reduction in gun violence across all neighborhoods found in this randomized controlled trial are meaningful shifts that greatly extend the findings of prior quasi-experimental studies conducted at different times and in multiple cities such as Youngstown, Chicago, and Philadelphia.[27, 42, 43] These findings have now added much needed experimental evidence to a new knowledge-base showing that cost-effective[34] structural interventions that are scalable to entire cities, like vacant land restoration, can have significant and lasting effects on seemingly intractable public safety issues such as gun violence and fear. Moreover, several of the beneficial effects found here were most pronounced in the poorest city neighborhoods making these interventions presumably even more attractive to municipal policymakers and planners looking to reduce economic and quality-of-life disparities in effective, yet acceptable, ways for historically under-resourced urban communities.[44]

Urban violence leads to fear, even among residents not directly involved in the violence itself. Together, violence and fear can increase abandonment of previously vibrant city spaces and lead to a spiral of decay in urban neighborhoods.[45] As this experimental study has shown, direct changes to vacant urban spaces may hold great promise in directly breaking the urban cycle of violence, fear, and abandonment and doing so in a cost-effective way that has broad, citywide scalability.[46]

Blighted vacant lots visibly signal that a neighborhood has not been attended to by both the public and private sectors and that a physically decayed infrastructure has taken over creating unmanaged public space conducive to incivilities and crime that may be intimidating, demoralizing, or even have the effect of coopting some residents. As a result, unsafe behaviors, such as gun violence, can become sheltered and prevalent.[34, 47] Such unsafe behaviors, although committed by a small number of individuals, are often street-based, occurring outside and in plain view for otherwise unconnected residents to witness and personally experience, despite not being actual victims of a crime or a shooting. These unsafe behaviors may even have audible cues, such as the sound of a firearm being discharged, extending their negative effects beyond simply what people see or the spaces within which they occur. The differences found here between gun violence and nongun violence partially supports these mechanisms.

It follows that the abatement of vacant lots studied here generated enhanced perceptions of safety and reduced fear among neighborhood residents, encouraging them to spend time outside their homes and socialize with their neighbors. The positive effects of increases in face-to-face neighborly interaction are consistent with classic urban studies of "eyes on the street" and "social capital" as being

effective mechanisms for crime reduction and neighborhood stabilization. This literature critiqued high-rise urban modernist architectural projects that failed to recognize the importance of sidewalk sociality and mechanisms of interactive social control in poor and working class neighborhoods.[48] Thus the physical environmental shift of vacant lot restoration may have also led to a social environmental shift.

Unwanted and illegal activity that is often accompanied by gun violence, such as drug trafficking, is also able to proceed more easily in or in front of vacant lots than it is in front of occupied residences. Our ethnographers confirmed that drug sellers purposefully conducted business in front of vacant lots to reduce the likelihood of being "snitched on" (i.e. having the police called on them by neighbors).[49] On several occasions residents in neighborhoods dominated by open-air illegal drug markets also explained to the ethnographers that they did not generally dare confront drug sellers unless they were operating directly in front of the rowhome in which they lived. On multiple occasions, ethnographers observed drug sellers being shooed away from the front of occupied rowhomes by both their drug bosses and residents and being allowed to settle again down the block in front of vacant properties.

Our ethnographic field notes contained multiple references to overgrown vacant lots providing concealment for routine drug use and escape routes during police raids. Larger lots with rubble and overgrowth occasionally became open air "shooting galleries" where heroin and cocaine users congregated to buy syringes and inject behind bushes, discarded construction materials, or in the ruins of buildings. The crisscrossing pathways to shooting galleries through overgrown lots is visible in several of our field video footage and Google street view images. Located in the heart of a former industrial zone, drug sellers in one of the poorest areas of Philadelphia reported that they paid weekly rent to drug bosses ("bichotes") for the right to sell on blocks where inhabited rowhomes were interspersed with vacant properties. Some of these blocks generated rents of $5,000 a week to their "owners". Our team of ethnographers also documented over a dozen gun battles for control of these inhabited, but infrastructurally decaying territories over a seven-year period that overlapped with the dates of this randomized controlled trial.[50] Significantly however, blocks that were too desolate and uninhabited appeared to render drug sellers excessively visible to the police.

Most of these ethnographic findings were collected in a micro-neighborhood where the poverty rate was approximately twice the citywide rate and may be consistent with the greater magnitude in the size of the reductions in gun assaults, burglaries and nuisances found in neighborhoods below the poverty line. Another mechanism behind the significant reductions in gun violence found here may be that vacant lots and the immediate areas around them create out-of-sight staging areas for illegal firearms until they are needed by individuals participating in illegal activity. This out-of-sight staging may occur on the vacant lots themselves, as other studies, law enforcement, and landscape contractors have suggested, although it may also be that illegal firearms get stored in car trunks or hidden panels in cars that are often parked in front of vacant lots and abandoned buildings.[27, 51, 52]

Study Limitations

The current cluster randomized controlled trial was undertaken as a significant extension of prior studies that were limited by residual confounding and omitted variable biases. The study has also built in and directly tested concerns of spatial displacement, demonstrating that the reductions in violence found here were real reductions and not simply the relocation of violence "around the corner".[53] In these regards it has methodologically and analytically taken a large step forward, although some limitations remain.

One limitation is duration. The study assessed the effect of greening vacant lots over a reasonably long year-and-a-half follow-up period. However, we cannot know for certain what the impact of these interventions would be beyond the study period, although prior quasi-experimental evaluation of the same vacant lot intervention found similar significant effects for some of the same outcomes, such as gun violence, that persisted for over 3.5 years on average.[27]

A more overarching concern is that the interventions implemented as part of this study, and any subsequent uses of this place-based intervention, may lead to widespread gentrification and the

unintended displacement of low- and middle-income residents. This is possible, although prior analyses have found economic indicators, such as property taxes, to be unchanged and, if anything, reduced, after implementation of the greening interventions tested here.[27] In addition, over the course of this study, local municipal legislation was also passed to limit property tax increases for longtime residents in curtailing displacement due to gentrification and only a very small percentage (< 5%) of the vacant lots that were remediated using the intervention strategies described here have been developed into homes or commercial businesses.[54, 55] Thus almost all of the vacant lots that were remediated here have remained open to residents for continued use and recreation.

To further investigate, our ethnographic team also analyzed qualitative field data on neighborhood gentrification patterns. Significantly, one of the first ethnographic observations on protocol fidelity was the importance of reminding field staff of the scientific principle of random sampling in the early phase of the intervention when lots were being selected for eligibility. They were told to disregard former priorities for selecting lots based on prior municipal contracts that had included, among other criteria, enhancing commercial corridors and school zones.[56] Our ethnographic team initiated parallel studies of reactions by neighbors to greening interventions in two micro-neighborhoods – one subject to rapid gentrification/racial displacement and one poorer micro-neighborhood unaffected by rises in property values that were occurring unevenly across the city during the years of the intervention. The team documented racialized tensions in the gentrifying micro-neighborhood that included explicit hostility to greening by some residents. In the poorer, more infrastructurally isolated micro-neighborhood not affected by gentrification, virtually all residents we encountered were more consistently positive about the greening of vacant lots. We documented no residents who left either micro-neighborhood as a result of our intervention.

It is important to note that the vacant lot greening interventions studied here were not designed to lead to luxury housing developments or upscale, single-site recreational installations that would act as destination amenities to draw in nonresidents. They were explicitly chosen for study because they were inexpensive, scalable, and designed to be installed immediately proximal to lived space, oftentimes in low-income neighborhoods, to give local residents ready access to new, albeit basic amenities that they otherwise would not have had.[34] Other work has found that newly greened vacant lots provide informal and accessible recreation space to nearby neighbors, based on evidence such as picnic tables, barbeques, and recreational equipment.[57]

Conclusions

We have demonstrated, in the first citywide randomized controlled trial of its kind, that structural dilapidation and abandonment can be key causes of negative outcomes in terms of people's safety, both their perceptions of safety and their actual, physical safety. When left untreated, vacant and abandoned urban spaces contribute to increased violence and fear. The physical components of neglected and impoverished urban environments can be changed in inexpensive and sustainable ways as a direct treatment strategy for violence and fear in cities. Restoration of vacant urban spaces using well-delineated intervention protocols, such as those described here, is an effective, scalable, and politically acceptable treatment that can significantly and sustainably reduce persistent urban problems.

The effectiveness of infrastructural interventions in decreasing gun violence and crime and increasing perceptions of safety offers a practical example of a public health approach that transcends the conventional model of targeting behavior change on the individual-level. It suggests that macro-level upstream approaches can have significant, positive population-level effects without conscious commitments by individuals to lifestyle changes. In the mid-nineteenth century the disciplines of social medicine, public health and epidemiology emerged out of the success of large public investments in interventions like sewage and potable water infrastructure which curbed large-scale epidemics and transformed the health of entire cities.[58] Infrastructural approaches to improving health at a population level may again offer pragmatic strategies for addressing the complex social determinants of health of today.

Figure 1. Vacant land treatment process showing blighted pre-period conditions and post-period restorations. The top center magnification shows the grass seeding method used to rapidly complete the treatment process. Lots shown here are representative of those in the study although for purposes of confidentiality are not actual study lots.

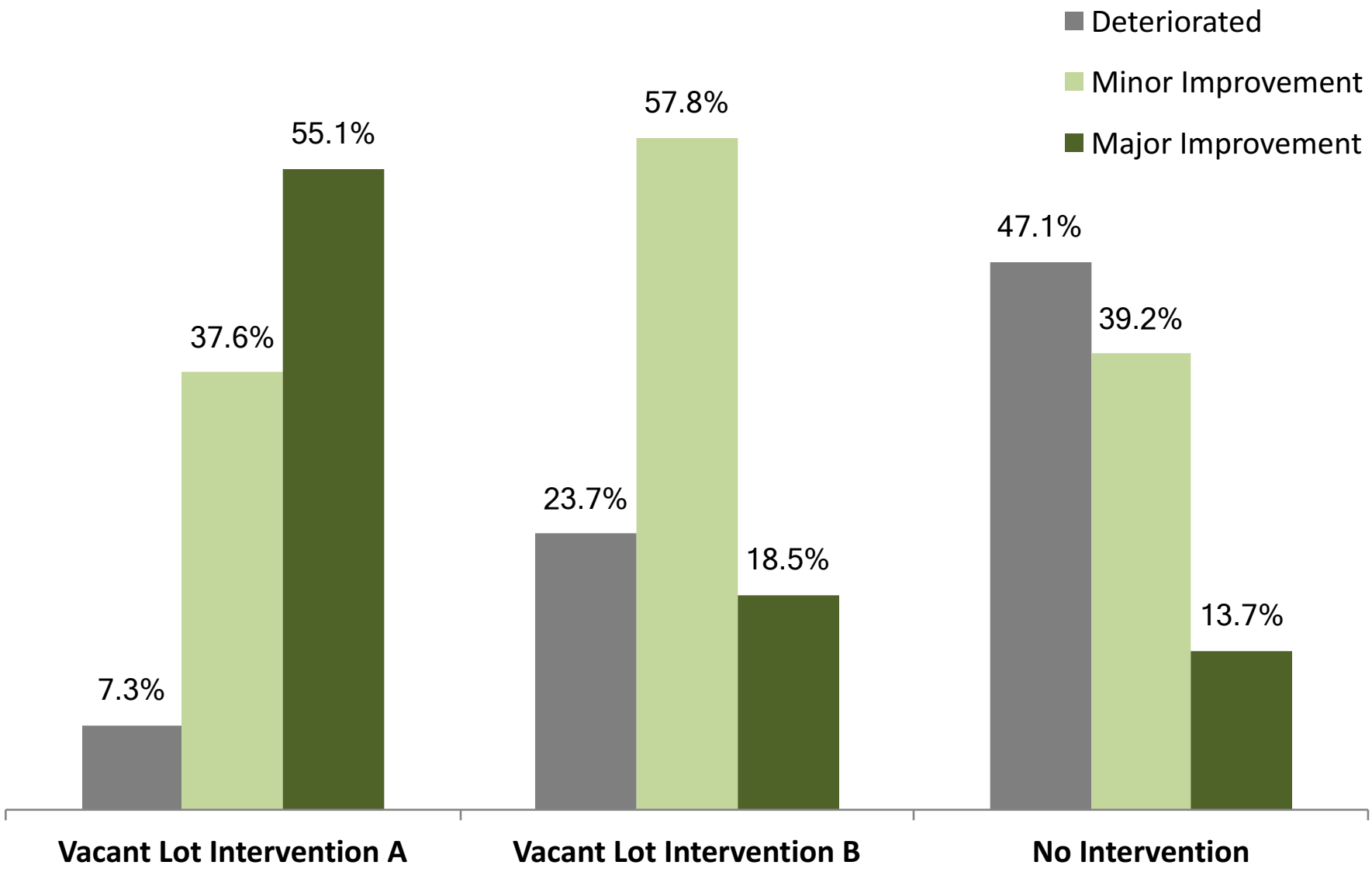

Figure 2. Actual shifts in conditions of vacant lots within the three randomly allocated study arms.

	Vacant lot intervention A	Vacant lot intervention B	No Intervention
Participant-level:			
Total number of participants	148	147	150
Age	44.1 years	46.2 years	45.9 years
Tenure in home	12.7 years	14.7 years	13.5 years
Female	63.2%	64.4%	59.2%
Hispanic	9.7%	8.5%	11.2%
Black	78.6%	79.4%	69.1%
Any college	25.7%	23.3%	29.7%
Unemployed	34.7%	23.5%	25.0%
Family income <$25K	46.6%	49.8%	42.6%
Cluster-level:			
Resident population	288 people	297 people	285 people
Serious crimes	16.5 crimes	18.3 crimes	17.1 crimes
Total eligible vacant lots	38.3 lots	43.1 lots	38.1 lots
Prior treated lots	6.7 lots	5.3 lots	5.6 lots
Total number of study lots	201 lots	174 lots	166 lots
Study lots per cluster	5.4 lots	4.8 lots	4.5 lots
Study lots total area per cluster	4,844 ft^2	4,935 ft^2	4,872 ft^2
Study lots mean separation	75.6 ft	71.3 ft	73.5 ft
Study lots bounding polygon area	10,110 ft^2	11,881 ft^2	10,649 ft^2

Table 1. Baseline balance among key participant and cluster-level variables compared as means between three randomly allocated study arms.

	All neighborhoods			Neighborhoods below poverty line		
Vacant lot intervention A vs. No intervention						
Not going out because of safety concerns	-57.8%	[-82.0% , -3.0%]	*	-70.9%	[-93.0% , 17.0%]	
Too much drug use	-25.1%	[-52.0% , 16.0%]		-18.0%	[-64.0% , 85.0%]	
Vandalism is common	-39.3%	[-61.0% , -6.0%]	*	71.9%	[-24.0% , 288.0%]	
There is a lot of crime	-36.8%	[-59.0% , -3.0%]	*	-15.8%	[-62.0% , 88.0%]	
My neighborhood is safe	-14.8%	[-46.0% , 33.0%]		60.3%	[-30.0% , 266.0%]	
People watch out for each other	12.1%	[-28.0% , 75.0%]		131.0%	[0.0% , 435.0%]	
People take care of their houses	-5.5%	[53.8% , -41.9%]		-17.0%	[100.0% , -65.8%]	
Hanging out, relaxing, socializing outside	75.7%	[163.2% , 16.3%]	**	61.9%	[257.1% , -26.5%]	
Vacant lot intervention B vs. No intervention						
Not going out because of safety concerns	-36.5%	[-72.0% , 42.0%]		-66.2%	[-91.0% , 23.0%]	
Too much drug use	-35.3%	[-59.0% , 1.0%]		-28.6%	[-67.0% , 53.0%]	
Vandalism is common	-14.7%	[-46.0% , 35.0%]		34.6%	[-38.0% , 192.0%]	
There is a lot of crime	-40.3%	[-62.0% , -7.0%]	*	-29.2%	[-67.0% , 51.0%]	
My neighborhood is safe	-44.5%	[-65.0% , -12.0%]	*	-18.2%	[-62.0% , 77.0%]	
People watch out for each other	-23.9%	[-52.0% , 22.0%]		26.6%	[-42.0% , 179.0%]	
People take care of their houses	32.2%	[117.4% , -20.6%]		101.4%	[376.2% , -15.3%]	
Hanging out, relaxing, socializing outside	2.4%	[56.3% , -32.9%]		-16.5%	[75.4% , -60.0%]	

* p<=0.05, ** p<=0.01, *** p<0.001, 95% confidence intervals in brackets

Table 2. Intention-to-treat (ITT) analysis of vacant lot treatments and participant-reported outcomes

	All neighborhoods				Neighborhoods below poverty line			
Vacant lot intervention A vs. No intervention								
Gun assaults	-2.7%	[-5.2% ,	-0.2%]	*	-9.1%	[-13.2% ,	-5.0%]	***
Nongun assaults	63.2%	[-14.9% ,	141.2%]		-4.4%	[-7.3% ,	-1.4%]	**
Burglary	-6.3%	[-8.3% ,	-4.4%]	***	-7.7%	[-10.6% ,	-4.8%]	***
Robbery/theft	-1.1%	[-2.5% ,	0.3%]		0.3%	[-1.7% ,	2.3%]	
Nuisances	-12.8%	[-21.4% ,	-4.2%]	**	-15.7%	[-27.2% ,	-4.3%]	**
Illicit drugs	1.5%	[-1.3% ,	4.3%]		-0.3%	[-4.8% ,	4.2%]	
Vacant lot intervention B vs. No intervention								
Gun assaults	-6.7%	[-9.3% ,	-4.0%]	***	-11.6%	[-16.0% ,	-7.2%]	***
Nongun assaults	60.4%	[-23.8% ,	144.5%]		-6.0%	[-9.1% ,	-2.9%]	***
Burglary	-1.1%	[-3.1% ,	1.0%]		-8.1%	[-11.0% ,	-5.2%]	***
Robbery/theft	-0.9%	[-2.3% ,	0.5%]		-0.4%	[-2.5% ,	1.6%]	
Nuisances	-1.7%	[-9.4% ,	6.0%]		-8.6%	[-18.5% ,	1.3%]	
Illicit drugs	-4.1%	[-7.2% ,	-1.0%]	*	-4.5%	[-10.5% ,	1.4%]	

* p<=0.05, ** p<=0.01, *** p<0.001, 95% confidence intervals in brackets

Table 3. Intention-to-treat (ITT) analysis of vacant lot treatments and police-reported outcomes

	All neighborhoods				Neighborhoods below poverty line			
Vacant lot intervention A vs. No intervention								
Gun assaults	-5.8%	[-11.3% , -0.3%]	**		-17.4%	[-25.3% , -9.6%]	***	
Nongun assaults	94.4%	[-72.5% , 261.2%]			-8.4%	[-14.1% , -2.8%]	*	
Burglary	-13.7%	[-18.0% , -9.4%]	***		-14.6%	[-20.1% , -9.1%]	***	
Robbery/theft	-2.4%	[-5.4% , 0.5%]			0.6%	[-3.2% , 4.5%]		
Nuisances	-27.5%	[-46.3% , -8.7%]	*		-28.1%	[-49.5% , -6.7%]	*	
Illicit drugs	3.4%	[-2.8% , 9.5%]			-0.7%	[-9.2% , 7.9%]		
Vacant lot intervention B vs. No intervention								
Gun assaults	-27.1%	[-38.4% , -15.8%]	***		-63.5%	[-89.3% , -37.7%]	***	
Nongun assaults	180.9%	[-158.7% , 520.5%]			-33.3%	[-50.9% , -15.7%]	**	
Burglary	-4.1%	[-12.5% , 4.2%]			-43.5%	[-60.9% , -26.0%]	***	
Robbery/theft	-3.7%	[-9.4% , 2.0%]			-2.3%	[-13.2% , 8.7%]		
Nuisances	-3.4%	[-34.8% , 27.9%]			-40.2%	[-93.1% , 12.7%]		
Illicit drugs	-17.1%	[-30.1% , -4.1%]	**		-25.1%	[-57.8% , 7.6%]	*	

* p<=0.05, ** p<=0.01, *** p<0.001, 95% confidence intervals in brackets

Table 4. Contamination-adjusted intention-to-treat (CA-ITT) analysis of vacant lot treatments and police-reported outcomes

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Title: A citywide cluster randomized trial to restore blighted vacant land and its effects on violence, crime and fear

Supplementary Materials:

Materials and Methods

Trial design

A controlled, parallel-group, cluster randomized trial of standardized interventions for vacant lots of land was conducted citywide in Philadelphia. This trial was approved by the University of Pennsylvania Institutional Review Board and registered with the International Standard Randomised Controlled Trial Number (study ID ISRCTN92582209). All sections of this paper were written using the Consolidated Standards of Reporting Trials (CONSORT) statement for the reporting of cluster randomised trials.[1] Geographic information systems technology (ArcGIS 10, ESRI, Redland, California) was used throughout the trial to support cluster, lot, and participant selection and follow-up and spatial data calculations.

The trial used a random selection procedure followed by a stratified random assignment of eligible vacant lots into two land intervention arms and a no intervention arm matched within four city sections: north, south, west/southwest, and northwest. Intervention status was randomly assigned and matched within each of the four city sections to promote comparability between trial arms. Clearly delineated roadway and water boundaries were used to define these four geographically and demographically distinct city sections.

We also integrated a qualitative ethnographic component to the project. A team of ethnographers collected observational field notes on processes, fidelity and larger community context following a previously tested protocol of direct, real-time participant-observation for randomized controlled trials.[2] The ethnographic component allowed us to monitor the consistency of time-sensitive field procedure logistics as well as staff and subcontractor fidelity to study protocols. On an analytical level, the ethnography also qualitatively explored the particularities of micro-neighborhood characteristics, identified neighborhood typologies, including potentially unexpected or unwanted effects, and identified causal mechanisms for differential micro-neighborhood responses to the interventions.[3] The ethnography also generated qualitative hypotheses for further quantitative stratifications and analyses.[4]

Random sampling of clusters and participants

From among master lists of all vacant lots citywide available from city records in January 2011 (n=44,768), vacant lots that were authorized by municipal ordinance as "blighted" and eligible for the intervention (n=34,149) were randomly sampled for the trial. These authorized/eligible lots constituted 76.3% of lots citywide and were included if they specifically: (1) had existing violations signaling blight, including illegal dumping, abandoned cars, and/or unmanaged vegetation growth greater than a certain height; and (2) had been abandoned, as confirmed through contact with the owner of record who was given 10 days to reply and did not; or (3) had been authorized for the intervention by the owner of record (including the city itself for publicly owned lots) within the 10 day period. Excluded were lots that were not eligible because of insufficient blight or lack of authorization (n=4284), lots that were >5,500 square feet (n=3,755), and lots that were

existing private or commercial parking lots (n=2,580). The ethnographic team also accompanied field staff to provide added fidelity to our sampling protocol.

Clusters were then formed as randomly selected places chosen to represent the entire city.[5] All 34,149 eligible vacant lots were ordered based on the assignment of random numbers within the four city sections. Polygons representing each eligible vacant lot's parcel of land were assigned the longitude-latitude point of their centroids, or geometric centers. The first vacant lot in the randomly ordered list in each section was then chosen as an "index lot" and a ¼ mile radius buffer circle was generated around its centroid. All other eligible vacant lots within this radius were then used to form a cluster of vacant lots that summed to between 4,500-5,500 total square feet in area and were excluded from consideration as future index lots. Using satellite images and Google Street view photos, a group of eligible vacant lots that were as geographically close to one another as possible within each cluster was formed.

This process then cycled to the next randomly ordered index vacant lot on the list that was at least ¼ of a mile away from the edge of prior clusters until a total of 110 clusters were formed. These clusters contained 541 vacant lots that were ultimately enrolled into the trial. This process guaranteed that no clusters overlapped reducing later spillover and contamination effects across trial arms.

Randomly chosen cluster locations then served as the basis from which outcomes data were collected. The outer bounding polygon and its centroid were calculated for each grouping of vacant lots per cluster. This centroid represented the point location that was mathematically closest to all the study vacant lots in each cluster. The address of the closest building to this point location was then determined as the starting point for house-to-house random sampling and enrollment of survey participants.

At each starting address, a two-person survey team walked in a predetermined, randomly chosen direction and path on the city block of the address and then on randomly chosen, adjacent city blocks within the cluster until a total of 5 participants had been identified, consented, and interviewed. Only one participant per household was chosen; in households with multiple eligible participants, the individual with the most recent birthday was chosen. Both English and Spanish speaking individuals 19 years and older were administered the survey by the two-person team in the language of their choice. Only two Spanish language surveys were administered.

Households with individuals that refused to participate or did not qualify to participate in the survey were marked as such and surveyors moved on to the next closest household. Upon completion of a first in-person interview, participants were asked to then participate in 3 subsequent in-person interviews. The first two, pre-intervention interview waves were conducted in the 18 months from October 2011 to March 2013 and the last two post-intervention interviews were conducted in the 18 months from June 2013 to November 2014. Each participant was compensated $25 per interview and surveys took an average of 39.6 minutes to complete. Based on standard formulae, our survey response rate was 47.4%.[6] Our participant response rate matched or exceeded that of other surveys and was high enough to produce a reasonably representative sample of our target population.[7, 8, 9]

A total of 445 participants were interviewed during the pre-intervention period and 343 of these original participants were interviewed during the post-intervention period. This amounted to a 22.9% loss-to-follow up; 78.4% of these 102 lost participants moved and 21.6% refused to participate in subsequent waves. All 102 participants that were lost to

follow-up were replaced with additional randomly selected individuals living in their same cluster so that a total of 445 survey participants were ultimately analyzed.

We determined sample size taking into account anticipated intracluster correlation, participant response prevalence and number of events, effect size, and power. We calculated the minimally detectable effect size given 80% power for the participant-level outcomes and 4 time points based on the group-pre vs. post interaction test for any pairwise comparison among the randomly allocated groups of lots. The minimally detectable effect size was the smallest Cohen's effect size (group-pre vs. post interaction/standard deviation of outcome) that was significant with 80% power under the following assumptions[10]: within-participant correlation (ρ_y) for participant-level outcomes = 0.70; within-lot correlation (ρ_y) for participant-level outcomes = 0.20; within-lot correlation (ρ_x) for the -1,1 dummy variables for group & pre-post indicator variables = -0.33; and an α=0.05. Given these assumptions, we computed a minimally detectable effect size of 0.50 under a nested random effects model to account for the within-lot and within-participant correlations. This is a medium effect size based on Cohen.[11] From this, and predicting a 25% loss-to-follow up rate, we estimated that we would maintain >80% power if we randomly surveyed three people per cluster for 35 vacant lot clusters per trial arm, twice before and twice after the intervention.

Interventions and outcome measures

The purpose of this trial was to determine the effect of two vacant lot restoration interventions on violence and crime outcomes in the nearby areas of surrounding clusters as well as on perceptions of fear and safety outcomes among participants who lived in surrounding clusters.

Both interventions tested involves the "cleaning and greening" of vacant lots via standard, reproducible processes completed by well-coordinated teams of landscape contractors, many of whom came from local urban neighborhoods. The Pennsylvania Horticultural Society and the Philadelphia Office of Housing and Community Development designed and coordinated these interventions with cost-savings and rapid implementation in mind. Vacant lot intervention A involved removing trash and debris, grading the land, planting grass using an economical hydroseeding method that can quickly cover large areas of land by spraying a slurry mixture of seed and mulch, planting a small number of trees to create a park-like setting, and installing low wooden perimeter fences to show that the lot was cared for and to deter illegal dumping. Vacant lot intervention B involved removing trash and debris and mowing existing grass on the lot. Both interventions were performed by the Pennsylvania Horticultural Society and also included regular monthly maintenance of treated lots including grass cutting, tree pruning, fence repair, and trash cleanup. All vacant lot interventions occurred over a two-month springtime period, from April to May 2013, to maximize the probability of survival for newly planted vegetation. (Figure 1)

Both interventions were randomly assigned and applied at the cluster level. All vacant lots within a cluster received one of the two interventions, or no intervention as a control condition allowing us to test the effects of both interventions on the clusters. Because individual participants lived within the ¼ mile radius clusters, we were also able to test the effects of both interventions on them. At the end of the post-intervention period in

November 2014, the vacant lots that were not randomly assigned to either intervention during the trial were also scheduled for cleaning and greening.

Both area-wide outcome measures in and around each cluster, as well as participant-level outcome measures were collected and analyzed. Violence and crime data were collected from the Philadelphia Police Department and aggregated by month for 18 pre-intervention months and 18 post-intervention months, for a total of 36 observation periods. These data included the dates and address locations of six outcomes: gun assaults, nongun assaults, burglaries, robberies and thefts, narcotics possession, sales, and trafficking, and nuisances. Nuisances were defined as the summation of curfew violations, disorderly conduct, public drunkenness, illegal dumping, loitering, noise violations, prostitution, and vandalism. The address location of each violence and crime event was geographically assigned to a point-in-space and a kernel density estimate was used to calculate events per square mile for all outcomes at the centroid point of each vacant lot.[12,13,14]

Perceptions of violence, crime, nuisances, and fear for one's safety were surveyed from participants. The same questions were asked to all participants across all 4 waves of the survey. Participants were asked to focus their responses to their experiences within the past 30 days to avoid telescoping and over-estimation by participants. The following survey questions were analyzed for changes from the pre to the post-intervention period: (1) "Did you not go someplace in your neighborhood during the day because you felt you would not be safe?"; (2) "There is too much drug use in my neighborhood"; (3) "Vandalism is common in my neighborhood"; (4) "There is a lot of crime in my neighborhood"; (5) "My neighborhood is safe"; (6) "In my neighborhood, people watch out for each other"; (7) "People in my neighborhood take good care of their houses and apartments"; and (8) "I spent time hanging out, relaxing, or socializing on porches, stoops or front yards in my neighborhood". Similar survey items have been successfully used in prior studies.[15, 16]

Documentation of the changing conditions in all study vacant lots was also recorded in the pre- and post-intervention periods. Teams of individuals who were independent of the household interview teams took field video footage of study vacant lots and downloaded Google street view images of study vacant lots over time.[17, 18] These video and street view images were then graded using a 1-10 scale of orderliness with 1 being disorder and 10 being high order. This scale was averaged and then differenced between the pre and the post-intervention periods to grade each vacant lot in terms of whether it had: (1) deteriorated (a negative pre-post scale difference), (2) experienced minor improvement (a positive pre-post scale difference of up to 5), or (3) experienced a major improvement (a positive pre-post scale difference of 5 or greater); these three categories were separated using tertile breaks.

Random allocation and blinding of interventions

All 110 clusters were stratified within the four city sections and then assigned computer generated random numbers. The clusters within each city section were then randomly allocated to the first vacant lot intervention A (n=37 clusters), the second vacant lot intervention B (n=36 clusters), or the no intervention (n=37 clusters) arms of the trial using a repeat randomization procedure.[19] The repeat randomization procedure functioned under a predetermined protocol agreed upon by the study team that permitted repeated random allocation of the three study arms until statistically significant balance (at

$p<0.05$) was achieved in select confounding variables of importance to the study. These variables were: the total area, mean separating distance, and outer bounding polygon area of the of the study vacant lots in each cluster as well as the total vacant lots, resident population and number of serious crimes (Part I violent and property crimes) in each cluster.

Only the study PI had access to the randomization codes and the final random assignment of each cluster into one of the three trial arms. Randomization codes were securely filed in electronic format and inaccessible to maintain blinding of the other members of the study team, the field interviewers and staff, the contractors implementing of the different interventions, and the study participants. Contractors were given only the addresses of the vacant lots that were in each of the two intervention groups and instructed as to which intervention should be performed over the two-month intervention period. Field interviewers were only given street addresses from which to begin their household interviews with no mention of vacant lots in the surrounding neighborhoods. Study participants were told that they were responding to a survey about urban health and their local environments with no mention of specific vacant lots in their neighborhoods.

Statistical methods and analyses

The units of analysis for the violence and crime outcomes were a balanced panel of 541 vacant lots with monthly observations measured over 38 months. The units of analysis for the perceptions of violence, crime, and safety outcomes were a balanced panel of 445 survey participants with observations taken in 4 survey waves, during pre-and post-intervention periods, over 38 months. Baseline individual and cluster-level variables were also inspected for balance between the randomly allocated arms of the trial.

Intention-to-treat (ITT) analyses of vacant lots and survey participants were conducted according to the intervention group to which they had been randomly allocated. Some vacant lots that were randomly assigned to the intervention groups for improvement actually deteriorated and some that were assigned to the no intervention group naturally improved instead of deteriorating over the course of the study. Using the change in orderliness gradations that had been calculated for each vacant lot over time, contamination-adjusted intention-to-treat (CA-ITT) analyses were also completed in accounting for the level of improvement that had actually occurred in each lot, regardless of its random assignment. These CA-ITT analyses used two-stage instrumental variables regressions with random treatment assignment as the instrument (as it was orthogonal to the outcomes studied) and provided complementary information in terms of adjusting for treatment non-adherence and avoiding as treated and per protocol analytic biases.[20, 21, 22]

Pairwise comparisons were completed for all study outcomes between the two intervention groups and the no intervention group. These pairwise comparisons were tested for statistical significance (defined as $p<0.05$) using random effects, cross-sectional time series regressions that accounted for the cluster design of the study. Regressions accounted for the clusters and month fixed effects for police-reported outcomes and wave fixed effects for participant-reported outcomes. All statistical analyses were conducted using Stata 14.1 (College Station, Texas).

Difference-in-differences were calculated as interaction terms of 1-0 intervention-control differences multiplied by 0-1 pre-post differences. These difference-in-differences interaction terms were the primary independent variables of interest interpreted as the

true effect of the interventions on the various outcomes studied. In addition, using the previously fit regression models, marginal effects where the difference-in-differences beta coefficients = 1 and 0 were also estimated. These marginal effects were differenced to obtain absolute magnitudes of reduction for each outcome in the post-period. Absolute magnitudes of reduction were then divided by the total magnitude of occurrence for each outcome in the post-period to obtain percentage reductions. [23, 24, 25]

Additional subset analyses of all outcomes were also completed using the poverty level for Philadelphia in 2010. Pairwise statistical tests of the intervention conditions versus the no intervention condition were then completed within neighborhood subsets below the poverty level.

Displacement analyses were also completed for the crime outcomes. Crime events were counted within a 1/16th mile radius of each vacant lot and then between 1/16th and 1/8th mile distance from each vacant lot. Similar counts were obtained within a 1/8th mile radius of each vacant lot and then between 1/8th and 1/4th mile distance from each vacant lot. This permitted "donut hole versus donut" spillover tests of the effect that the interventions were having to be conducted at two different spatial scales.[26, 27, 28, 29]

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