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Does the Association Between Flows of People and Crime Differ Across Crime Types in Sweden?

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Abstract
Places with persistently high levels of crime, hot spots, are an important object of study. To some extent, the high levels of crime at such hot spots are likely to be related to flows of people. City center locations with large flows of people are quite often also hot spots, e.g., hot spots for pick pocketing at a central train station, or hot spots for assault in the nightlife district. This can be related to crime pattern theory, or to the routine activity perspective, which both suggest that flows of people can affect crime. The present study attempts to explore and quantify whether there are differences in the association between flows of people and crime for different crime types. The analysis considers locations with high crime counts for six crime types in the city of Malmö, Sweden. For each crime type, hot spots are identified and mapped, and in order to explore whether, or how, these are related to flows of people, the crime levels are then analyzed in relation to the number of people who boarded a local bus ($N = 33{,}134{,}198$) nearby. The paper shows that all six crime types are associated with flows of people, although less so for arson and vandalism. This is hypothesized to be due to the relatively constant target availability for these crimes as opposed to the other crime types studied.

Keywords Hot spot · Crime · Routine activity · Crime pattern · Ambient population · Public transport

Introduction

Some places experience a substantial amount of crime year after year, and these places are often labeled hot spots of crime (Sherman et al. 1989; Sherman 1995). A key finding in criminology over recent decades is that focusing police resources on such locations, hot spot policing, can lead to a significant reduction in crime (Sherman and Weisburd 1995; Braga et al. 2019). In order to improve the effectiveness of hot spot policing, attention has been directed at

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how hot spots should be understood, and what specific interventions might be effective for different types of hot spots. It has been argued that it is very important to have a theoretical basis for such analyses (Eck et al. 2005), and for the specific mechanisms that may be driving crime at a given location (Weisburd and Telep 2014).

One component in understanding hot spots is found in the flows of people present at the location in question. Places that many people pass by will tend to have higher crime counts than other locations.[1] City center locations with large flows of people are quite often also hot spots, e.g., hot spots for pick pocketing at nodes of public transportation (Ceccato et al. 2015), or hot spots for assault in the nightlife district (Scott and Dedel 2001; Pridemore and Grubesic 2013). This can be related to crime pattern theory, which states that nodes at which many people converge will be expected to have more crime (Brantingham and Brantingham 1995), and to the routine activity perspective, which states that crime may be produced by the convergence of potential offenders and suitable victims under conditions of a lack of guardianship (Cohen and Felson, 1979; Felson and Eckert 2017).

The associations between flows of people and hot spots of crime are likely to differ between crime types however, and in the present study, an attempt will be made to explore and quantify such differences. The analysis will consider locations with high densities of crime in the city of Malmö, Sweden, for the crimes of outdoor assault, outdoor personal robbery, theft from a car, bicycle theft, vandalism, and illegal fire setting (e.g., arson). For each crime type, hot spots will be identified and mapped, and in order to explore whether, or how, these are related to flows of people, the crime levels will then be analyzed in relation to the number of people who boarded a local bus ($N = 33{,}134{,}198$) nearby. The transport data are linked to geocoded locations, and while they constitute an imperfect measure of flows of people, the geographical quality of the data is high, allowing for micro-place analysis. The paper is expected to result in an understanding of the extent to which hot spots for the six crime types are related to nearby flows of people, as measured by bus journeys. Systematic differences between crime types for this type of association within a single city can improve our understanding of how flows of people differentially affect crime hot spots.

Crime Concentrations and Hot Spots

It is well established that locations with persistently high levels of crime, hot spots, exist, and more generally, that crime clusters to a small proportion of locations in a city (Weisburd 2015). That a hot spot should have *high levels of crime* at a *small location* is generally agreed upon, but there is some variation in how the concepts of high levels of crime and small location are operationalized. As noted by Eck et al. (2005), one key difference is whether a spot is defined based on addresses, blocks, or groups of blocks. Another difference is how a *high* level of crime is to be operationalized. Eck et al. (2005: 2) opt for a general definition, suggesting that a hot spot should be a place with above average crime or victimization. In practice, definitions of hot spots will tend to set a higher bar than "above average," however. Leaving definitions aside, some crimes exhibit higher concentrations than others. Sherman et al. (1989) noted that about 3% of places were responsible for 50% of crime, but also noted that there were differences across crime types. The fact that crime is strongly clustered to a few locations

[1] The risk for victimization after adjusting for the population at risk may be lower at such locations; however, something that has been shown with regard to violence in public spaces for the city studied here (Gerell 2018); Ceccato et al. (2013) noted similar findings for the Stockholm subway.

has prompted the formulation of a law of crime concentration, which states that a large proportion of crime will take place at a small proportion of places (Weisburd 2015). This has been confirmed in multiple studies (Bernasco and Stenbeek 2017; Haberman et al. 2017; Levin et al. 2017; Weisburd and Amram 2014; Gill et al. 2017).

While we know that hot spots of crime exist, there is still surprisingly little research on how hot spots can be understood, as noted by Weisburd (2015). Sherman (1995: 48) has argued that one challenge is to "identify the most important aspects of routine activity theory," but 24 years later, many questions remain unanswered. There is a large body of literature on how we can explain crime at specific places, and much of this is likely to be relevant to our understanding of hot spots, but it seems plausible to assume that locations with high volumes of crime—hot spots—may need slightly different explanations than crime locations more generally.

For the wider issue of why some places have more crime than others, most researchers within the field employ the routine activity perspective (Cohen and Felson 1979), rational choice (Cornish and Clarke 1987), or crime pattern theory (Brantingham and Brantingham 1995) as their point of departure. The routine activity perspective states that crime will occur at locations and times where motivated offenders come into contact with potential targets under conditions of low guardianship (Felson and Eckert 2017). Rational choice theory states that offenders will respond rationally to cues in their environment and weigh risk and rewards in deciding whether to commit a crime (Cornish and Clarke 1987). Crime pattern theory in turn suggests that crime will tend to take place at locations where people meet (nodes), along the routes between such nodes (paths), and in locations that lie between different types of environment in which more opportunities may arise and rule enforcement may be more difficult (edges). The theory also distinguishes between crime generators and crime attractors, where generators draw lots of people to a location to generate crime whereas attractors specifically draw offenders, who generate crime over and above the effect of the number of people (Brantingham and Brantingham 1995).

These three theoretical perspectives all include the idea that a key variable is the *situation* in which an offender interacts with a potential target or victim and that understanding when and where such situations arise is key to understanding crime. All three perspectives also more or less explicitly acknowledge that this is impacted by the level of social control in a given situation. If a capable guardian is present, a crime is much less likely to occur (Felson and Eckert 2017).

Recently it has been argued that opportunity-based theories such as routine activities, rational choice, and/or crime pattern theory can be combined with social disorganization theory to yield better explanatory power (Weisburd et al. 2014). In one example of the application of this approach, this argument was tested using the data employed in the present paper, where it was found that both collective efficacy (social disorganization theory) and the presence of restaurants or bars (routine activity perspective) could help explain why some bus stops experience higher levels of public violence (Gerell 2018). Another study that is consistent with such a combination of theories found that vandalism is associated with both neighborhood-level socioeconomic status and opportunity-related risk factors such as the proximity of playgrounds or schools (Newton and Bowers 2007). As has been noted, however, most studies consider associations between crime and other variables when considering which variables are associated with more crime, rather than focusing on hot spots per se.

When it comes to understanding hot spots, Eck et al. (2005) have argued that our understanding of these locations will differ depending on how we define the "spot," e.g., what type of geography we consider. While this is related to how a hot spot is defined, understanding why such locations are hot spots is a different issue. For specific places, place management is a key component. A hot spot bar is more likely to be characterized by a lax enforcement of rules than a non-hot spot bar. If we consider streets, however, it may be more a question of how offenders and targets congregate on some streets rather than others. For even larger "spots," such as neighborhoods, the focus turns to social disorganization and concentrations of youth and crime targets. To some extent, these types of hot spots, and their corresponding explanations, are likely to overlap. A hot place may well be located on a hot street in a hot neighborhood. This is not always the case, however, and as noted by Weisburd and colleagues (2012), most places have little to no crime even in high crime neighborhoods.

Sherman et al. (1989) highlighted the fact that crime hot spots tend to be related to concentrations of people. A high crime hotel was used as an example of a hot spot for crime that actually had a lower per capita risk for crime than the city as a whole. Another hot spot however, a bar, had a substantially higher per capita risk than the city as a whole when using an estimated "population" of the bar as the denominator. This is similar to the findings of Block and Block (1995) who noted that while some bars have very high levels of crime, the association between such bars and nightlife clusters was weak in Chicago. Hot spots for crime may thus be related to the number of people at a location in different ways. It is complicated. The present paper aims to add to the knowledge on this topic, since studies that focus explicitly on correlates associated with hot spots rather than on correlates of crime more generally are rare. We turn next to a discussion of how flows of people might be expected to impact on crime locations from a theoretical perspective.

Flows of People and Crime

The theoretical idea that concentrations of people may lead to concentrations of crime can be identified in several different theoretical perspectives, among them the above-mentioned crime pattern theory, routine activity perspective, and rational choice theory (Brantingham and Brantingham 1995; Cohen and Felson 1979; Cornish and Clarke 1987). This idea also features in other theoretical traditions, albeit less explicitly, for instance in social disorganization theory, where some versions include measures of population density in their statistical models (Bruinsma et al. 2013; Sampson and Groves 1989). A distinction can be made between activity generators, locations with lots of people but not much crime, and crime generators, activity generators with lots of crime. On average however, locations with lots of people tend to have lots of crime, although the risk for crime may be lower when calculated as the rate of crime in the population at risk (Newton 2018).

The association between concentrations of people and crime has also been empirically tested in a number of studies. Malleson and Andresen (2016) tested the association between theft and census data on residential and daytime populations in addition to twitter data and mobile telephone activity counts and found that all measures were significantly associated with crime. The best predictor turned out to be the daytime population, suggesting that theft is strongly clustered to locations with many visitors. The same authors also considered how high crime rates could be understood differently depending on the crime denominator. Places with high crime rates relative to the ambient population tended to have fewer restaurants or pubs, which might be considered possible crime generators using the terminology of Brantingham and Brantingham (1995). For crime to be high in spite of the lack of crime generators, there might be a presence of crime attractors, which specifically draw criminals to the area to commit crimes. Similarly, some areas had high crime rates in relation to both the residential population and the daytime population, and these tended to be areas that were mostly residential but where there were also entertainment facilities that could draw outside visitors to the location, possibly indicating both the presence of both crime generators and crime attractors (Malleson and Andresen 2016).

Felson and Boivin (2015) used a survey to measure journeys within a Canadian city and noted that the number of daily visitors was strongly associated with crime. Census variables on the population, the proportion of low-income households, and similar showed a much weaker association with crime. This appeared to partly be driven by the fact that the distributions of both crime and visitors were very skewed, whereas the census data variables were more evenly distributed across the city. Breaking the visitors down into different categories, the authors also noted that for three types of visitors the association with crime became weaker with a very high number of visitors. The fourth type, however, recreational visitors, was found to present both the strongest association with crime, and no diminishing returns with higher numbers of visitors (Felson & Boivin, 2015).

The association between flows of people and crime has also been presented specifically for public transport nodes, with several studies finding that such locations tend to have higher levels of crime (Weisburd et al. 2014; Ceccato and Uittenbogard 2014; Bernasco and Block 2011; Gerell, 2018). Ceccato et al. (2013), however, noted that while subway stations with many passengers did tend to have high levels of crime, they did not have higher levels of crime per capita when adjusting for the number of passengers passing the location. Similarly, Newton (2008) found that there were more crimes per bus passenger in neighborhoods with a higher population, more buildings, and higher population turnover. This is consistent with social disorganization theory (Sampson et al. 1997) which suggests that such neighborhoods may have a lower level of guardianship in the form of informal social control. This was also explicitly shown in a paper on outdoor violence around bus stops, which noted that bus stops in neighborhoods with low collective efficacy tended to have both more crime and more crime per bus passenger (Gerell 2018).

The fact that some locations have high crime but a low crime risk could possibly be explained by considering that more people results not only in more potential offenders and victims at a location but also more potential guardians (e.g., Cohen and Felson 1979). This is most obvious when considering low-volume times of day. In the middle of the night, most locations have zero people present. Some locations will have one person present. This person will then be able to commit a crime against property with no one able to intervene or witness the crime. If there are two people present, then one of them may act as a capable guardian, reducing the likelihood of a crime against property. With two people present, there is now a risk of a crime against the person, an assault, or a robbery, with no capable guardian. Locations with at least three people may have both a potential offender and a potential victim and also a potential guardian—if we consider them as independent actors. Locations where three people are present in the middle of the night independent of one another are very rare relatively speaking. We could thus hypothesize that the effect of more people on a location may differ depending on the crime type and that very high volumes of people may mean a more constant level of guardianship that has the potential to deter crimes (Felson & Boivin 2015). Expressed another way, one might suggest that inter-personal crimes would be highest at locations with a medium-high number of people present. Locations with few people have too few targets, and locations with a lot of people have too many potential guardians (Clarke et al. 1996).

If this is the case, it could potentially be shown by an increasing number of people having a decreasing impact on crime at locations that already have a high number of people present. The patterns and relationships are thus complicated, with potential variations across different types of places, different crime types, and for different types of people. The present paper will add to the literature by considering whether the association between flows of people and whether or not a location is a hot spot differs for different crime types, and/or for different degrees of *hotness*, measured as crime density at a location.

The guardianship factor is further complicated by the possibility that persons who are in their own neighborhood may be more likely to act as guardians than people who are in less familiar territory. Wickes et al. (2017), for instance, found that residents were more likely to engage in action when they have a higher density of social ties. While their study only considered residents, it would appear plausible that such an effect would extend to produce a lower likelihood to take action in neighborhoods in which an individual has no ties at all due to being a temporary visitor. The level of actual guardianship will also vary by many other characteristics of a location. Reynald (2011) has shown that actual guardianship at micro-locations varies with physical, spatial, demographic, and social factors. Actual guardianship was measured by observations recording whether it was possible to monitor the street, whether it was actually monitored, and whether someone intervened. A location further from the city center had more guardianship, while a location with more people having moved into the location had less guardianship. Importantly, there was also less guardianship at locations with greater flows of people, net of all the other variables included in the study (Reynald 2011). It should however be noted that the study only considered guardianship by occupants of the buildings, not that of passers-by. This suggests that the relationship between people and guardianship may be quite complicated and is likely to be non-linear. Locations with large flows of people should have a higher *potential* for guardianship from these flows, but the actual guardianship expressed among the people living at the location may be reduced. Furthermore, the addition of more people may have a very different effect at a location which already has lots of people as opposed to a location which has fewer people, an aspect of guardianship discussed as the business of a location by Newton (2018). On average however, it would appear likely that higher odds of a bystander being present at a location should yield a higher likelihood of there being a capable guardian, and the presence of more people should therefore on average result in higher levels of guardianship.

This theoretical reasoning is summarized in Fig. 1. We assume that large flows of people, as measured through the number of bus passengers, on average lead to more offenders for all crime types, more targets for crimes against the person such as violence or theft from a person, but less so with regard to targets for vandalism, and more capable guardians. This means that we can consider crime as a function of flows of people using a simple equation in which more people results in more potential crime through more offenders and targets (for some crime types), but in less potential crime as a result of more potential guardians.

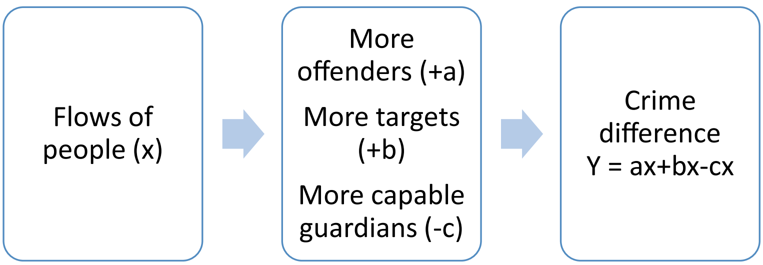

Fig. 1 Theoretical model of how flows of people impact on crime based on the routine activity perspective

In the present paper, we add to the literature by analyzing the association between high densities of bus passengers and high densities of crime. Bus passengers are expected to impact on crime—and on the presence (or not) of a hot spot—through the presence of more potential targets, more potential offenders, and more potential guardians. The paper will contribute both by improving the empirical knowledge on how hot spots (high crime density) can be understood and, on a more theoretical level, by improving our understanding of the complicated interactions generated by flows of people on potential offenders, targets, and guardians. This paper differs from other studies in that it explicitly studies hot spots of crime, rather than general associations with crime. In addition, the paper tests whether there are differences related to the hotness of the location. Are there different associations between flows of people and places with extremely high levels of crime as compared to places that merely have a very high level of crime?

Methods

Data

The present study only uses register data on bus trips and crimes, and in the initial descriptive analysis some demographic neighborhood data for the city of Malmö.

The crime data are derived from the police register of reported crimes in the city of Malmö in 2014 and relate to six crime types: assault in public environments, personal robbery in public environments, theft from a car, bicycle theft, vandalism against government property, and illegal fire setting (e.g., arson or vandalism through fire). The data were geocoded by the police but include some incidents with unknown locations or locations outside the municipality of Malmö, which were excluded.

The denominator data are drawn from data on local bus journeys between March 2014 and February 2015 ($N = 40{,}157{,}943$). A fairly large proportion of these bus trips lacked locational information, and in addition, bus stops with fewer than 10,000 passengers were excluded, resulting in a final sample of 33,134,626 bus journeys distributed across 586 bus stop locations. When aggregated to neighborhoods, the mean number of bus passengers is 243,636 (min = 0, max = 4,407,140, std dev 529,970).

The neighborhood level analysis also employs census population data from the municipality of Malmö for 2014. The city consists of 136 neighborhoods, 104 of which have at least 100 residents and were included (Table 1). The total population of these neighborhoods was 315,599.

Research Design

The basic idea behind the paper involves considering how flows of people impact on whether locations become crime hot spots for different types of crime. Theoretically we may expect that more people at a location would generate more potential offenders at the location, more potential targets at the location (for most crime types), but also more capable guardians at the location. Based on prior research, we expect the negative effects (more offenders and targets) to outweigh the positive effects (more guardians).

The analysis is performed by considering the micro-level association between crime density and bus passenger density. The point crime and bus passenger data were analyzed using kernel

Table 1 Descriptive statistics for 104 populated neighborhoods and bivariate correlations

Variable	*N*	Neighborhood census pop correlation	Neighborhood bus trip correlation	Proportion of pixels at least 2 std dev above mean
Robbery	547	0.59**	0.39**	0.036
Assault	1220	.63**	.43**	0.033
Bike theft	3355	.63**	.58**	0.037
Theft from a car	2398	.63**	.55**	0.057
Vandalism	1122	0.48**	.28*	0.046
Arson	515	0.41**	.15	0.041
Bus passengers	27.5 M	0.39**	1	0.023

*$p < 0.05$, **$p < 0.01$

density analysis to produce a raster of densities in the city for each of the six crime types and bus passengers. For the bus trip data, it is a reasonable assumption that a kernel density can yield a fair estimate of locations in which there are lots of people, since passengers need to go to and from bus stops, and this is unlikely to only yield activity at the precise location of the bus stop. For the crime data, this is a more dubious assumption, since crimes are bounded to precise locations. It has been shown, however, that crime data that are assigned addresses will tend to look more precise than they actually are, with a median error of 83 m having been noted for torched cars, for example (Gerell 2018). It would therefore appear reasonable to smooth out the crime data out using kernel densities to provide a general idea of where crime levels are elevated. KDE was chosen instead of Gettis-Ord-Gi* since there was a need to transform the data sets into raster data for comparisons, and since using standard deviations on the raster data produce a straightforward and easy-to-understand measure of high density crime locations. Using GI* would have added an additional layer of analysis on top of the already artificially generated raster, and since the KDE by definition generates locations with similar values near each other, using GI* could also have inflated what would constitute a hot spot definition.

For all seven data sets, the processing frame was set to the municipal boundaries, and the pixel size was set to 50 × 50 meters and the search radius 500 m. The resulting rasters were then converted to point layers and combined to create a table with density values for all six crime types and the bus journey data. The file was clipped at the municipal boundaries, reducing the number of pixels from 112,056 to 64,638. The densities were converted to z-scores by standardizing in terms of the number of standard deviations from mean. Associations between the density of bus trips and crime were then regressed linearly to check for general associations, with a dichotomized version of the crime data using standard deviations above the mean as a threshold to identify locations with high densities of crime to operationalize hot spots.

The paper employs three different operational definitions of hot spots. The *spot* is defined as the pixel, 50 × 50 meters, in all three definitions. Whether a location is *hot* is determined statistically by considering standard deviations above the mean crime density, which is similar to the method employed by Townsley and Pease (2002) to identify hot spots. The first definition specifies locations that are two standard deviations above the mean crime density as being *hot*. This is a measure that would correspond to about 2.5% of the locations in the data set if the data had been completely normally distributed (which they are not however, see Table 2). This roughly corresponds to the way in which hot spots are discussed in much of the

Table 2 Descriptive statistics for densities of the 64,638 pixels and bivariate associations

	Robbery	Assault	Bike theft	Theft from a car	Vandalism	Arson	Bus passengers	Min-max	Mean (standard deviation)
Robbery	1	0.88	0.77	0.68	0.52	0.49	0.51	0–193	3.8 (12.2)
Assault		1	0.76	0.70	0.52	0.53	0.62	0–341	8.5 (25.4)
Bike theft			1	0.75	0.43	0.34	0.60	0–872	22.1 (65.6)
Theft from a car				1	0.57	0.50	0.50	0–38	5.4 (7.4)
Vandalism					1	0.71	0.32	0–278	7.3 (18.8)
Arson						1	0.29	0–151	3.4 (9.9)
Bus passengers							1	0–15,600,000	203,626 (748,740)

literature on the law of crime concentration (Weisburd 2015). In the current context, however, this results in thousands of hot spot locations, and we therefore also test definitions of *hot* that correspond to three and four standard deviations above the mean in order to produce a more restrictive measure.

Results

In our first step, we present descriptive statistics for the six crime types and the bus passenger data. Before turning to the pixel data on densities, we consider the raw count data in relation to city neighborhoods. Table 1 presents the number of crimes, bus trips, and the neighborhood-level bivariate associations with census population data and bus trip data for the 104 neighborhoods with more than 100 residents. The final column specifies the proportion of pixels for each data set with crime densities over two standard deviations above the mean, our main definition of hot spots. The number of bus trips is lower in this sample, since 32 low-population neighborhoods have been excluded in order to generate population estimates.

The associations are stronger with census population size than with bus passengers for all crime types, but neighborhood-level crime is also significantly associated with bus trips for all crime types except arson. While neighborhood associations are not the main focus of this paper, this illustrates that even at such an aggregated level, there are significant associations between crime and bus passenger density.

Next, we turn to the pixel density data and consider bivariate correlations (Table 2). All seven density data sets are significantly associated with each other, which is unsurprising given that we have 64,368 units of analysis. The lowest correlation (0.29) is for the relationship between arson and bus trips, and the highest value (0.88) for robbery and assault. Arson and vandalism are closely related to each other (0.71) but are generally more weakly associated with the other four crime types (all other values below 0.54). The other four crime types are closely related, with no correlation being below 0.68. Bicycle theft, theft from cars, robbery, and assault thus tend to cluster in similar locations, and these locations also tend to be characterized by large numbers of bus passengers. Arson and vandalism cluster in similar locations to each other, but these locations are less similar to those in the other four crime types cluster, or to locations with high volumes of bus passengers. This is a pattern that is fairly similar to the neighborhood level patterns described above.

The bivariate associations between bus trips and the six crime types are shown in Fig. 2. As can be seen, the correlations with arson and vandalism are fairly weak, whereas those with the other four crime types are moderately strong.

Since the main topic of interest here is hot spots rather than linear correlations, the crime density variables were transformed into z-scores and dichotomized above and below 2, 3, or 4 standard deviations over the mean value. Our preferred operationalization for a hot spot is 2 standard deviations above the mean, but for robustness, we also test three and four standard deviations above the mean. The locations that are 2 standard deviations above the mean capture approximately the top 4% of locations in the city with the highest densities of crime for each crime type. This is slightly higher than the 2.5% that would be expected in normally distributed data. For the 3 (about 2%) and 4 (about 1%) standard deviation operationalizations, the differences as compared to a normal distribution are greater. Our data have longer tails than a normal distribution, which is probably due to the smoothing produced by the kernel density estimation.

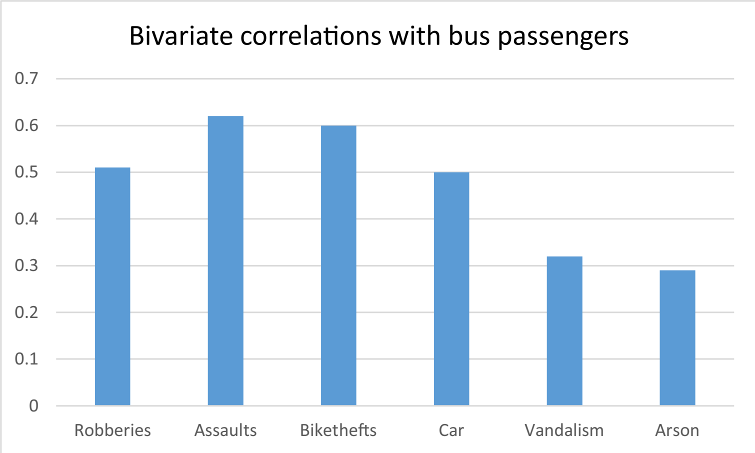

Fig. 2 Bivariate correlations of crime density with bus passenger density for six crime types

A logistic regression was then specified for the hot spot variable with the bus trip data as the independent variable. The results are shown in Fig. 3, with all crime types showing significant associations with bus trip density. A location with one standard deviation more bus passengers has between a 3.3 and 4.5 times greater chance of being a hotspot (at least two standard deviations above the mean) for robbery, assault, bike theft or theft from a car. This figure drops to a 1.6–2.7 times greater chance to be at least 3 standard deviations above the mean, and a 1.4–2.3 times greater chance to be at least 4 standard deviations above the mean. As noted

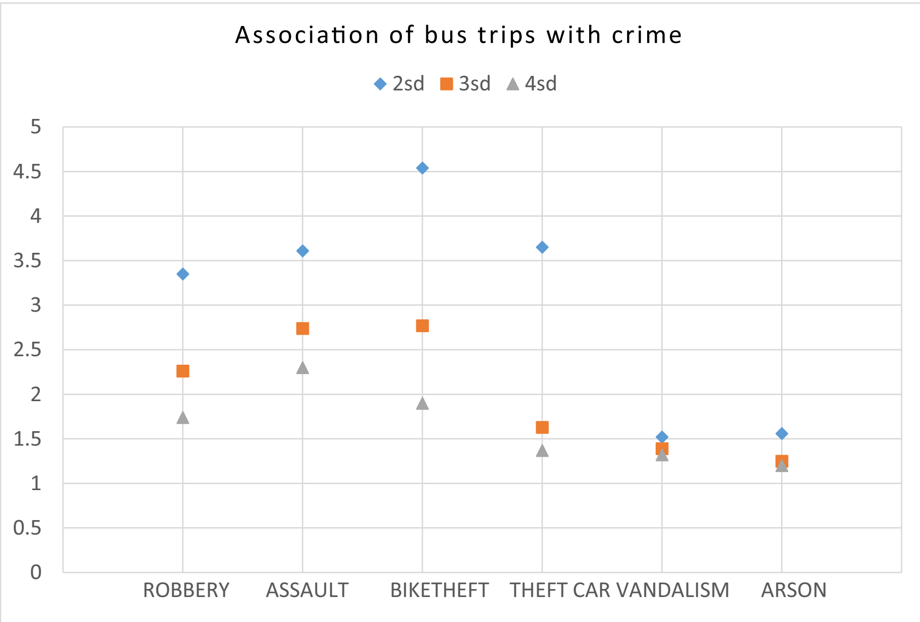

Fig. 3 Logistic regression analyses for three degrees of hot spot hotness and six crime types, expressed as odds ratios

above, this roughly translates into the top 4%, 2%, and 1% of crime density pixels in the city, with some crime type variation.

The odds ratios are lower for vandalism and arson, and for these crime types, there is also very little difference between the three tested operationalizations of hot spots. For arson, the odds ratios are between 1.2 and 1.6 and for vandalism between 1.3 and 1.5. How these findings might be interpreted are discussed further below and in the discussion section.

The analysis cannot tell us why the odds ratios decline at higher crime densities. It could be due to some locations having high numbers of bus passengers without the very high densities of crime needed to qualify as a hot spot under the more restrictive definitions employed. It might also be the case that the association between flows of people and crime is non-linear, which will be discussed further in the discussion section. To shed more light on this issue, we also examine the relative bus trip density for hot spots vs non hot spots. How much greater is the average passenger density at a hot spot compared to any other location in the city? For the 2 standard deviation hot spots, we find fairly large differences. The bus passenger density for hot spots is close to 3 standard deviations above the mean for robbery, assault, and bike theft (2.7, 2.9, 3.0), 1.9 for theft from a car, and 1.1 and 1.2, respectively, for vandalism and arson. Pixels that can be labeled hot spots for crime thus tend to have more bus passengers nearby than non-hot spots, although this is less so for vandalism and arson.

Tentative Test of the Theoretical Model

Thus far it has been shown that flows of people appear to be a fairly important predictor of whether or not a specific location is a hot spot, but also that this differs between crime types. Based on this analysis, we cannot say how much of this effect is attributable to different aspects of more people being at a location. It is likely that the presence of both more potential offenders and more potential targets contribute significantly to this effect, whereas the effect of more guardianship is less certain but should theoretically be negative (i.e., reducing crime). For assault, robbery, bicycle theft, and theft from a car, it appears that the crime difference associated with large flows of people is rather substantial, suggesting that the presence of more offenders and more targets has a far greater impact than that of more capable guardians.

The pattern is somewhat different for vandalism and arson. While these crimes are also significantly associated with bus passenger density, the associations are much weaker. One potential explanation for this discrepancy could be linked to the target of the crime. As argued above, there will tend to be more targets for violence and theft at locations where there are lots of people. Targets for vandalism, and to a lesser degree arson, could be anything, and these are arguably more evenly distributed throughout the urban environment. Buildings, cars, park benches, bus shelters, and garbage containers are all typical targets of vandalism and/or arson (Blomquist and Johansson 2008) and can be found all over a city. While the availability of targets for vandalism is not random, it is more dispersed than the target availability of many other crime types. This means we can hypothesize that the theoretical model presented in the introduction (Fig. 1) would be similar for all crime types, but with the impact of flows of people on increased target availability closer to zero for vandalism. If we assume that this is true, we could consider the bus passenger effect size on arson and vandalism as an effect of there being more offenders at the location following adjustment for the increased guardianship ($y = a + 0*b\text{-}c$ or $y = a\text{-}c$). A location with more people will have more offenders and more capable guardians, but on average, the negative effect of offenders has a greater impact than

Table 3 Extrapolation of the relative importance of more targets at locations with many bus passengers for explaining hot spots for four crime types

Crime type	Proportion attributable to potential targets (b) (using arson)	Proportion attributable to potential targets (b) (using vandalism)
Robbery	76%	78%
Assault	78%	80%
Bicycle theft	84%	85%
Theft from a car	79%	80%

the positive effect of increased guardianship, so that a location with (1 std dev density) more people will have a 52% greater chance of being a hot spot for arson or vandalism.

For crimes where target availability varies more with the bus passenger data, we cannot solve the equation without extrapolation, but if we assume that the above identified effect from the presence of more people on offenders and guardianship in relation to vandalism also holds true for the other crime types, we can estimate the relative impact of more targets for each of our crimes. We thus assume that the value for offenders (a) minus guardianship (c) is the same across the crime types, which allows us to calculate the relative importance of target availability for the four crime types where we expect this to be an important factor (robbery, assault, bicycle theft, theft from a car). This is an exercise that needs to be interpreted with great caution, as it rests on major assumptions that are likely to be wrong. In reality, the types of offenders and guardianship that are of importance are likely to differ across crime types. As a theoretical exercise, it might nonetheless be useful to consider what the relative importance of potential targets may be for these four crime types.[2] As Table 3 shows, these numbers appear to be fairly consistently placed around 80%. This is clearly an oversimplification and is likely to be wrong, but it is nevertheless an interesting though experiment that allows us to start considering how we might understand the impact of different theoretical factors on the emergence of hot spots of crime.

Discussion and Conclusion

The present paper has examined the association between places with high densities of bus passengers and places with high densities of crime for six different crime types. Locations with high levels of crime also tend to have high levels of bus passengers, a finding that is unsurprising given opportunity theories (Felson and Cohen 1979; Cornish and Clarke 1987). The association is particularly strong for the crimes of violence and theft included in the study, which again is unsurprising. At a location with lots of bus passengers, there will tend to be more bicycles that could be stolen, cars that could be broken into, or people who could be assaulted. These locations will also tend to be better known to offenders (Brantingham and

[2] The difference equals the odds ratio minus 1, which is to be inserted as a solution for the equations. For example, calculating (a-c) from the vandalism equation ($y2$) and using it in the equation for robberies (y1) yields:

($y1$) $2.35 = a + b - c$

($y2$) $0.52 = a - c$

($y1$) $2.35 = 0.52 + b$

($y1$) $b = 1.83$

And the proportion of the effect size attributable to b is thus 1.83/2.35 = 77.9%.

Brantingham 2011) and are likely to have more offenders present at any given point in time. More potential offenders and more potential targets equal more crime. While these locations will also tend to have more capable guardians—bystanders who could intervene against crime, or at least witness it—it appears as though the increase in offenders and targets is of greater importance than the increase in capable guardianship that can be hypothesized to come with more people. The effect sizes are fairly large. An increase of one standard deviation in bus passenger density, which in plain language means going from a location with an average amount of people to a location with quite a large number of people, produces at least a threefold increase in the odds of that location being in the top 5% of high-density crime locations for the public violence and theft crimes studied.

The two other crime types examined, vandalism and arson, are more weakly associated with bus passenger density. The odds of a location being a hot spot only increase by about 50% with a one standard deviation increase in bus passenger density. While this is still a fairly large and significant association, it is nevertheless interesting to note that it is far weaker than for the four above mentioned crime types. In the present paper, it is suggested that this may be due to the fact that potential targets for vandalism and arson could include almost anything and that such potential targets are thus fairly evenly distributed throughout the urban environment. This distinguishes these offense types from the other four types of crime, which will tend to exhibit heavy clustering to locations with a large number of people.

While this is a theoretical hypothesis rather than an empirical observation, we developed a hypothetical example of how these differences might be used to shed some light on the relative impact of potential targets in relation to potential offenders and guardians in understanding crime. By assuming that (a) targets for vandalism/arson are constant across space and that (b) the association between bus passengers and potential offenders and guardians is constant across crime types, we calculated what the relative importance of more targets at a location with many bus passengers would mean for crime. In this theoretical extrapolation, we noted that the presence of more targets appears to be of major importance, but this is a purely theoretical exercise intended to underline the need for a better understanding of the situational mechanisms that generate crime. Prior work has shown that the risk for robbery on subway platforms declines in a linear fashion with an increase in the number of people present, which suggests a much greater importance for guardianship (Clarke et al. 1996). In addition, flows of people may well have other non-linear properties, as they may lead to increased anonymity and thus to a reduction in the mean levels of guardianship expressed by potential guardians (Reynald 2011). Guardianship may also function very differently depending on how many people are present at a location, its business (Newton 2018). One should therefore be careful in interpreting the high level of importance ascribed to targets in the thought experiment presented in the present study, and more studies are needed to ascertain the relative importance of the routine activity concepts.

As was noted in the introduction, several studies have considered the association between flows of people and crime. The present study considers the association between flows of people and locations with very high levels of crime, hot spots. This is a slightly different question, which warrants some examination. While the findings presented in this paper are highly exploratory, one finding is that the association between flows of people and crime is weaker for the places with the highest crime densities.[3] Potentially, then, the relationship is not

[3] Figure 3 only showed 2, 3, and 4 standard deviation pixels. The odds ratios for 1 standard deviation pixels are 6.1 (robberies), 5.96 (assaults), 7.78 (bike thefts), 28.95 (theft from a car), 2.27 (vandalism), and 2.03 (arson).

linear, and once a certain threshold is reached, adding more people to a location has a smaller impact on crime. This is very similar to the findings of Felson and Boivon (2015) who noted that for three of the four types of visitors, they studied that there was a negative quadratic effect, implying diminishing returns at some point. One potential interpretation is that locations that have very high numbers of visitors consistently throughout the day tend to have some potential for capable guardianship, whereas lower volume locations will be without potential guardians at times when fewer people are around. The times at which this occurs may well differ across crime types, and it has previously been shown that peak crime times can vary across hot spots (Townsley, 2008).

Future studies should further consider how the concepts surrounding opportunity theories are impacted by flows of people and, more generally, how we can assess the relative contribution of each theoretical component. The present paper adds a little piece of the puzzle to the research literature by showing that while all of the crime types studied are associated with flows of people as measured by bus passengers, the association is much weaker for arson and vandalism than for the other crimes. This is hypothesized to be due, at least partly, to the fact that suitable targets for arson and vandalism are much less reliant on the presence of large numbers of people. The convergence in time and space of a motivated offender and a location lacking guardianship becomes key to understanding such crimes, and this will happen both in locations frequented by many bus passengers (at times when they are not around) and in locations that few bus passengers pass. Future studies would do well to isolate these impacts in a more robust manner, which might actually generate insights into the relative importance of potential offenders, targets, and guardians on the criminogenic nature of a situation. A better theoretical understanding of such mechanisms could generate better possibilities for prevention, thus reducing harm (Eck et al. 2005).

The present paper has focused on locations with very high densities of crime, which are typically labeled hot spots of crime. As argued, there may be some differences in how these locations function by comparison with the more general associations between spatial characteristics and crime. Theoretically, this too could be due to guardianship interactions, with the chances of a guardian being present being higher at locations with very large flows of people. As noted in the previous paragraph, more robust studies on these interactions and patterns would be helpful both theoretically and practically, as a means of better understanding and dealing with high crime locations.

The analysis could be further improved upon by considering temporal factors. Crimes are not evenly distributed across the day, and public violence, for instance, tends to occur disproportionately at night, when there are on average far fewer bus passengers. By considering how flows of people change across the day, more insights could be obtained into the relationships between capable guardians, potential offenders, and suitable victims.

The present study has several limitations. One obvious limitation is that the bus passenger data constitute an imperfect measure of flows of people. While they will broadly tend to capture locations characterized by large flows of people, some locations will have large flows of people despite not having a bus stop nearby. In addition, it may well be that the association between flows of people and crime is partly confounded by risky facilities that attract people but generate crime as a result of other aspects of these facilities, with crime then radiating out from the risky facility (Bowers 2014). Means of public transport can be seen as crime generators that are at the same time spatially associated with other potential crime attractors (Bernasco & Block 2011). Both the flow of people generated by the bus stop and nearby facilities can have independent effects on crime, and the present study only considers the effect from the people generated by the public transport system. A further limitation is that the present study used densities to compare crime with bus passengers, and while densities are easy to work with, they may hide local differences that are of theoretical importance.

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