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The Homicide Drop in Recife, Brazil: A Study of Crime Concentrations and Spatial Patterns

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Abstract

Studies in crime concentrations have focused primarily on North America with a rather restrictive set of crime types. In this article, we analyze the crime concentrations and spatial patterns of homicide in Recife, Brazil. Brazil's homicide rates have remained stable but at high levels, approximately 30 homicides per 100,000. Some places have experienced notable decreases in homicide: In Recife, the capital of Pernambuco, there has been a drop in the homicide rate of 46.67%, 2000 to 2012. We analyzed the decline of homicides finding that it continues to be highly concentrated, but the decrease has not been uniform.

Keywords

homicides, crime concentrations, spatial point pattern test, Pact for Life Program

Introduction

In Brazil, between 1980 and 2010, more than one million people were murdered (Waiselfisz, 2012). According to Julio Jacobo Waiselfisz, a researcher in Brazil, the situation in this country can be considered an epidemic because its rate is greater than 10 homicides per 100,000 inhabitants, a threshold set by the World Health Organization (United Nations Development Programme [UNDP], 2013). Brazil has a higher homicide rate than the most-populous countries in the world such as China, India, the

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United States, Indonesia, Pakistan, Nigeria, Bangladesh, Russia, Japan, and Mexico (Waiselfisz, 2014a), and is more similar to countries like South Africa with its levels of violence (Breetzke, 2010).

Although Brazil had made many efforts to reduce crime in recent years, the number of homicides is increasing. In 2002, the country had a homicide rate of 28.5 per 100,000 inhabitants, with a small decrease to 25.2 per 100,000 inhabitants in 2007. After 2007, Brazil had an increase in its homicide rate, reaching 29 homicides per 100,000 inhabitants in 2012 (Waiselfisz, 2014b). Such a trend at the national level is counter to the international crime drop that began in the 1990s for most crime types and most countries that have been investigated (Farrell, Tilley, & Tseloni, 2015; Farrell, Tseloni, Mailley, & Tilley, 2011; LaFree, 1999; Ouimet, 2002; Tseloni, Mailley, Farrell, & Tilley, 2010; van Dijk, Tseloni, & Farrell, 2012).

The growth of these homicides is not a trend for all states. Some states have been highlighted by the reduction in homicides, such as Pernambuco, São Paulo, and Rio de Janeiro. In 2000, Pernambuco was considered the most violent state in Brazil, with 54 homicides per 100,000 inhabitants (Waiselfisz, 2012). According to the Secretariat for Social Defense of Pernambuco (SSD; 2014), this homicide rate dropped to less than 32 homicides per 100,000 inhabitants in 2013. This is a large magnitude drop (approximately 40%) but is counter to much of the international crime drop literature that has found decreases in crime rates at both the national and subnational levels, indicating that similar processes are operating at different scales of analysis (Farrell et al., 2011; Farrell et al., 2015; Ouimet, 2002). Clearly, Brazil and its states are different, and understanding local conditions (local and micro places) may prove to be important for understanding the decrease in homicides within Pernambuco and Recife, specifically. Such an understanding could prove to be instructive for not only Brazil but also the international community in general because of the implications for reducing violent crime.

Theoretical Background

Some of the research over the past 25 years within spatial criminology has shown that crime is highly concentrated in a small number of places (Curman, Andresen, & Brantingham, 2015; Sherman, Gartin, & Buerger, 1989; Weisburd & Amram, 2014). These places are referred to as micro-spatial units of analysis, such as street segments and intersections or actual addresses. This relatively small literature has been able to replicate this finding in a number of cities across the United States, Canada, and Israel. Because of the consistency of these results, David Weisburd, Groff, and Yang (2012) have put forth the "law of crime concentration at places" and recognize the presence of chronic street segments in parallel with the long-known fact that a few chronic offenders commit the vast majority of crimes (Wolfgang, Figlio, & Sellin, 1972), along the lines of the Pareto principle.

The first study to emerge in this literature considering an entire city was that of Sherman and colleagues (1989) investigating robbery, motor vehicle theft, and rape in Minneapolis, Minnesota. These researchers found that 3% of street segments in Minneapolis accounted for 50% of these crimes: 2.2% for robbery, 2.7% for motor vehicle thefts, and 1.2% for

rape. In a similar study on Seattle, Washington, Weisburd, Bushway, Lum, and Yang (2004) found that 5% of Seattle's street segments accounted for 50% of police calls for service over a 14-year period. Weisburd and colleagues (2012) replicated this over a 16-year period as well as in the context of juvenile offending (Weisburd, Morris, & Groff, 2009). Also in the United States, Braga, Hureau, and Papachristos (2010, 2011) found similar percentages in the contexts of gun violence and commercial street robberies in Boston, Massachusetts.

In a Canadian context, Andresen and Malleson (2011) and Andresen and Linning (2012) found similar results for Vancouver, British Columbia, and Ottawa, Ontario, respectively. Specifically, analyzing assault, burglary, robbery, sexual assault, theft, theft of vehicle, and theft from vehicle in Vancouver, Andresen and Malleson (2011) found that 50% of the police calls for service for these crimes were accounted for with 1% to 6% of street segments, most often less than 3% of street segments. In Ottawa, analyzing burglary (commercial and residential), robbery (commercial, individual, and other), and theft of vehicle, Andresen and Linning (2012) found that 50% of these crimes occurred in less than 1.7% of street segments. And most recently, Weisburd and Amram (2014) found that 4.5% of street segments accounted for all criminal incidents in Tel Aviv-Jaffa, Israel.

Within this crime at places literature, there are two studies that have investigated the patterns of crime decreases: Weisburd and colleagues (2004) and Curman and colleagues (2015), in Seattle, Washington, and Vancouver, British Columbia, respectively—Weisburd and colleagues have also undertaken some extensions of this work, and Braga et al. (2010, 2011) have used another method (growth curve analysis) with similar results. Both of these studies reported a decrease in crime at the level of the city (24% and 40%, respectively). Most interesting is that even though the overall crime patterns at places were stable over time, the crime drops in each of these cities could be explained only considering a small percentage of street segments. In Vancouver, all street segments were stable or decreasing over time, but in Seattle, some street segments were increasing in their levels of crime.

The crime and place literature has generated a number of interesting facts regarding the spatial concentrations of crime and the stability of those concentrations. There have also been a number of interesting theoretical and practical applications of this work. For example, researchers have argued that we need to consider the micro place when understanding theory. In the context of routine activity theory, motivated offenders and suitable targets converge in time and space (with the lack of a capable guardian) for a criminal event to occur (Cohen & Felson, 1979). This convergence occurs at a discrete location. Knowing why the convergence occurred at one street segment and not the one next to it could prove to be of theoretical importance (Andresen & Malleson, 2011; Groff, Weisburd, & Yang, 2010). Weisburd et al. (2012) have undertaken some interesting analyses in the context of social disorganization theory, finding significant variability of social disorganization theory variables within larger geographic units. And in the context of practical applications, crime prevention, Sherman et al. (1989) noted how it is easier to change the routine activities of places than people. Of course, these researchers were speaking of how people used these places for their routine activities, but this highlights the importance of understanding the places at which crime concentrations occur.

Although instructive for theoretical and crime prevention considerations, one crime type that is missing from these analyses is homicide. Homicide may be included in the "all crime types," but most often, there are not enough homicides for an analysis of their spatial patterns and concentrations. Brazil has a high volume of homicides, with many cities having such a large volume of homicides that their patterns can be studied in hopes of preventing local homicides as well as obtaining a better understanding of this phenomenon to prevent homicides in other areas around the world.

In this study, we investigate crime concentrations and spatial homicide patterns in a Brazilian city, Recife, Pernambuco. Recife has a high homicide rate, even in the context of Brazil. It has also seen a reduction in homicide in recent years, consistent with the international crime drop and the general homicide decrease in Pernambuco. Stemming from this, we have the following two research questions:

Research Question 1: Do homicides in Recife follow the law of crime concentration at places?
Research Question 2: If present, are these spatial concentrations stable over time?

With regard to the first research question, our hypothesis is that homicides in Recife follow the law of crime concentration at places. With regard to the second research question, our hypothesis is that the spatial patterns of homicide are relatively stable over time. Through this analysis, we contribute to the literature on crime and place and homicide in a number of ways. First, we investigate crime concentrations outside of the most common North American and Western European perspectives. Previous research is of great value, but undertaking this research in a more international context proves instructive for the generalizability of the crime and place literature. In the context of homicide, we are able to analyze a large volume of these events that is not possible within most North American and Western European contexts. And because of the nature of the analysis, we are able to speak of the possibilities for the prevention of homicide, benefiting both the Brazilian and the international community.

Data and Method

Recife is located in the state of Pernambuco, Brazil. In 2010, Recife had 1,537,704 inhabitants, with an estimated 1,608,488 inhabitants in 2014, according to the Brazilian Institute of Geography and Statistics (BIGS; 2013, 2014). The gross domestic product (GDP) of Recife was R$33.15 billion in 2011 (approximately US$12.5 billion), ranking the 10th position among the 26 capitals of Brazil and the 15th position among the 5,565 Brazilian municipalities.

Crime Data

The homicide data used in this study come from the SSD. The data contain the date of the occurrence, the time of day (morning, afternoon, evening, or dawn), and the geographic coordinates of the crime. Homicides that occurred between 2009 and 2013 are

included in the data. These years are used because 2009 is the first complete year with the registration of geographic coordinates (it began in June 2008), and 2013 is the most recent complete year when data were requested. The City of Recife had 808, 665, 675, 568, and 442 murders, respectively, for the years 2009 to 2013.

Data from the SSD are reliable and considered more accurate than the data reported by the health system (Sauret, 2012). The data collection in Pernambuco went through significant improvements, considering new procedures and incorporating more technology into this process. Since 2008, for example, all homicides were recorded with a global positioning system (GPS).

Homicide data were provided by SSD with geographical coordinates, so a geocoding process was not necessary. Consequently, we did not have to address the problems typically related to geocoding, such as errors in typing addresses or problems with the database (consideration of new streets). Therefore, the geographical coordinates given by SSD were directly mapped.

In rare cases, the geographical coordinates of homicides are not available. In 2009, two events presented this problem, two in 2011, three in 2012, and three in 2013. Thus, there are 10 occurrences without geographic coordinates between 2009 and 2013, representing 0.137% of the 3,158 homicides in Recife. With more than 99% of our data being properly georeferenced, we proceeded with our analyses without any significant concerns with spatial bias—our data are georeferenced with a hit rate percentage much greater than 85%, set by Ratcliffe (2004).

Spatial Unit of Analysis

Two spatial units were used to analyze the heterogeneity of homicides in Recife: census tracts and street segments. Census tracts are basic territorial units of the demographic census, defined by BIGS. Street segments were obtained from Recife's street network, creating areas with Thiessen polygons. Street segments were converted into Thiessen polygons because of the highly specific nature of the GPS coordinates; less than half of the homicides in Recife actually occurred on the street—they occur within a residence or in a parking lot, for example. The creation of Thiessen polygons was the simplest method of assigning each homicide to its nearest street segment. In Recife, there are 1,854 census tracts and 31,777 street segments (Thiessen polygons). Both spatial units were applied to test the sensitivity of the results to the modifiable areal unit problem (MAUP; Fotheringham & Wong, 1991; Openshaw, 1984).

Empirical Methods

The methods necessary for answering our first research question are simple and straightforward. Similar to the crime and place literature, we calculate the percentage of census tracts and street segments with any homicides that account for 50% of homicides. In the crime and place literature, the percentage of street segments that account for 50% of a crime type is often reported (Weisburd et al., 2004), but because of the high degree of spatial concentration in homicide data, we omit this particular statistic.

To answer our second research question regarding the stability of the spatial patterns of homicide in Recife, an analytical technique that can identify statistically significant spatial change is necessary. The spatial point pattern test developed by Andresen (2009) has the ability to identify the degree of similarity between two data sets (Andresen, 2010; Andresen & Malleson, 2014; Tompson, Johnson, Ashby, Perkins, & Edwards, 2015). In this context, the use of this spatial point pattern test is appropriate to assess our second research question because it will verify whether there has been a homogeneous homicide reduction in the city, whether homicide reductions only occurred in particular places, or whether there was crime displacement to other, potentially more vulnerable (socially disorganized), areas. The spatial point pattern test can be summarized as follows. The first step is to identify one point-based data set as the base (2009 homicides, for example) and calculate the percentage of points within each spatial unit under analysis (census tracts, for example). Second, the other point-based data set is deemed the test data (2010 homicides, for example), and randomly sampled (with replacement) 85% of the test data are used to calculate the percentage of points within each spatial unit under analysis—85% is based on the research by Ratcliffe (2004). Third, repeat this sampling process 200 times.[1] Fourth, generate a 95% nonparametric confidence interval. This is obtained by calculating 200 percentages of points within each spatial unit of analysis from Step 3. Then, for each spatial unit of analysis, rank these percentages and remove the top and bottom 2.5%. Fifth, if the value within a spatial unit of analysis for the base data set (2009 homicides, for example) falls within the confidence interval, that spatial unit of analysis is deemed similar. Sixth, repeat Step 5 for all spatial units of analysis. Further details are available in Andresen (2009) and Andresen and Malleson (2011).

Finally, the degree of similarity between the data sets can be obtained through the similarity index *S*. The similarity index ranges between 0 (no similarity) and 1 (perfect similarity) and can be calculated by

$$S = \frac{\sum_{i=1}^{n} s_i}{n},$$

where s_i is equal to 1 if the pattern of two data sets are similar and 0 otherwise (this similarity is defined by Step 5 described above), and n is the number of areas. The similarity index, therefore, shows the percentage of areas that have a similar pattern. In the literature that has used this spatial point pattern test, a rule of thumb has emerged to indicate similarity, but not in a dichotomous manner. This is based on the literature investigating multicollinearity in a regression context. O'Brien (2007) stated that a variance inflation factor (VIF) indicates problematic multicollinearity when the VIF ranges from 5 to 10, or greater. In a bivariate context, a correlation that ranges from .80 to .90 would be considered potentially problematic for VIFs of this magnitude. Therefore, an *S*-index value of .80 is used to indicate that two spatial point patterns are similar. It is also important to highlight that the results of spatial point pattern test can be mapped using the s_i for each area, revealing where the differences are between the data sets (Andresen, 2009). Because of the large volume of census tracts and street

segments, the output maps from our tests were difficult to interpret when viewing the entire city of Recife. As such, these maps are available to the interested reader. A graphical user interface (GUI) was developed for the application of the spatial point pattern test that is freely available at the following website: http://code.google.com/p/spatialtest/. We used this GUI for performing all of these tests, discussed below.

Results

Homicide Trends in Recife, Brazil

In 2000, Recife had a homicide rate of 97.5 per 100,000 inhabitants and was considered the most dangerous capital of Brazil (Waiselfisz, 2012). In 2012, this rate dropped to 52 homicides per 100,000 inhabitants (Waiselfisz, 2014b). Figure 1a shows the volume of homicides in Recife between the months of January 2008 to August 2014. This figure clearly shows the declining trend in homicides, although there is seasonality. Figure 1b shows the homicide trends in Brazil, Pernambuco, and Metro Recife between 2000 and 2012. In this period, while the homicide rate in Brazil increased by 8.61%, in Pernambuco and Recife this rate fell by 31.3% and 46.67%, respectively. Despite this large magnitude drop in the homicide rate, the situation of Recife and Pernambuco is still dangerous.

Descriptive Statistics

Considering the span of 5 years (2009-2013), the city of Recife had 3,158 homicides occur within its 1,855 census tracts. Table 1 shows that the number of occurrences in Recife is decreasing, with the number of homicides in 2013 almost being one half of the number of homicides in 2009. Accordingly, the mean number of homicides in 2009 was 0.43 occurrences per census tract, which dropped to 0.24 in 2013.

One curious statistic to note is that the maximum value between 2009 and 2012 is related to the same census tract. This census tract is located beside the largest penitentiary of the State of Pernambuco. This is the census tract with most homicide occurrences in Recife from 2009 to 2013, only two homicides were recorded in 2013.

The second most dangerous census tract, with total of 22 homicides over the study period, is also in an area near a prison. In this case, homicides reduced from seven in 2009 to four in 2013. There are two census tracts with 20 homicides recorded over the 5 years. One of them is located at the central region of Recife, in an area of popular commercial activity, also known for prostitution, drugs, and low income. The other census tract is a residential area, marked by a lack of infrastructure and low income. In the first census tract, no homicides were registered in 2013, and in the second census tract, only one homicide occurred in 2013.

Analyzing the areas with the greatest volume of homicides between 2009 and 2013, we can suggest that change has occurred. Those areas had a disproportionate number of homicides relative to other areas in the city in 2009, but these numbers were disproportionately reduced by 2013, consistent with the crime and place literature. Beyond

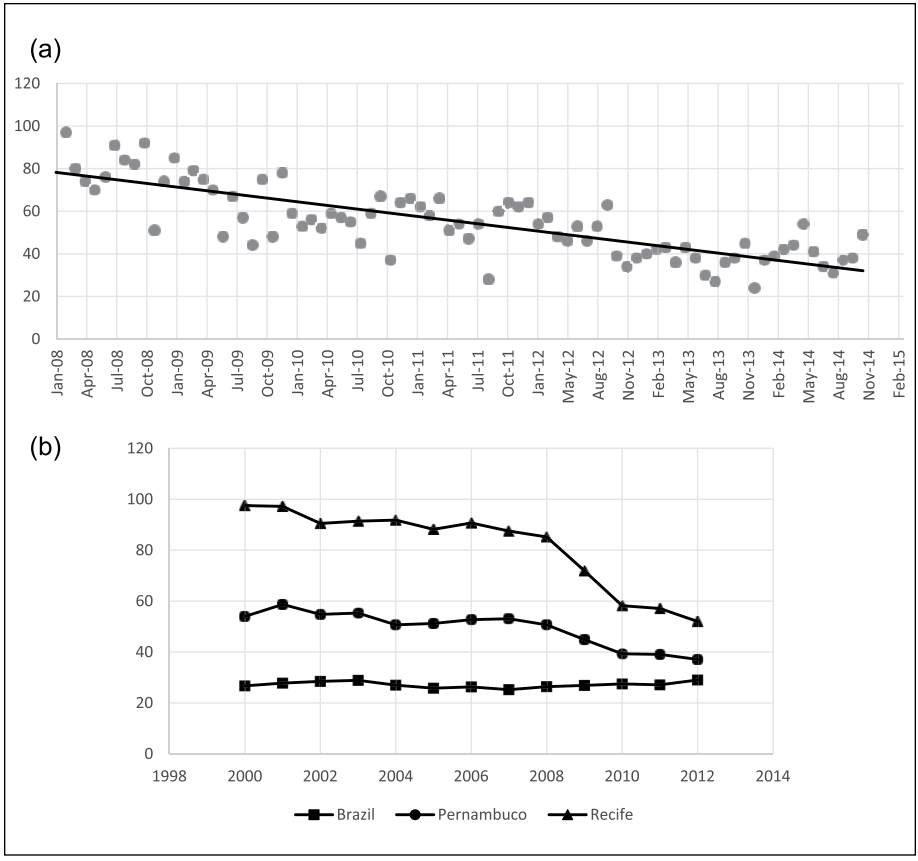

Figure 1. Trends for homicide in Recife: (a) homicide counts, monthly and (b) trends in homicide rates per 100,000 inhabitants.
Source. Secretariat of Social Defense of Pernambuco (2014) and Waiselfisz (2012, 2014b).

Table 1. Descriptive Statistics—Census Tracts.

	Total	Minimum	Maximum	*M*	*SD*
2009	808	0	11	0.43	0.849
2010	665	0	8	0.36	0.755
2011	675	0	13	0.36	0.762
2012	568	0	10	0.30	0.672
2013	442	0	4	0.24	0.536
All years	3,158	0	44	1.70	2.379

these examples, we can highlight that 17 census tracts in Recife had homicide drops greater than three occurrences between 2009 and 2013. Recife also experienced an increase of homicides in some areas. These census tracts are considered socially disorganized areas. In addition, the percentage of census tracts with no homicide occurrences has increased. This is a somewhat expected result because the number of homicides dropped by 45% in Recife during this period. In addition, the volume of homicides within census tracts also decreased: In 2009, the maximum value was 11, whereas this number was four in 2013. Overall, there is a concentration of homicides in Recife because the great majority of census tracts do not have any occurrences. At the same time, there is no evidence for concentrations within the concentrations because there is not a high frequency of homicides in any given census tract. Nevertheless, this topic will be discussed further below.

Considering street segments, two locations had more than 10 homicides between 2009 and 2013. These streets are cross streets and located beside the biggest prison of Pernambuco. This shows the importance of the scale of analysis because it illustrates how two street segments (one intersection) can drive the results for an entire census tract. Other street segments had between five and 10 homicides during the 5 years, and they are located in socially disorganized or low-income areas. Some of these places are areas with high levels of social interaction, near city squares and bars. One of the street segments is located in a wealthy neighborhood, beside a shopping center. This adjacent area is characterized by low levels of infrastructure and income. This example highlights the significant socioeconomic disparities that can be found in Recife.

Homicide Concentrations

To answer our first research question and test our corresponding hypothesis, Table 2 shows the degree of spatial concentration at the census tract and street segment levels. The first column shows that the percentage of census tracts with any homicides has decreased, 2009 to 2013: 29% to 19%. As such, many of Recife's census tracts are free of homicides. Given the high levels and rates of homicides in this city, such a result is interesting on its own. The second column shows that the percentage of census tracts with any homicides that account for 50% of homicides has been increasing: 29% to 39%. Any percentage here that is substantially less than 50% indicates a hot spot within a hot spot because of the concentration of homicides at the census tract level, as a whole. What has been occurring here is that homicides are occurring within fewer census tracts, but the distribution of those remaining homicides has become more dispersed.

Measuring homicides at the street segment level shows a far greater concentration of homicide. More than 8% of street segments had at least one homicide over the 5-year period, but in any given year, just 2.3% or less of the street segments had one or more homicides. In fact, there has been a steady decrease in the percentage of street segments that have any homicides: 2.32% to 1.3%. This is an incredible spatial concentration, particularly at the street segment level. Most often in the crime and place research, 5% of street segments (micro places) are able to account for 50% of crimes

Table 2. Percentages of Homicides—Census Tracts and Street Segments.

Year	Percentage of census tracts with homicides	Percentage of census tracts with homicides that account for 50% of homicides
2009	29.13	28.52
2010	25.35	29.36
2011	26.21	30.86
2012	23.25	34.57
2013	19.36	39.00
	Percentage of street segments with homicides	Percentage of street segments with homicides that account for 50% of homicides
2009	2.32	45.24
2010	1.93	45.93
2011	1.95	45.72
2012	1.68	47.19
2013	1.30	46.73

(Weisburd & Amram, 2014); in the current analysis, less than 2% of street segments can account for *all* homicides in Recife. Of course, homicide is a much rarer criminal event than most of the crime types investigated in the crime and place literature (assault, burglary, robbery, etc.), but this is a notably high degree of crime concentration, confirming our first hypothesis that the law of crime concentration at places holds for homicide in Recife, Brazil.

Because of this high concentration of homicides, it should come as no surprise that almost 50% of street segments with any homicides account for 50% of homicides in Recife. Of particular note here is that this last percentage has been stable during the drop in homicide rates. This result, in conjunction with the fact that the percentage of street segments with any homicides has decreased, gives an indication that the spatial pattern of homicide has changed during this time period; in other words, these spatial concentrations may not be stable.

Stability of Spatial Concentrations

The results of spatial point pattern test are shown in Table 3. The *S* indices for 2009 homicides compared with the other available (complete) years (2010-2013) are shown for both census tracts and street segments. In addition, the spatial point pattern test was employed on all spatial units available as well as only those spatial units within which homicides occurred. This was done as a sensitivity analysis for the stability of homicides over time because there are many spatial units of analysis that have zero values in all years (Andresen & Malleson, 2011)—this is particularly important for the street segments.

We can see in Table 3 that the degree of similarity, *S* index, is moderately high, though not considered "similar" for the analyses using all census tracts. An *S*-index

Table 3. Spatial Point Pattern Test Results.

	2009-2010	2009-2011	2009-2012	2009-2013
All census tracts (1,854)	.752	.752	.749	.758
Census tracts with occurrences (1,169)	.606	.609	.603	.619
All street segments (31,777)	.977	.977	.978	.977
Street segments with occurrences (2,596)	.722	.722	.726	.718

value of approximately .75 indicates that the spatial pattern of homicides was similar for 75% of census tracts in Recife, comparing 2009 with the other available years—similar results are present when comparing other year combinations, 2010-2011, for example. This means that there is variability from year to year, with a moderate amount of stability for homicide in Recife. Turning to the results of the spatial point pattern test only using census tracts that have at least one homicide in any of the years under analysis, we see that the *S* indices have decreased to a level that cannot be considered similar, at or just above .60. For the 5 years under analysis, homicides only occurred in just more than 63% of the census tracts in Recife, 1,169 of 1,854 census tracts. As such, part of the stability found, considering all census tracts, is the result of the zero values for homicides in approximately one third of Recife. These results provide moderate support for our second hypothesis at the census tract level.

The results of the spatial point pattern test for all street segments, Table 3, show a remarkably high degree of similarity: *S*-index values greater than .97. This is clearly a high degree of similarity year to year for homicides in Recife at the street segment level. Because of the high degree of concentration of crime at the micro place, there is a high degree of zero values that inflates these results. For all 5 years under analysis, homicides only occur on just more than 8% of street segments in Recife, 2,596 of 31,777 street segments. Consequently, as with the census tract results, part of the stability found here is an artifact of the presence of so many zero values.

Returning to Table 3, the *S*-index values for the analysis with only those street segments with any homicides over the 5-year study period are still moderately high, given that all the zero values have been removed. Essentially, all the values are .72, indicating that the spatial pattern of homicides at the street segment level was similar for 72% of the street segments in Recife, comparing 2009 with the other available years—similar results are present when comparing other year combinations. This indicates that over time, there has not been a major spatial shift in the pattern of homicides in Recife, as it has experienced a significant drop in this crime type. This supports our second hypothesis when considering street segments as the unit of analysis.

Overall, considering both spatial units of analysis, the results of the spatial point pattern test give mixed results for the support of our second hypothesis: The spatial patterns of homicide are stable over time. The census tract results indicate that the spatial patterns of homicide are not stable over time, but at the street segment level, the *S*-index values are approaching the level considered to be similar. As the results in Table 2 show, there appears to be a substantial change in the spatial patterns of homicide: The number

Table 4. Spearman Correlations, Census Tracts, and Street Segments.

	2009	2010	2011	2012	2013	All years
2009		.217**	.222**	.190**	.152**	.612**
2010	.058**		.221**	.214**	.169**	.581**
2011	.062**	.062**		.194**	.188**	.582**
2012	.067**	.053**	.028**		.177**	.541**
2013	.027**	.034**	.036**	.041**		.491**
All years	.521**	.474**	.477**	.442**	.387**	

Note. Census tracts are presented in the upper right and street segments are presented in the lower left.
** Correlation is significant at the .01 level (two-tailed).

of street segments with any homicides has decreased approximately 40%, but the percentage of street segments with any homicides that account for 50% of homicides has remained stable. This gives the appearance that a portion of the homicide drop in Recife is the result of homicides no longer occurring on that 40% of street segments. This has occurred in those street segments with the highest volumes of homicide.

Given that the results are not conclusive regarding the stability of spatial patterns over time, we also consider the correlations between the number of homicides for both census tracts and street segments, comparing all available years. As can be seen in Table 4, the maximum correlation among census tracts is .194 and for street segments is .067. Low correlations were expected because of the reduction on homicides by 45% in Recife. Moreover, in a span of 5 years, the local dynamic can experience some changes: different interaction areas, drug point locations, and bars, for example. Even with these considerations, the numbers within Table 4 show that the relation between homicides over time is weak, considering both census tracts and street segments. Therefore, we can say that the Spearman correlation does not support the hypothesis of stable spatial patterns over time, moderately consistent with the results from the spatial point pattern test using census tracts.

Discussion and Conclusion

In this article, we have investigated the crime concentrations and changing spatial patterns of homicide in Recife, Brazil, in the context of the homicide drop in recent years. We found that there is a high degree of concentration in homicide. As noted above, in any given year, homicides only occur on 1.30% to 2.32% of street segments. In the case of 2009 (2.32%), this represents more than 700 street segments in Recife that have homicides—just more than 400 in 2013. Moreover, the spatial patterns have changed somewhat in recent years, but in a particular way. Overall, we find strong support for our first hypothesis that the law of crime concentrations at places applies to homicide in Recife and mixed support for our second hypothesis that these spatial patterns are stable over time.

In the city of Recife, homicides decreased by 44.75% from 2009 to 2013. The reduction in the percentage of street segments with homicides (2.32%-1.30%) is a 44% drop. Moreover, the percentage of street segments needed to account for 50% of homicides remains unchanged over the study period. Collectively, these results imply that homicides have decreased at approximately the same degree as the concentration of homicides at the street segment level has increased, with the density of homicides remaining the same. If homicides had decreased everywhere by the same degree indicating a more general decrease in violence, we would not expect these two numbers to change in this way. Rather, the percentage of street segments with homicides would also remain relatively stable over time, with fewer homicides per street segment. This implies that just more than 40% of the street segments that had homicides in 2009 no longer had homicides in 2013, and we know this included some of the highest volume street segments in the city.

Although we do not conduct trajectory analyses to investigate the stability of spatial homicide patterns, our results are best compared with this research. Weisburd et al. (2004) found that 84% of the street segments in Seattle, Washington (1989-2002), had stable trajectories over their study period. In the context of the crime drop that occurred in Seattle, a 24% decrease in crime over the study period, 14% of the street segments had decreasing crime trends. Through the use of growth curve analysis, Braga et al. (2010, 2011) found similar results in the context of robberies in Boston, Massachusetts (1980-2008). Specifically, the concentrations of robbery are relatively stable over time, and, consequently, a small percentage of street segments and intersections accounted for the majority of the crime drop. Most recently, Curman et al. (2015) used the same trajectory analysis method as Weisburd et al. (2004) and found that 70% of the street segments in Vancouver, British Columbia (1991-2006), had stable trajectories, with the crime drop (a 40% decline) being driven by 30% of the street segments in the city—these numbers are in line with the street segment results above. Using a different trajectory analysis method, Curman et al. (2015) found that 94% of the street segments had stable trajectories, with 6% of the street segments being the driving force of the crime drop in Vancouver. Overall, this research has found that criminal opportunities are largely stable over time and that a relatively small percentage of street segments have exhibited the greatest drops in criminal activity. These results imply that crime prevention activities that are place-based have the greatest promise for dealing with criminal activity (Braga et al., 2010, 2011).

In the context of homicide in Recife, our results exhibit a similar pattern when considering census tracts. With a reduction in homicides of more than 40% and homicides occurring in so few places within the city, something must have occurred at very specific places rather than citywide initiatives. Moreover, the decrease in homicides had a particular pattern: Fewer census tracts currently experience homicides, and the distribution of homicides has become more even. This result implies that the relatively small percentage of census tracts that had high volumes of homicides experienced the greatest drops. If the drop in homicides was uniform across all places, the percentage of census tracts that account for 50% of homicides would have remained low, showing a concentration within a concentration. This percentage of census tracts increased (see Table 2), indicating that the greatest volume census tracts had the greatest decreases.

Although the same result was found for the street segments in the context of a decreasing percentage of street segments with any homicides, the degree of uniformity across those street segments has essentially remained unchanged—a uniform distribution of homicides from 2009 to 2013. Recall from the discussion above that there are street segments with disproportionately high volumes of homicide in Recife that also had the largest drops. Although these drops in homicide were not enough to manifest themselves in the citywide statistics, they do occur, supporting the place-based crime prevention activities put forth by Weisburd et al. (2004) and Braga et al. (2010, 2011).

At this stage of the research, place-based crime prevention activities are hypotheses that need to be tested, but the necessary data are not available to us for any such hypothesis testing. In the context of the international crime drop, explanations for this phenomenon are unsatisfactory, particularly for violent crime (Farrell, 2013). There has been a crime prevention initiative in Pernambuco, Brazil (Recife is its capital), that has been implicated for being responsible for the homicide decline.

The Pact for Life in Pernambuco, Brazil, began in 2007, the year before the reductions in homicide for the entire state of Pernambuco and the City of Recife, see Figure 1b. This is circumstantial without any scientific evaluations to date, but it is a promising explanation, given that homicide for Brazil, as a whole, increased after 2007. The Pact for Life involves 138 projects, grouped along six lines of structuring actions: qualified repression, institutional improvement, information and knowledge management, training and capacity, social prevention of crime and violence, and democratic management. Specifically, in the context of the suggestions of Weisburd et al. (2004) and Braga et al. (2010, 2011), these programs include investments in policing that include improvements in police intelligence. Moreover, the Pact for Life considers a holistic treatment with the engagement of multiple actions with different time horizons—see Ratton, Galvão, and Fernandez (2014), Oliveira (2012), Nóbrega Júnior (2014), and Zaverucha and Nóbrega Júnior (2015) for nonevaluation-based accounts of the Pact for Life contributing to the homicide decrease in Recife, and Pernambuco more generally.

Evaluating Pact for Life is beyond the scope of this study. Future research should continue the evaluations of Pact for Life in addition to considerations of alternative explanations for the drop in homicide in Recife, Brazil. The programs that are found to be effective can be replicated elsewhere in Brazil and possibly in cities in other countries where homicide is an issue.

Despite these implications, our study is not without its limitations. First, we limit our analyses to data on reported homicides. Homicides have a high rate of reporting to the police, but because of the relatively low counts of this crime, it is possible that any missing cases are not random. Second, geographic information systems (GIS) technologies have advanced significantly in recent years, but we were not provided with the accuracy of the GPS units used for data collection. And third, though the focus of our analyses is homicide, other crimes of violence need to be investigated in an international context. As such, the generalizability of our results for other violent crime types in Brazil needs to be confirmed.

Such future research is important not only for the well-being of Recife, Brazil, but also for other locations that have a high degree of violence. We are moving toward a

better understanding of the forces behind the international drop in property crime, namely opportunity, but the corresponding international drops in violent crime are less understood (Farrell et al., 2015). Because of the high volume of homicides, places in countries like Brazil provide an opportunity to better understand criminological events that are relatively rare in many countries. As a consequence, we may be able to learn more about these phenomena to prevent them.

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Note

1. Often in the spatial analysis literature, 50 repeated samples are used (Davis & Keller, 1997). Early research on Monte Carlo experiments by statisticians showed that as few as 20 repeated samples would provide good results (Hope, 1968). We use a 200 repeated random sample for the purposes of being conservative and to provide convenient cutoff values for the confidence interval.

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