
How Concentrated Are Police on Crime? a Spatiotemporal Analysis of the Concentration of Police Presence and Crime

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Abstract

Research Question What were the spatiotemporal patterns of police patrol in a major European city across the pre-COVID year of 2019, how did these patterns change over time, and to what extent did the concentrations of patrol correspond to concentrations of crimes?

Data We analyzed more than 77 million GPS signals from 130 police patrol cars showing where and when police patrols were present in police districts and street segments. We also plotted location, time and days of the week of the locations, and times of more than 50,000 recorded crimes.

Methods We calculated concentration ratios within both crimes and patrols relative to their distributions in time and space. We then compared the concentration ratios for crime to the concentration ratios for patrols. We concluded the analysis by comparing the extent to which concentrations of crime and patrol locations and times were overlapping.

Findings We found that police patrols, much like crime, were concentrated on a small proportion of street segments. Yet spatiotemporal police presence is unrelated to local levels of crime and crime concentration. Relative to temporal crime concentrations, police patrols were substantially under-concentrated from 1500 to 0100 h, all day on Fridays, and the entire months of June, July, August, and December. There was very little overlap in patrol concentrations with crime concentrations.

Conclusions After three decades of research showing crime prevention benefits of patrol concentrations on micro-level crime concentrations, police in one European city concentrate patrol presence at locations, times, days, and months where crime is not concentrated. Whether this conclusion can be reached in other cities will depend on replications of this study, both in Europe and other continents.

Keywords Tracking · Policing · GPS · Police presence · Hot spots

Introduction

“If crime is so concentrated at specific places in the city, then policing and other crime prevention resources also should be concentrated” (Weisburd, 2015, p. 143)

Patrol has always been at the core of police officer’s duties (Carrabine, 2009; Emsley, 1983, 2006; Kelling et al., 1974; Wain & Ariel, 2014: 274). Over the centuries policing practices have evidently changed. What started with foot patrol based on “fixed-point systems”¹ developed into largely undirected motor patrol, within large beats. This change from a strictly guided approach to large police beat strategies provided officers with a substantial level of discretion and freedom (Wain & Ariel, 2014, p. 276).

Being able to independently decide where, when, and how to police while on duty still remains highly important to police officers (Cordner, 1981; Koper et al., 2020), despite substantial research that has shown crime to exhibit a high spatiotemporal concentration (Weisburd, 2015). More important, over 80 experiments have found that focused police action can effectively reduce reported crime at targeted locations, usually with little displacement to surrounding areas (see Ariel et al., 2019; Braga et al., 2019a, b; Hutt, 2020). While scientific knowledge about optimizing police prevention of crime (e.g., Lum & Koper, 2017; Mitchell, 2017; Sherman, 2006, 2013; Telep, 2013) has focused on microgeographic units (e.g., Andresen et al., 2020; Ariel et al., 2019; Hutt, 2020; Li et al., 2011; Vandeviver & Steenbeek, 2019; Weisburd, 2015; Weisburd et al., 2010), everyday policing has shown little attention to micro-level differences in crime concentrations. A recent survey in the USA has shown that less than one-third of police agencies deploy hot spots patrols and just about half are engaged in crime analysis (Koper et al., 2020). This gap between research and practice suggests a need for research to measure the extent to which patrol allocation as delivered is in correspondence to the places and times of local crime.

Concentration of Crime

Evidence-based policing is based on three kinds of decisions based on reliable evidence: targeting, testing, and tracking (Sherman, 2013). Research for *targeting* police resources has that crime clusters unevenly across place and time and is not random. Weisburd (2015) has shown that across eight cities, half of all crime incidents concentrate on 2.1–6.0% of all street segments. Andresen et al. (2017) provided evidence that spatial crime concentration exhibits a temporal stability over a 10-year period. Thus evidence-based targeting of where, and where not, to patrol is clearly possible.

¹ “Fixed” reporting points were distributed across patrol beats for officers to report back to patrol sergeants and to receive intel on their assigned patrol beat. This system offered additional security for officers but came with a certain level of supervision (Wain & Ariel, 2014).

Crucially, most locations in any city have no reported crime at all. Due to temporally stable concentrations and the fact that there are often more spatial units than crimes, a proportion of street segments naturally tends to remain “crime-free” (Bernasco & Steenbeek, 2017; Levin et al., 2017). Unfortunately, temporal research that tracks whether police patrols at the micro-level (e.g., street segments, street blocks) are actually directed at crime concentrations has not received much attention (Felson & Poulsen, 2003; Ratcliffe, 2010).

Nevertheless, testing of patrols at well-targeted hot spots has tracked police patrol presence in relation to crime reduction. These tests have been accomplished through the introduction of focused police actions, most importantly *hot spots policing* (e.g., Ariel et al., 2019; Braga et al., 2019a, b; Mitchell, 2017; Williams & Coupe, 2017). When policing is focused upon crime hot spots, crime can be reduced effectively.

A key part of this effect depends not just on deterrence while police are present but also after they leave. Ariel et al. (2019) show that 93% of the deterrent effect of policing occurs after police leave the scene. With what is regarded as the *Koper curve*, Koper (1995) indicated that police officers have to be present at crime hot spots for 10 to 15 min to effectively realize these “residual deterrence” effects. Williams and Coupe (2017) have further provided evidence that police visits to hot spots of crime are more effective when delivered longer rather than shorter visits more frequently, supporting the 15-min temporal optimum of the Koper curve (although contrary findings have also been reported, including Mitchell, 2017).

Tracking Patrol Presence

To our knowledge, no research has yet focused on the third T of evidence-based policing: *tracking* the spatiotemporal delivery of police presence in relation to crime. This gap in research is mainly due to two structural challenges. First, police chiefs are faced with balancing *surveillance* and *accountability* of police officers (Wain & Ariel, 2014). Police officers value discretion and providing them with freedom on where and how to patrol are important aspects of job satisfaction (Cordner, 1981; Koper et al., 2020; Wain & Ariel, 2014). In contrast, introducing performance evaluations can potentially be perceived as loss of trust in officer’s intuition and patrol conduct. Second, highly detailed spatiotemporal analyses have just recently been enabled through technological advances in the Global Positioning System (GPS) (Davies & Bowers, 2019; Elevelt et al., 2019; Ridgeway, 2018; Vandeviver & Bernasco, 2017). Documenting patrol activity has so far been tedious and cost-intensive work. Either police officers used paper-based documentation to report how, when, and where they were engaging in policing tasks (Elevelt et al., 2019, p. 2) or radio calls were manually documented by police staff at headquarters (Ariel et al., 2019).

With the introduction of Global Positioning Systems (GPS), that tedium can now be avoided. The advent of easily accessible as well as low cost Automated Vehicle Locators (AVLs) and handheld GPS trackers enables police departments to track their officers and vehicles while being deployed (Davies & Bowers, 2019; Ridgeway, 2018; Wain & Ariel, 2014). Although this technological improvement allows for more detailed and precise data collection, researchers are now facing substantial

amounts of data to analyze. Due to very precise GPS pings², research is often limited to look at few hotspots or short periods of time (Davies & Bowers, 2019; Oatley et al., 2019). For example, Oatley et al. (2019) studied bike patrol officer's ability to map crime hotspots over a 10-week period, which required analysis of 1.7 million GPS signals³ from smartphone devices.

Research Question

As Weisburd (2015) suggested, we expect police presence to be just as concentrated as crime. Therefore, the question this paper aims to answer is how much police patrol is concentrated in space and time and how well this concentration corresponds to local crime patterns.

The paper first describes the datasets and methods before moving to the empirical tracking results, showing that policing activity is highly concentrated on a small proportion of street segments and remains rather stable across space but not time. Further, the concentration of police patrols corresponds weakly with local crime. We argue that these novel findings contribute to the understanding of how policing is carried out in everyday practice. We hope they will encourage comparative research on the concentration of police presence in relation to crime in other cities and countries.

Data

We use data provided by the Antwerp Police Department (APD) across 21 police zones. Antwerp, as the second-largest city in Belgium, stretches over 204 km² and is populated by around 530,000 people. Data were collected from January 1, 2019 to December 31, 2019 from the APD crime database and through AVLs from 130 patrol cars⁴ with a general GPS ping of 4 s.

In order to understand the spatiotemporal concentration of policing activity, we analyzed 77,680,983 unique GPS signals from patrol cars and 52,512 reported crime events. The crime data were categorized according to APD classification and aggregated to internationally comparable categories. All crimes categorized as *public order* infractions were dropped from the dataset. For more detailed analysis, seven crime types were selected: *drug crimes*, *theft*, *motor vehicle theft*, *burglary*, *assault*, *vandalism*, and *criminal homicide*. Open-source street network data was retrieved

² GPS pings describe the frequency with which GPS signals are sent to the receiving unit. Pings vary due to technology and patrol types. Foot patrols are tracked through body worn radios and send signals every 30 s to 5 min. Motor patrol can carry more powerful AVLs, which often have GPS pings of under 10 s (Hutt et al., 2018, p. 343).

³ Oatley et al. (2019) have not reported the GPS ping of the tracking app used to collect the officer GPS data.

⁴ The 130 analyzed patrol cars constitute 38% of the APD vehicle fleet, including unmarked and service cars.

through the Flemish Roads Register and encompassed 31,156 street segments on each street from one intersection to the next. All data were processed using Python 3.8 and R 3.6. The geocoordinates were map matched with a static map matching algorithm, which was run on a high-performance computing cluster.

Methods

A multi-level spatiotemporal analysis been deployed to analyse the data. Descriptive statistics are used to present the concentration of police presence and crime on the meso- (police districts) and micro- (street segments) levels. Police presence is calculated from the GPS data generated by individual patrol car. Signals are assigned a time value (e.g., 4 s) based on the calculated lag between two consecutive pairs of GPS pings. We excluded all GPS signals that were recorded at the police headquarters or at police stations. Crime levels correspond to the number of reported crimes. “Concentration” of both crime and patrol is operationalized as the proportion of spatial units that receives a certain (larger) percentage of the phenomenon, expressed as the statistic called the Gini coefficient. It is important to note that with a Gini coefficient, a low proportion of units relative to a higher proportion of the phenomenon expresses a “high” concentration and vice versa⁵. This measurement approach was adapted from Weisburd (2015).

Spatially, the meso-level consists of the APD police zones ($n = 21$, mean area = 9.58 km²) and the micro-level of all street segments in Antwerp⁶ ($n = 31,147$, mean length = 93.3 m), respectively. Both levels were included. The zones are of high importance for the police department in terms of patrol management; street segments allow for a fine-grained spatial analysis of crime and police. This decision allowed us to investigate how much we can learn from the two distinct levels of analysis in regard to the spatiotemporal patterns of police presence and crime. It also led to our abandoning the meso-level after we found it was too large to track in relation to crime concentrations.

Temporally, policing activity and crime events were analyzed at the month, week, day, and hour levels. In addition, linear correlation analyses (Pearson’s correlation coefficient) were used to investigate the association between the level of police and crime and their respective concentration at the 25, 50, and 75% levels⁷ of street segments. We also employed a week-rank comparison between the street segments that received most police presence and crime events, respectively. The rank comparison was conducted on, both, the one hundred and ten most frequented street segments.

⁵ Given that 10% of all streets experience 25% of all crime at time x and that 5% of all streets experience 25% of all crime at time y , it follows that 5% is more concentrated as a lower number of streets experience 25% of crime.

⁶ Open access data retrieved from Flemish Roads Register (<https://www.vlaanderen.be/>)

⁷ The percentage levels describe that, for example, 10% of street segments receive 25% of all recorded crime. The levels for police and crime are fixed, as we are interested in the proportion of street segments that receive these levels of police and crime and, thus, examining their concentration.

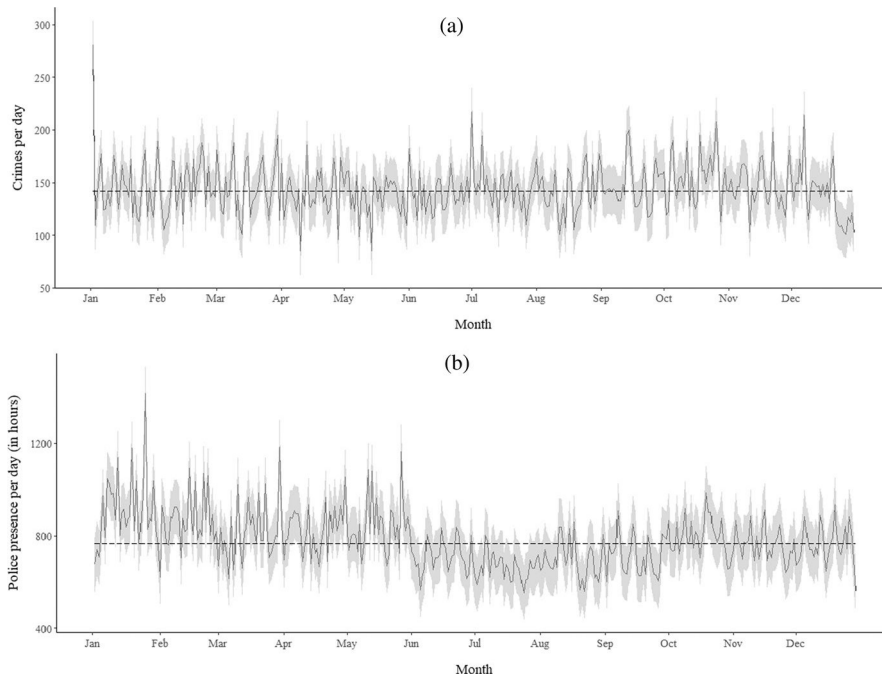


Fig. 1 Daily levels of crime (a) and police presence (b) in 2019. Dotted line indicates annual median

Findings

Police and Crime by Day of the Year

The number of daily recorded crimes peak at the first day of the year ($n = 281$). Overall the daily number of crimes remains stable over the course of the year ($SD = 23.1$), although slightly rising in the second half of the year. A rise during the summer months (June to August), especially in July ($n = 217$), and a drop in late December are visible (Fig. 1a). In contrast, police presence per day varies substantially over the course of the year, with a decrease as the year progresses ($SD = 118.1$). The beginning of the year receives little police presence compared to the rest of January (675h). During summer (June to August), police presence remains mostly under the annual median of 769 h. Likewise, to the trajectory of recorded crimes, police presence experiences a drop in late December (558 h) (Fig. 1b).

Spatial Concentration of Police and Crime

Across the police zones, crime is more concentrated than police presence (Fig. 2a). The meso-level of analysis (police zones), concentration of crime, and police

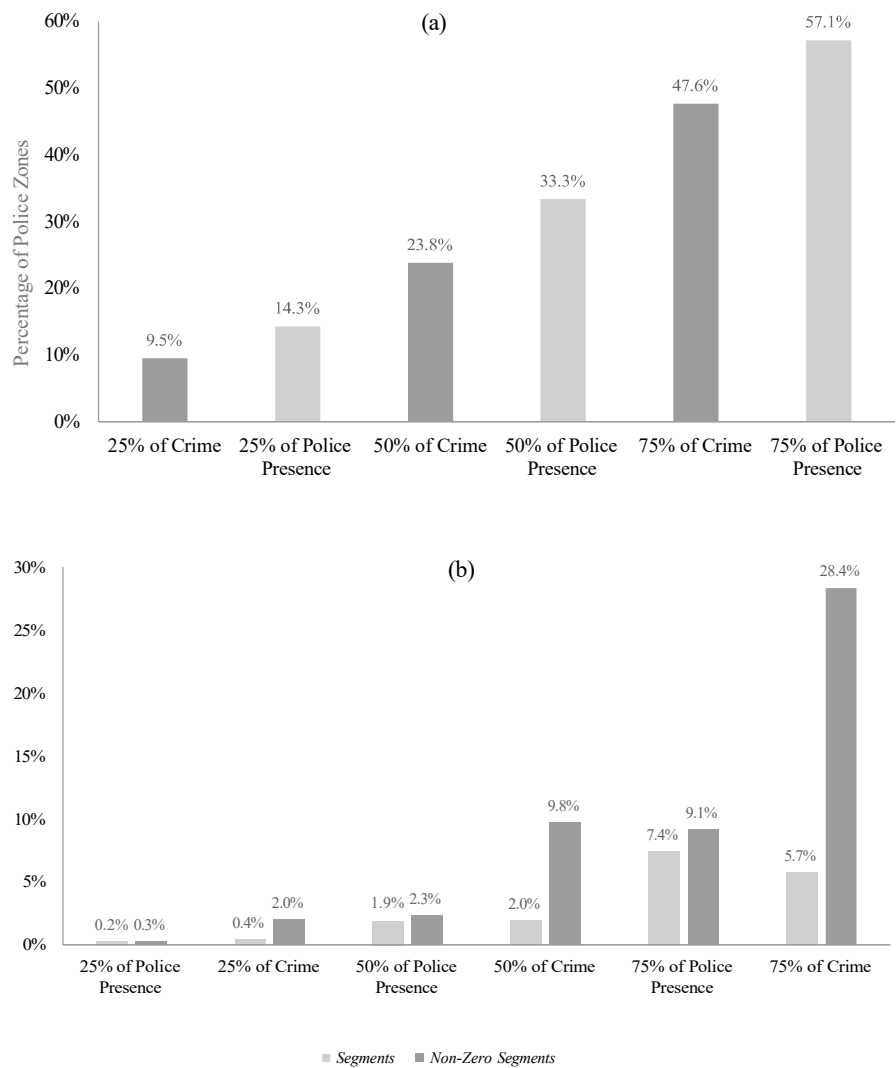


Fig. 2 Concentration of crime and police across police zones (a) ($n = 21$) and street segments (b) ($n = 31,156$)

presence show low differences in magnitude⁸. On the micro-level of analysis (street segments), however, police presence shows far less concentration than crime. On the 25% and 50% levels, police presence is more concentrated than reported crime, across both all street segments and non-zero street segments⁹. The magnitude of difference varies most across non-zero street segments. Across non-zero segments,

⁸ As there are 21 zones, each zone presents 4.76% of all meso-level places.

⁹ Non-zero street segments include all segments that received crime or police presence at least once during the study period.

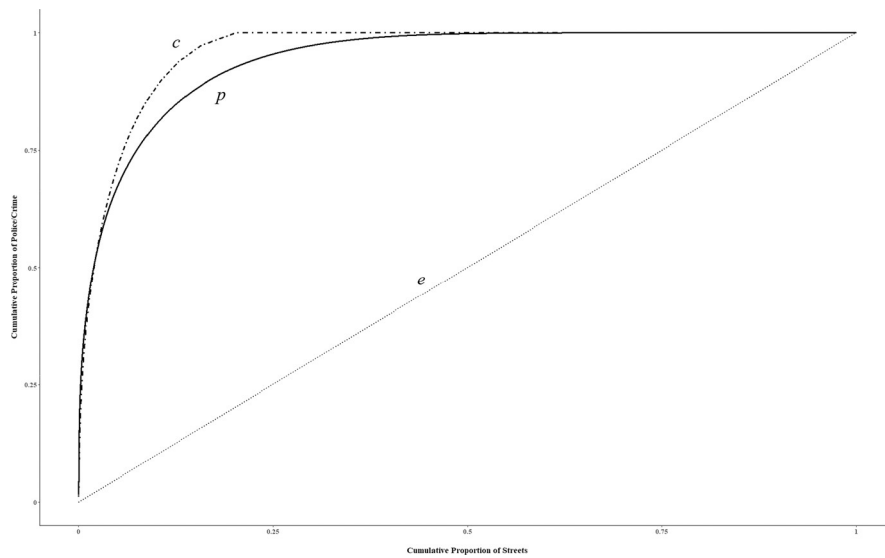


Fig. 3 Lorenz curve for distribution of police presence (p) and crime (c) across street segments. *e* represents a theoretical equal distribution

police presence is substantially more concentrated (25% of policing in 0.3% of segments, 50% of policing in 2.3% of segments, and 75% of policing in 9.1% of segments) than reported crime (25% of crimes in 2.0% of street segments, 50% of crimes in 9.8% of segments, and 75% of crimes in 28.4% of segments) for non-zero segments. However, this analysis cannot distinguish whether police concentrations are found at segments with high concentrations of crime (Fig. 2b).

Overall, police are more likely to concentrate their presence where police presence or crime has been previously recorded. Yet police are far more present across all street segments than is crime. Around 81.4% ($n = 25,373$) of all street segments receive at least one GPS signal of police presence, while only 20% ($n = 6,296$) do so for crime. Looking at the concentration across all segments, crime (c) experiences a somewhat higher level of inequality than police presence (p) (Fig. 3). The Gini coefficients, which measure the intensity of concentration, for crime and police are 0.92 and 0.89, respectively (Table 1).

Spatial Concentrations over Time

Over time, the spatial concentrations on the meso-level of both police presence and crime remain stable (Fig. 8 in Appendix). Given that stability, we were interested to find that the level of police concentration occurs in the same police zones each month. A rank ordering of the zones showed that the proportional distribution across police zones remained stable over the course of months (see Table 2). Only three (of 21) police zones experienced rank changes, expressed by the standard deviation of monthly ranks, higher than 2.5. That means that the same police zones

Table 1 Overview of concentration of police presence and crime in proportions across all units of analysis

	Police zones	Street segments	Non-zero segments
25% of police presence	<i>0.143</i>	<i>0.002</i>	<i>0.003</i>
50% of police presence	<i>0.333</i>	<i>0.019</i>	<i>0.023</i>
75% of police presence	<i>0.571</i>	<i>0.074</i>	<i>0.091</i>
At least 1 visit	<i>1</i>	<i>0.814</i>	<i>1</i>
Min	<i>0.019</i>	<i>0</i>	<i>0.000</i>
Max	<i>0.085</i>	<i>0.015</i>	<i>0.015</i>
Mean	<i>0.048</i>	<i>0.000</i>	<i>0.000</i>
SD	<i>0.018</i>	<i>0.000</i>	<i>0.000</i>
<i>N</i>	<i>21</i>	<i>31,156</i>	<i>25,373</i>
25% of crime	<i>0.095</i>	<i>0.004</i>	<i>0.020</i>
50% of crime	<i>0.286</i>	<i>0.020</i>	<i>0.098</i>
75% of crime	<i>0.524</i>	<i>0.057</i>	<i>0.284</i>
At least 1 crime	<i>1</i>	<i>0.202</i>	<i>1</i>
Min	<i>0.005</i>	<i>0</i>	<i>0.000</i>
Max	<i>0.135</i>	<i>0.012</i>	<i>0.012</i>
Mean	<i>0.048</i>	<i>0.000</i>	<i>0.000</i>
SD	<i>0.031</i>	<i>0.000</i>	<i>0.000</i>
<i>N</i>	<i>21</i>	<i>31,156</i>	<i>6296</i>

are consistently ranked high and low. As the meso-level yields no further insights into micro-level changes within the respective zones, we drop the meso-level from here on.

At the street segment level, the spatial concentration experiences change in its spatiotemporal (space-time) trajectory. At the 25% and 50% levels, the concentrations of police and crime cross each other. Spatial concentration of police at the 25% level is higher than crime concentration during January to June, but then policing concentration levels out and shows similar levels to crime concentration thereafter (see Fig. 9a in Appendix). At the 50% level this change already manifests in March. However, for the rest of the year, police presence remains less concentrated than crime. For non-zero segments, crime is more concentrated than police presence at each month. The trajectories diverge considerably at the 50% and 75% levels during the period of September to November (see Fig. 9b in Appendix). Over the course of the year, we see that police presence is increasingly less concentrated as the year goes on and that crime concentration remains rather stable over time.

Over the course of the day, the spatial concentration of police and crime shows instability and dissimilarities. Across all street segments, police presence is less concentrated than crime at each hour of the day at the 50% and 75% levels, except for the time between 6.00 a.m. and 6.59 a.m. At the 25% level, police presence is mostly more or equally concentrated as crime (see Fig. 4a). At non-zero street segments, spatial concentration is more unstable. During night and early morning (1 a.m. to 7 a.m.), crime is more concentrated than police presence but remains less concentrated

Table 2 Results of rank test for each month on the police zone level. Ranks were assigned from lowest to highest; thus, rank 1 represents the police zone with most recorded police presence and rank 21 the police zones with the least recorded police presence. The names of the police zone were anonymized due to confidentiality requirements

	Delta 1	Echo 1	Tango 1	Echo 3	Zulu 3	Zulu 1	Charlie 2	Foxtrot 1	Foxtrot 2	Echo 3	Delta 2	Tango 3	Echo 2	Charlie 3	Delta 4	Charlie 1
January	4	1	8	7	5	2	9	10	3	6	11	12	14	13	15	17
February	4	1	6	5	8	3	7	11	2	12	15	14	13	18	16	17
March	4	1	7	5	6	3	8	9	2	10	11	13	12	14	16	15
April	5	1	7	6	4	2	11	9	3	10	12	8	13	14	15	16
May	3	7	4	5	6	1	8	9	2	11	12	10	15	13	14	16
June	2	3	5	1	4	8	6	7	15	10	13	9	14	11	12	17
July	1	2	3	4	5	9	6	7	15	8	10	11	13	14	12	17
August	1	6	2	5	3	10	4	8	15	9	7	12	14	13	11	18
September	1	3	2	4	5	7	6	10	14	11	8	9	15	12	13	18
October	2	1	3	4	5	6	7	10	14	9	8	12	11	15	13	17
November	1	4	2	6	3	7	5	9	14	8	11	12	10	13	15	16
December	1	4	3	6	5	7	2	12	14	9	8	10	13	11	15	16
Mean	2.42	2.8	4.3	4.8	4.9	5.4	6.6	9.3	9.4	9.4	10.5	11.0	13.1	13.4	13.9	16.7
Mode	1	1	3	5	5	7	6	9	14	10	11	12	13	13	15	17
SD	1.44	1.99	2.09	1.46	1.32	2.93	2.25	1.42	5.95	1.55	2.29	1.73	1.44	1.80	1.61	0.85
Range	4	6	6	6	5	9	9	5	13	6	8	6	5	7	5	3
	Delta 3	Zulu 2	Tango 2	Alpha	Zulu 4	Tango 3	Echo 2	Charlie 3	Delta 4	Charlie 1	Delta 3	Zulu 2	Tango 2	Alpha	Zulu 4	
January	18	16	19	20	21	12	14	13	15	17	18	16	19	20	21	
February	10	9	20	19	21	14	13	18	16	17	10	9	20	19	21	
March	18	17	20	21	19	13	12	14	16	15	18	17	20	21	19	
April	18	20	19	17	21	8	13	14	15	16	18	20	19	17	21	
May	18	20	17	19	21	10	15	13	14	16	18	20	17	19	21	
June	16	19	18	21	20	9	14	11	12	17	16	19	18	21	20	

Table 2 (continued)

	Delta 3	Zulu 2	Tango 2	Alpha	Zulu 4	Tango 3	Echo 2	Charlie 3	Delta 4	Charlie 1	Delta 3	Zulu 2	Tango 2	Alpha	Zulu 4
July	16	19	18	21	20	11	13	14	12	17	16	19	18	21	20
August	16	17	19	21	20	12	14	13	11	18	16	17	19	21	20
September	19	17	16	21	20	9	15	12	13	18	19	17	16	21	20
October	19	16	18	21	20	12	11	15	13	17	19	16	18	21	20
November	19	17	18	20	21	12	10	13	15	16	19	17	18	20	21
December	17	19	18	20	21	10	13	11	15	16	17	19	18	20	21
Mean	<i>17.0</i>	<i>17.2</i>	<i>18.3</i>	<i>20.1</i>	<i>20.4</i>	<i>11.0</i>	<i>13.1</i>	<i>13.4</i>	<i>13.9</i>	<i>16.7</i>	<i>17.0</i>	<i>17.2</i>	<i>18.3</i>	<i>20.1</i>	<i>20.4</i>
Mode	<i>18</i>	<i>17</i>	<i>18</i>	<i>21</i>	<i>21</i>	<i>12</i>	<i>13</i>	<i>13</i>	<i>15</i>	<i>17</i>	<i>18</i>	<i>17</i>	<i>18</i>	<i>21</i>	<i>21</i>
SD	<i>2.38</i>	<i>2.82</i>	<i>1.11</i>	<i>1.19</i>	<i>0.64</i>	<i>1.73</i>	<i>1.44</i>	<i>1.80</i>	<i>1.61</i>	<i>0.85</i>	<i>2.38</i>	<i>2.82</i>	<i>1.11</i>	<i>1.19</i>	<i>0.64</i>
Range	<i>9</i>	<i>11</i>	<i>4</i>	<i>4</i>	<i>2</i>	<i>6</i>	<i>5</i>	<i>7</i>	<i>5</i>	<i>3</i>	<i>9</i>	<i>11</i>	<i>4</i>	<i>4</i>	<i>2</i>

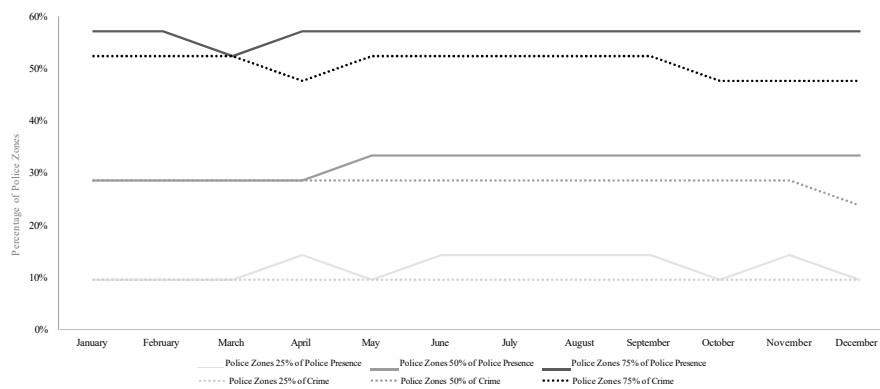


Fig. 4 Concentration of police presence and crime across street segments (a) and non-zero street segments (b) for each hour block of the day. Hour blocks express time slots from, for example, 2:00 a.m. to 2:59 a.m.

thereafter. A similar but weaker trend is visible at the 50% level of concentration. At the 25% level, police presence is consistently more concentrated than crime (see Fig. 4b). Overall, police presence experiences less variation in its concentration over the course of the day than crime.

Temporal Concentration of Police and Crime

The temporal concentration of police presence and reported crime in this analysis refers to the proportionate distribution of both resources over time at the micro-level. Police presence increases steadily across the days of the week, with the lowest proportion being deployed on Monday and peaking at Saturday, before decreasing again (Fig. 5). Crimes are proportionally fewest on Wednesdays but peak during Saturdays. Thus, weekdays receive less crime and police presence than expected under the assumption of an equal temporal distribution. The trajectories of crime and police presence are rather similar in that regard. Likewise, these trajectories progress similarly over the hours of the day (Fig. 6). The proportions for both are lowest during early morning hours (1 a.m. to 7 a.m.) and increase thereafter above expected equal proportions. However, crime and police presence do not peak at the same times during the day. Policing is most heavily deployed during the period from 9 a.m. to 2 p.m. The highest proportions of crime are reported at 12 p.m. and at 5 p.m. While crime is at its highest proportion, police presence steadily reduces and regresses to the level of equal proportions. Although crime and police follow similar trajectories, they are misaligned by about 3 h.

Geography of Police and Crime

Police presence is more concentrated across street segments than crime, especially at the highest level of concentration. The pattern for police presence shows that it spreads

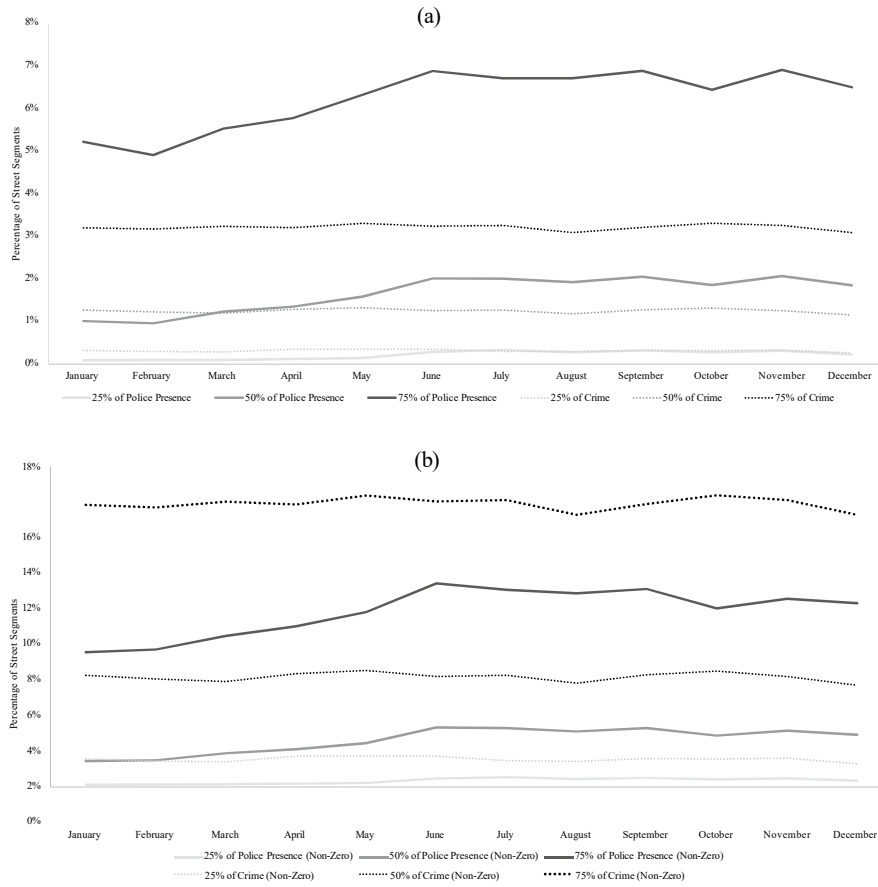


Fig. 5 Proportions of police presence and crime for each day of the week. Dotted line expresses theoretical equal proportions

out across the street network more extensively than crime. Crime events are more clustered around the center and sparse around the edges of the city's core. Police presence is less clustered and is recorded from South-Eastern parts to the West of the municipality. Highest levels of police concentration are along longer segments, which appear as connecting streets within the network, whereas crime events are highly concentrated on visually shorter segments. Further, it appears that street segments with the highest concentration of crime do not receive the highest level of police presence, and vice versa. Through the geographic extent of police presence, it also becomes apparent that police presence is spread out further across the street network. Thus, the North-Western part shows many street segments with no crime, which nonetheless receive low levels of police presence.

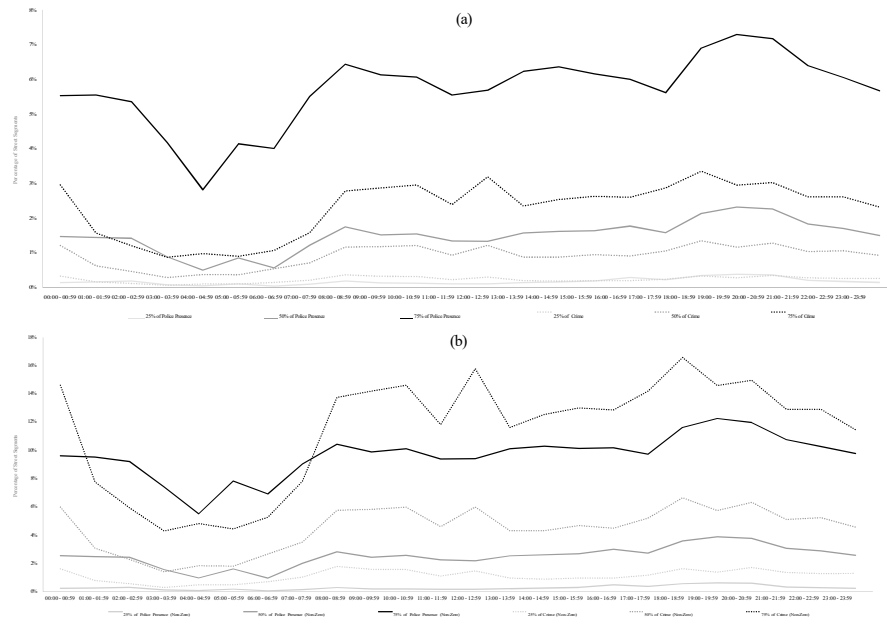


Fig. 6 Proportions of police presence and crime for each hour block of the day. Dotted line expresses theoretical equal distribution

Spatiotemporal Independence of Police and Crime

In order to understand the spatiotemporal relationship of police and crime, we have analyzed the daily levels and concentration of police presence and recorded crime. We see that the level of crime has almost no statistical influence on the level of police nor on police concentration. The daily levels of crime are temporally stable as there is no relationship between day of year and level of crime ($r = 0.007$). The amount of police presence and the degree of its concentration show statistically significant moderate negatives on all levels, apart from a weak negative relationship at the 75% level ($r = -0.475$). In general, the more police that are deployed, the more concentrated police presence is in space¹⁰. The strongest correlation of police presence with its concentration is seen at the 25% level ($r = -0.598$). However, levels of police and its concentration are not stable over time. The daily levels of police presence declined significantly during the course of the year ($r = -0.367$). Similarly, police concentration declines gradually over the course of the year, most strongly at the 25% level ($r = 0.577$).

The correlation analysis suggests that crime at the street segment level has no statistical relationship with the level of police presence nor with its concentration. Comparing the distribution of highest weekly ranked street segments for police

¹⁰ Higher levels of police are negatively associated with the proportion of segments that hold a certain percentage of police presence, thus, expressing a higher concentration.

presence and crime confirms this. We calculated both the 100 and the ten highest ranked street segments for each week for police presence, with all crime, and with selected crime types (*assault, theft, motor vehicle theft, vandalism, burglary, drug crimes, and criminal homicide*). We report four major findings from the week-rank analysis.

First, we see a high level of concentration of police presence and crime for both modes of analysis. This concentration does not describe the concentration of all crimes or police presence across all segments; it describes the concentration *within* the highest ranked street segments. Further, we report a slightly higher concentration at the 25% level for police presence (2.38%) than for crime (2.64%) for the 100 highest (*h100*) ranked segments, but find that crime (1.75%) is substantially more concentrated than police presence (3.26%) for the ten highest (*h10*) ranked segments (Table 3).

Second, the overlap¹¹ of street segments that are within both ranked sets is rather low. The overlap between all crime and police presence lies at about 23% for the 100 highest and 2% for the ten highest segments. This supports the dissimilar spatial pattern that is visible in the geographic maps (Fig. 7).

Third, certain crime types show particularly higher overlap with police presence. At *h100* the overlap for assault is at 29.74%, the highest reported overlap across all crime types. At *h10* motor vehicle (5.43%), drug crimes (4.35%), theft (4.35%), assault (3.26%), and vandalism (3.26%) show higher overlap than all crimes combined. Further, we report high concentrations of crime at both *h100* and *h10*, with theft and drug crimes being most concentrated at the 25% level (Table 3).

Fourth, the spatiotemporal alignment of police presence and crime is found to be low. We calculated the exact overlap of all rankings of police presence, all crime, and all analyzed crime types. The spatiotemporal exact overlap did not exceed 0.3% for any of the crime types nor all crime.

Discussion

Policing activity at a macro-level shows similar overall trends in its concentration as crime activity, which can be expressed through the Gini coefficients of 0.89 and 0.92 for police presence and crime, respectively. However, at the *micro*-level we have found a twofold *policing paradox*. First, *police presence and crime are misaligned in space and time*. High concentrations of police presence are recorded at street segments that do not receive equally high proportions in crime, and *vice versa*. Temporally, police presence is recorded along a similar trajectory across hours of the day but appears to be ahead of crime by about 3 h. Researchers have repeatedly demonstrated benefits from hot spot-orientated policing at the right places (e.g., Ariel

¹¹ The overlap describes the number of segments that were included in the subsets for the whole year. It shows whether one street segment that ranked at least once in *h100* or *h10* for police presence is within the set of ranked segments for crime (and crime types). The spatiotemporal exact overlap expresses that one segments ranked the same during the same week for both police presence and crime.

Table 3 Results of Pearson's *R* correlation analysis for police and crime on street segments and non-zero street segments

	No.of Crimes	CC (25%)	CC (50%)	CC (75%)	CC (25%) NZ	CC (50%) NZ	CC (75%) NZ	Police Presence	PC (25%)	PC (50%)	PC (75%)	PC (25%) NZ	PC (50%) NZ	PC (75%) NZ	Days
No.of Crimes	1	0.111*	0.610***	0.856***	0.111*	0.610***	0.856***	0.161**	0.124*	0.114*	0.034	0.124*	0.114*	0.034	0.007
CC (25%)		1	0.813***	0.580***	1***	0.813***	0.580***	-0.093	0.087	0.034	-0.043	0.087	0.034	-0.043	-0.066
CC (50%)			1	0.931***	0.813***	1***	0.931***	-0.017	0.139**	0.101	-0.003	0.139**	0.101	-0.003	-0.030
CC (75%)				1	0.58***	0.931***	1***	0.062	0.148**	0.119*	0.014	0.148**	0.119*	0.014	-0.015
CC (25%) NZ					1	0.813***	0.580***	-0.093	0.087	0.034	-0.043	0.087	0.034	-0.043	-0.066
CC (50%) NZ						1	0.931***	-0.017	0.139**	0.101	-0.003	0.139**	0.101	-0.003	-0.030
CC (75%) NZ							1	0.062	0.148**	0.119*	0.014	0.148**	0.119*	0.014	-0.015
Police Pres- ence								1	-0.598***	-0.566***	-0.475***	-0.598***	-0.566***	-0.475***	-0.367***
PC (25%)									1	0.920***	0.800***	1***	0.920***	0.800***	0.577***
PC (50%)										1	0.952***	0.920***	1***	0.952***	0.530***
PC (75%)											1	0.80***	0.952***	1***	0.452***
PC (25%) NZ												1	0.920***	0.800***	0.577***
PC (50%) NZ													1	0.952	0.530
PC (75%) NZ														1	0.452***
Days															1

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

CC, crime concentration; PC, police concentration

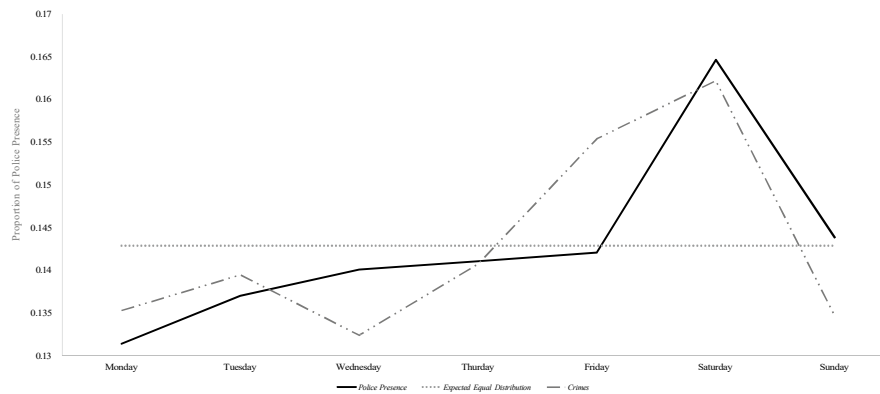


Fig. 7 Map of cumulative proportions of crime and police presence across all street segments in Antwerp. Lighter color (yellow) indicates segments that are in the top 25th percentile. Darker color (purple) indicates segments that are in the lowest 25th percentile

et al., 2016, 2019; Braga et al., 2019a, b; Sherman & Weisburd, 1995; Williams & Coupe, 2017). In this study, we raise the issue of whether police activity is focused not only on the right places but also at the right time.

We see that there is an overall decline in the level of police deployed over the study period and over the course of the day. This might be due to staffing plans or administrative work that needs to be completed before the end of patrol shifts. As *routine activities* have been recognized as a cause of crime events (Cohen & Felson, 1979), police (routine) activities could be more effective when oriented toward these¹². This is not the case for our study. During summer, when outdoor activities increasingly take place, the level of police presence was lowest. This could be caused by a lower number of patrol officers available during summer holidays.

Further, policing in Antwerp is not well calibrated with the elevation of crime risk when many people come together in time and space and thus create more *opportunities for crime* (Felson & Clarke, 1998; Nagin et al., 2015). This finding is visible in the analyzed crime dataset. Arguably, times of high mobility (e.g., rush hours and commuting times) are moments when myriad crime opportunities arise. In our data we see that the policing activity responds to that general pattern during morning hours (6 a.m. to 10 a.m.) with a peak at around 9 a.m., but not in the evening hours. The second peak of police presence occurs around 2 p.m. and activity regresses toward the mean proportion afterward. The pattern of police presence and crime could be better aligned by deploying police resources proportionally to recorded crime as it rises later in the day, and potentially altering shifts in order to lower the 3-h lag between police presence and crime.

The second dimension of the policing paradox we found is that an increase in the amount of police presence leads to higher concentration of presence at the

¹² Felson questioned the ability of police officers to act as a guardian due to the unlikelihood of their presence as crimes occur infrequently and police beats are hard to cover in their entirety (Felson, 2002)

street segments. In contrast, increases in the daily level of crime lead to lower crime concentrations. These antithetical relationships require consideration. We offer three.

First, the sample size for the crime data is 52,512, compared to 31,156 street segments. Theoretically, recorded crimes cannot be equally distributed across the street segments. Thus, around 31.5% of street segments ($n = 9800$) would receive 50% less crime than the remaining street segments in a theoretically equal distribution. As we know from prior analysis (see, Weisburd, 2015) and have demonstrated here, crime is highly concentrated and not randomly distributed on the micro-level. Therefore, increasing numbers of crime raise the probability that we would encounter fewer non-zero-crime segments, as the number of street segments remains constant, and thus lowers the concentration of crime. In contrast, increases in police presence lead to an increase in its concentration. This, arguably, could be caused by their dependence on the street network. As we have seen in Figure 9, high concentrations of police presence are found isolated from crime in the north and at longer street segments at the center of the city. The high number of signals in the north is due to proximity to the police station, where all patrol cars are parked. Longer street segments act as connectors in the street network and, as Davies and Bowers (2019) remarked, show a high level of “betweenness.” Police officers need to frequent these streets in order to reach their point of destination, may it be in response to an emergency call or during officer-initiated patrol. Therefore, these streets will inevitably show higher values of police presence.

Second, in contrast to crime, the entire trajectory of police vehicles is mapped and not just the event or patrol visits per se. Further, increases in the overall police presence and thus increases in the number of deployed patrol cars and teams might free up officers to engage in self-initiated patrol. Therefore, high concentration of police presence at particular street segments might be a result of officer discretion in regard to patrolling activity and location.

That being said, the spatiotemporal concentration of police activity cannot be assessed on its space alone. Methodological frameworks that focus on micro-levels of both space *and* time are needed to identify alignment between deployed police forces and reported crime. Police departments need to investigate where and *when* criminal activity occurs and, based on that evidence, shape their *modus operandi* of patrol and response.

In our case we have found that police resources concentrate more when more time is spent in the field. Without knowledge on how this concentration is directed at places, an evaluation in terms of allocation remains impractical. In addition, theoretical and empirical implications need to be considered when looking at potential alignments and misalignments of police presence and crime. Prior research has shown that deterrent effects of police slowly decay over time, known as “deterrence decay” (see Sherman, 1990; Sorg et al., 2013). Following that, a certain temporal lead of police presence and a temporal (not spatial) misalignment might be favorable. When looking at the results of our analysis, we see that the overlap between police presence and crime is rather low (~23%) (see Table 4) over the course of the study period. This means that police focus seems to react little to spatial patterns of crime.

Table 4 Week-rank test for police presence, crime, and crime types for highest 100 and highest ten ranked segments per week in 2019

	Number of segments ranked in top 100	25% of occurrences	<i>n</i>	50% of occurrences	<i>n</i>	75% of occurrences	<i>n</i>	% of single occurrence	<i>n</i>	Overlap
Even distribution	5300	25%	1325	50%	2650	75%	3975	100%	530	/
Observed distribution (police presence)	1049	2.38%	25	5.34%	56	14.68%	154	61.11%	641	/
Observed distribution (crime)	1627	2.64%	43	9.53%	155	9.53%	155	55.01%	895	22.97%
Assault	2377	5.55%	132	19.73%	469	47.08%	1119	57.47%	1,366	29.74%
Theft	1791	2.85%	51	12.56%	225	36.85%	660	53.15%	952	22.88%
Motor vehicle theft	1773	7.16%	127	24.20%	429	56.68%	1005	64.92%	1,151	21.83%
Vandalism	1633	9.12%	149	26.88%	439	61.73%	1008	69.75%	1,139	20.50%
Burglary	1767	9.34%	165	27.45%	485	63.67%	1125	72.44%	1,280	19.07%
Drug crimes	1185	3.80%	45	17.30%	205	50.21%	595	65.82%	780	17.83%
	Number of segments ranked in top 10	25% of occurrences	<i>n</i>	50% of occurrences	<i>n</i>	75% of occurrences	<i>n</i>	% of single occurrence	<i>n</i>	Overlap
Even distribution	530	25%	133	50%	265	75%	398	100%	530	/
Observed distribution (police presence)	92	3.26%	3	7.22%	7	17.53%	17	58.76%	57	/
Observed distribution (crime)	171	1.75%	3	7.60%	13	29.24%	50	63.16%	108	2.17%
Motor vehicle theft	370	8.92%	33	29.19%	108	64.32%	238	75.95%	281	5.43%
Drug crimes	317	4.73%	15	20.50%	65	58.04%	184	75.39%	239	4.35%
Theft	141	1.42%	2	7.09%	10	21.99%	31	62.41%	88	4.35%
Assault	351	5.98%	21	24.22%	85	62.11%	218	78.63%	276	3.26%
Vandalism	415	10.36%	43	35.90%	149	67.71%	281	83.13%	345	3.26%
Burglary	426	11.97%	51	38.26%	163	69.01%	294	83.10%	354	2.17%

This finding suggests two future research paths. First, reliable measures need to be established to adequately assess the spatiotemporal focus of police on crime. By comparing policing programs in regard to their successfulness in deterring crime, the measures can be used to understand underlying spatiotemporal complexities and dependencies. Second, overall police presence needs to be investigated on a visit-by-visit basis. Given some evidence that optimal crime deterrent effects may be achieved by patrol visits between 10 and 15 min (Koper, 1995; Williams & Coupe, 2017), police presence needs to be assessed on this level. By doing so, we might be able to better understand how often police are at crime places and whether these everyday patrol visits are supporting crime deterrence.

In regard to the external validity of these findings, we urge researchers and police departments alike to attempt to replicate these novel findings of police concentration. As research has shown, focused police activity can deter crime effectively within high-crime hot spots (e.g., Braga et al., 2019a). The adaption of this knowledge into policing practice can be evaluated by first investigating spatiotemporal concentrations of police presence and then by modeling hot spots and hot times of crime and police against each other. Yet, this framework is not to be seen as a measure to impose surveillance on police officers but to act as a retrospective feedback loop to improve and validate contemporary policing practices. In some cases, police departments might focus their policing activity to the most crime-prone places but at the wrong times. In other cases, police officers might already be present in the right places and at the right time according to the local crime context and implementing innovative hot-spot policing programs ends up being costly with no practical benefits. We now have the capabilities to inform police chiefs, officers, and researchers alike on the evidence of spatiotemporal concentration of police presence.

Limitations

The study needs to be viewed within its quantitative context and understood in regard to the analyzed datasets. The developed map matching algorithm used static computation to assign each of the 77,680,983 signals to the appropriate street segment. A static approach was necessary due to computational limitations. Even though the static map matching approach is exposed to inaccuracies of GPS signals and could potentially assign signals incorrectly to street segments, these inaccuracies are negligible due to data size and precision. Our analysis focused on marked patrol cars of the APD ($n = 130$). These cars respond to emergency calls and take up patrol during the remainder of their shift. Thus, we cannot give any evidence in regard to policing activity of all police units (e.g., bike patrol, foot patrol, traffic patrol, unmarked service cars). However, our data are comprehensive for motor patrol units which make up most of policing resources.

In this analysis police presence represents the time police patrol cars were recorded at different street segments. Due to the fact that the GPS data is retrieved from Automatic Vehicle Locators, there is no information regarding the number of officers present. Thus, we report police presence in patrol time and not officer time (see the separate measures reported in, e.g., Williams & Coupe, 2017). GPS data do

not show what officers are doing and why they police certain places more (or less) than others (Wain & Ariel, 2014). This limitation can be overcome by developing and introducing novel spatiotemporal methodologies that combine data from, both, AVLs and officer-worn radios. These methodologies might enable us to differentiate between times when officers are conducting motor patrol and when they are engaging in foot patrol. As the amount of recorded police data continuously grows, understanding qualitative aspects of police patrol and its management becomes equally important.

Conclusions

This analysis examined the concentration of police presence and crime in a major European city and investigated both spatial and temporal patterns of that concentration. Police concentration and crime concentration follow somewhat similar patterns on the micro-level, but with potentially critical differences. By analyzing over 77 million GPS signals from police patrol cars, we have shown that police concentration and crime concentration are misaligned, both, temporally and spatially. This temporal misalignment consists of a lag of 3 h and could be addressed through consolidation of officer shifts.

Appendix

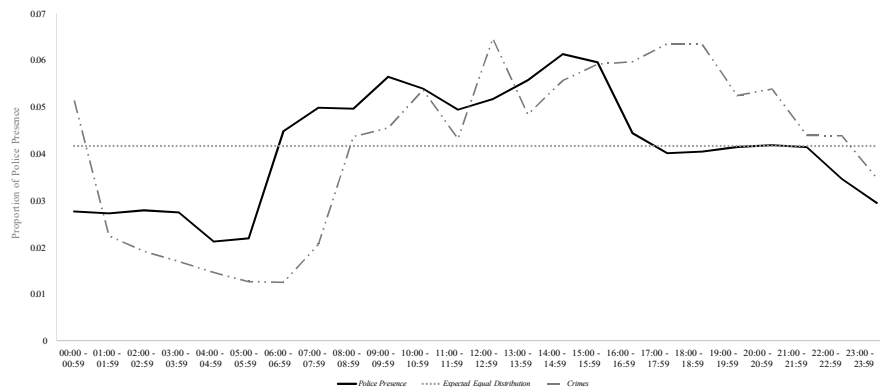


Fig. 8 Concentration of police presence and crime across police zones

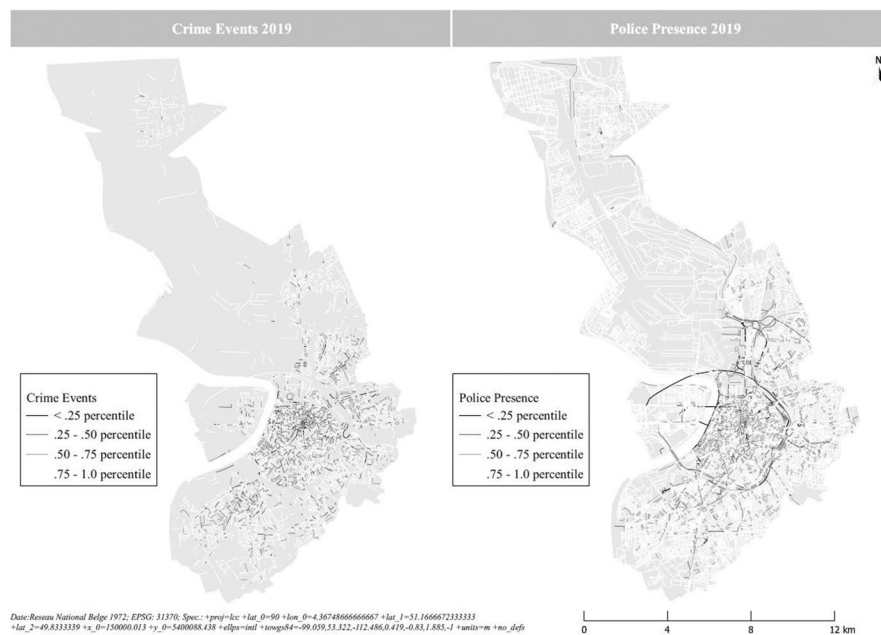


Fig. 9 Concentration of police presence and crime across street segments (a) and non-zero street segments (b)

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Availability of Data and Materials The research data (consisting of police recorded crime data and patrol car GPS data) and code cannot be publicly shared.

Declarations

Conflict of Interest The authors declare no competing interests.

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