Searching for Brazilian serial killers' home using a geographical offender profiling software

Denis Lino*
Federal University of Pernambuco

Abstract

Geographical offender profiling proposes that it is possible to predict the likely area where serial killers live by analyzing where and how they committed their crimes. This information could be used by police to prioritize suspects and make better use of their resources. Based on findings from years of research on the field, a software was developed to assist in this endeavor: Dragnet. While there have been tests of this software's applicability internationally, only one was conducted in Brazil but with a small sample. The present study sought to verify Dragnet's accuracy with a larger sample of Brazilian serial killers. Data was collected from police and court records of two capital cities. The sample consisted of 66 serial killers whose crime location and home address were available. In 84.9% of the cases the offender's home was within the area predicted by the software, and in 63.6% of the cases it was within the top areas suggested. While they show promise, these results are discussed as to how they could be improved and the importance of a qualitative analysis, considering factors that may influence offender's mobility. Future research projects are suggested to address these issues.

Keywords: Dragnet, Geographical Profiling, Offender Profiling, Psychology.

* Direct correspondence to the author: denisvictorlino@gmail.com, http://dx.doi.org/10.36889/IJCJ.2023.006
Received 14 April 2024; Revised 15 December 2023; Accepted 30 December 2023
INTERNATIONAL JOURNAL OF CRIMINAL JUSTICE, Vol. 5 Issue 2, December 2023, 59-91

Introduction

While some crimes happen at unknown or virtual locations, most of them are committed at a specific place: a person is kidnapped from the street, a house is burgled, a victim is approached by an offender on their way home from work, drug trafficking takes place in the parking lot of a supermarket. Information on where crime occurs can help police forces identify hotspots (geographical areas where most of the crimes are being committed) and act accordingly to reduce criminality in the area. Some examples include adding more police officers to survey that area, making changes to the environment, or even assisting potential victims to be safer when moving around that area. Although this approach focused on crime prevention is important, geographical information can also prove useful when investigating crimes as proposed by geographical offender profiling (geoprofiling). This is a field of research and practice, which aims to identify the location of serial offenders' unknown base of operation by analyzing how and where they committed their crimes (Lino, 2021). This spatial analysis technique considers the known locations of crimes committed by the same offender to determine the most probable area where they live, reside, or work (Rossmo & Rombouts, 2016).

There are dozens of scientific publications focused on providing a deeper understanding of the theoretical grounds that support a connection between crime locations and offenders' base, as well as empirical evidence of this link. Building upon Environmental Criminology theories and scientific evidence that dates as far back as 1932, geoprofiling now consists of a solid strategy to assist criminal investigations (Lino & Matsunaga, 2018). Some countries, such as the United Kingdom and Germany have expert Geographical Profilers working in police forces, whose main job is to generate geographical profiles and provide investigative recommendations (Knabe-Nicol & Alison, 2011).

Technological advances have also made the development of computerized decision-support tools possible. These tools are available to assist practitioners who wish to generate a geographical profile. Geoprofiling and, consequently, these decision support tools were developed to focus criminal investigation

efforts on identifying the base of serial offenders (a broad definition to encompass offenders who commit multiple crimes in a series). Due to this focus, they are significantly different from how other Geographic Information Systems (GIS) are used. GIS are routinely used to manage massive amounts of data from criminality in general, identify hotspots, visualize which types of crimes are committed in a specific place and at a specific time, identify crime patterns and trends, etc. However, they have not been designed to identify a serial offender's base (Butorac & Marinović, 2017).

Among the various types of serial offenders, serial killers have gained much attention in recent decades, mostly due to media portrayal in podcasts, TV series, movies, and novels. It has sparked the interest of both researchers and practitioners who wish to better understand these offenders and how to improve investigations to identify and stop their series of murders. Despite that, in Brazil, there is still a huge gap in our understanding of serial killers. There are nearly 47,000 murders each year, and only around 40% of them are solved, which hinders our ability to verify if there are active serial killers and who they might be (Fórum Brasileiro de Segurança Pública, 2022; Instituto Sou da Paz, 2022). The low clearance rates highlight the need for police forces to improve how they conduct their investigations and use every tool available at their disposal. Using geographical offender profiling software could prove useful in directing police resources to identify and imprison these offenders, which would bring justice to the families of the victims and increase residents' feelings of safety. However, before blindly using geoprofiling software, it is necessary to test whether it would assist an investigation. Therefore, the main goal of the present study was to verify the effectiveness of "Dragnet", a geographical profiling software, in identifying the home of serial killers in Brazil.

Theoretical Bases of Geographical Profiling

The main theoretical base that supports the application of Geographical Offender Profiling is the Crime Pattern Theory. It was developed by Brantingham and Brantingham in 1984 to explain how crimes are not random.

They are linked to how victims and offenders use and move around an area's environmental backcloth. There are two relevant concepts to help understand victims' and offenders' movement: nodes, which are the places where they spend most of their time during the day (home, work, pub, etc.), and paths, which refer to the routes they take to move between nodes (roads, streets, highways).

Furthermore, Crime Pattern Theory builds on knowledge from Cohen and Felson's (1979) Routine Activity Approach, which suggests that offenders will choose places to commit their crimes according to their routine activities. During their daily activities, offenders will undoubtedly move around the city, they must leave their homes to go to work, grocery shopping, and take part in leisure activities in places such as the beach, pool, bars, cinema, etc. As a result of their movement between nodes on a regular base, offenders develop detailed knowledge of that specific area, which is referred as "awareness space" (Brantingham & Brantingham, 1984). It represents their mental map, the locations they are familiar with, the presence of potential victims, and sources of risk for getting caught. A serial burglar who leaves his home to work every day will follow similar paths, during his trips he will become aware of his surroundings. He will learn which neighborhoods are wealthier and present more chances of higher financial gain, how many potential witnesses are in the streets around the time he is commuting, as well as which house appears to be less risky to target. According to this knowledge, he may opt to come back at a different time to attempt to rob the place (Lino & Matsunaga, 2018).

According to Crime Pattern Theory, geoprofiling is possible because offenders will most likely attack places that have some significance to where they live. First, offenders' awareness space is decisive in identifying potential targets. Offenders may be unaware of potential targets because they do not move around that area. The burglar from the last example may not attack other more suitable targets, which are less risky and produce high financial gain because he is unaware that they exist, since he does not travel to that area of the city. Second, awareness space is developed according to our routine activities, therefore, the crime location is connected to offenders' daily

activities and routines. For that reason, as van der Kemp (2021, p.37) suggests: "Predicting the anchor points of the offender based on where he committed his crimes is, in essence, the reversal of the prediction of where an offender commits his crimes that follows from the Crime Pattern Theory."

Another relevant theory that further supports geographical offender profiling is the Rational Choice approach, which suggests that offenders make rational decisions when considering how and where to commit a crime (Cornish & Clarke, 2016). It is expected that offenders will choose a victim, time, and place where they perceive their chances of being successful as higher than the probability of failure. They will weigh the pros and cons of committing a crime in that location, before deciding whether to move forward with their criminal actions. Indeed, research on robbers has highlighted their ability to assess the potential benefits and risks of attacking a specific target, as well as how to reduce the risks to optimize their chances of success (Morrison & O'Donnell, 1996).

In line with the Rational Choice approach, the Least Effort Principle, originally proposed by Zipf (1949), helps us understand offenders' movement to generate geographical profiles. This principle suggests that humans will attempt to do the least effort necessary to achieve their objectives. In the context of human movement, it means that we are likely to take shorter paths to reach our goals. Considering that criminals are also humans, bound by the same principles as everyone else, they will choose a location closest to their home to commit their crimes as long as they can find suitable victims and achieve their criminal objectives.

Taking these three theoretical approaches together, we can deduce that offenders actively decide where they will commit their crimes. However, this decision is bounded by cognitive and situational factors, such as the least effort principle and their knowledge of the area (awareness space). Accordingly, their awareness space will be constructed based on their routine activities. As a result, offenders do not commit crimes in random places, they have a pattern, which has a direct link to who they are, how they perceive the environment, how they move around the city, how they make their decisions, and, most importantly, where they may live (Rossmo & Rombouts, 2016).

Geographical Offender Profiling Empirical Base

Empirical research has been conducted to test the theoretical bases of geoprofiling and whether it is possible to fathom the link between a crime and its offender's base in an investigative useful way. The main body of empirical evidence is currently on the journey to crime of offenders, which is essentially how far from their homes they travel to commit a crime.

Nearly a century ago White (1932) conducted the first study analyzing how far burglars traveled to commit their crimes. Ever since then, multiple studies have replicated it using samples from different countries and various types of crimes. The main finding is that offenders do not usually travel far from their homes to commit their crimes (Martineau & Beauregard, 2016). In practice, researchers have found that criminals follow an exponential distance decay function (Figure 1). They will commit most of their crimes close to their home but the further they move away from it, the fewer crimes they are likely to commit (Willmott, Hunt, & Mojtahedi, 2021).

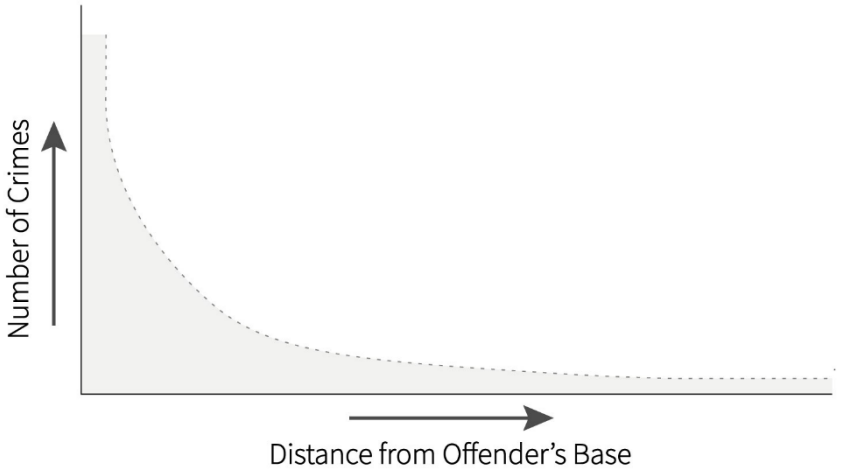

Figure 1: Example of an exponential distance decay.

It has also been identified that some offenders' and crime characteristics influence the distance traveled. Violent and interpersonal crimes are committed much closer to an offender's home when compared to property crimes or crimes motivated by financial gains. Levine and Lee (2012) found that, in the UK, violent criminals traveled on average 2.3km, while offenses motivated by financial gain had longer distances between the offender's home and crime location (2.9km). This relationship between the type of crime and distance traveled has also been found in the USA, where violent criminals traveled on average 2.1km less than property criminals (Ackerman & Rossmo, 2015). Similar findings were also identified in Canada, where violent criminals traveled a mean distance of 4.9km, while property criminals traveled on average 7.6km to commit their crimes (Wang, Lee & Williams, 2019).

Another important development in geoprofiling came from the work of Canter and Larkin (1993), who proposed the Circle Hypothesis (Figure 2). It is hypothesized that serial offenders will most likely have their base within their criminal range (a circular area created using the distance of the two farthest crimes of the series as the diameter). From this, serial offenders could be divided either as marauders or commuters. The first are serial offenders who leave their base searching for victims, attack them, and return home, they would have their base within their criminal range. The other type travels from their home to a different area, commits their crimes there, and travels back home, in this case, offenders' base and criminal range do not overlap.

The first study that proposed the Circle Hypothesis found that 87% of 45 serial rapists were marauders (Canter & Larkin, 1993). Additionally, Meany's (2004) study with 136 serial offenders showed that 93% of serial sex offenders, and 90% of serial arsonists were marauders. Eventually, empirical testing of the Circle Hypothesis has shown that it can work as a rather relevant 'rule of thumb', as it provides a good estimative when conducting a geographical offender profile of violent serial criminals (Willmott et al., 2021).

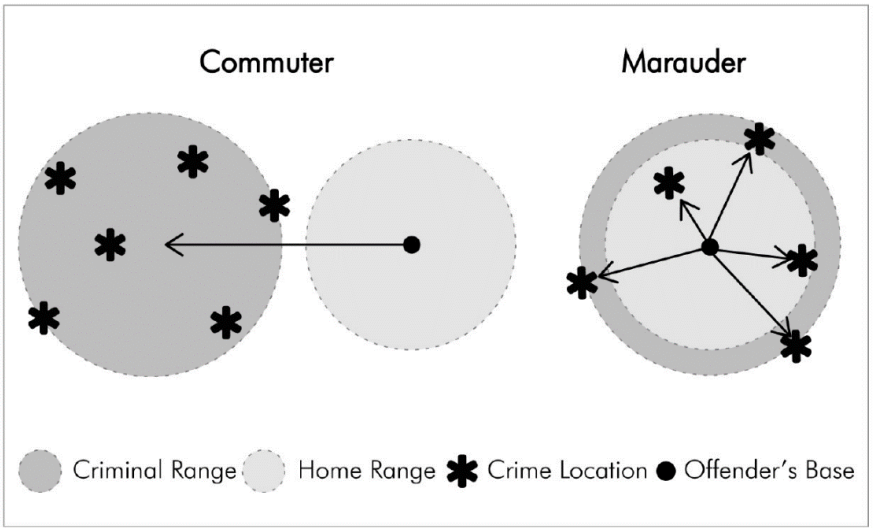

Figure 2: Example of the Circle Hypothesis

Individual factors such as offender's age have also been shown to be related to their journey to crime. Empirical evidence suggests that older offenders tend to travel longer distances to commit their crimes (Xiao, Liu, Song, Ruiter & Zhou, 2018). This could be explained by the fact that they may have a larger awareness space that has been built from years of moving around the city. Considering financial hindrance from younger populations that do not have a paid job and are dependent on others to fend for themselves, it could also be that older offenders have easier access to modes of transportation that facilitate travel and have more freedom to travel in search of a suitable victim without having to justify to others (e.g., parents or school) where they have been.

Similarly, offender's gender and race have also been found to be related to different patterns of movement. Most research has suggested that female offenders tend to travel shorter distances, while white offenders in the US have been found to travel longer distances when compared to African Americans and Hispanics (Ackerman & Rossmo, 2015; Xiao et al., 2018). A proposed explanation is that women and people from lower socioeconomic groups,

which is usually the case for non-white ethnicities in the US, have smaller activity spaces and thus, smaller awareness spaces.

Geographical Offender Profiling Software

Based on these advances in the field that allowed for the identification of how a crime location may be linked to an offender's base, and with the increased use of technology to assist humans in their everyday activities, computer software have been developed to assist geographical profilers and investigators. There are at least three different geoprofiling software available: Dragnet (Canter, Coffey, Huntley & Missen, 2000), Rigel Analyst (Rossmo, 2000), and CrimeStat (Levine, 2000). All three function in a very similar way: the user marks on the software where the crimes occurred, and the software uses algorithms based on distance decay functions to generate a heatmap. The heatmap indicates the degree of likelihood that the offender lives in that specific area, which varies from high to low probability. An example of Dragnet's output is presented in Figure 3 and should be interpreted as follows: red is the highest probability, grey is the lowest probability, and black squares are crime locations.

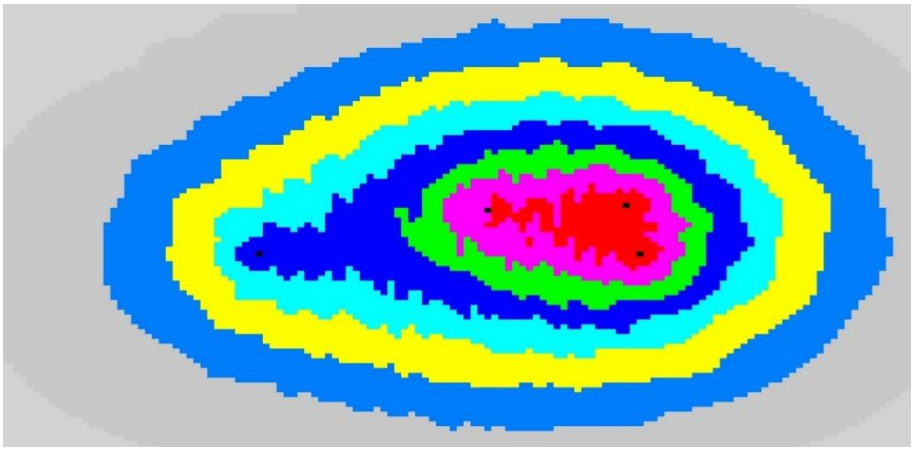

Figure 3: Example of a heatmap generated by Dragnet.

Although there are multiple computerized tools to assist a geographical offender profile, due to their similarities, they often achieve similar results (Berezowski, MacGregor, Ellis, Moffat & Mallett, 2021; Rich & Shively, 2004). Therefore, since the present study aims to assess the effectiveness of a computer software designed for geographical offender profiling, we will focus on only one of them: Dragnet.

It is important to note that the use of any geographical profiling software is not without its limitations. They are only useful when there is a series of crimes to analyze (Beauregard, Proulx & Rossmo, 2005), limiting their use to serial offenders. Additionally, the results require the interpretation from a human judge (geographical profiler or investigator), for example, to verify if it is possible for the offender to live in the prioritized area (Willmot et al., 2021).

Geographical Offender Profiling and Serial Killers

Many studies on geoprofiling have been conducted to analyze its applicability to serial killers. One set of research aims to verify the journey to crime of this type of offender. Considering that violent offenders travel shorter distances between their homes and crime locations, it is expected that serial killers will behave similarly. However, the mean distance traveled by these offenders is quite high. Lundrigan and Canter (2001) found that British serial killers traveled a mean distance of 18km, while serial killers from the USA traveled 40km on average. Snook, Cullen, Mokros, and Harbort (2005) found similar results in Germany, where serial killers traveled on average 16.8km.

The fact that serial killers have different reasons for committing their offenses when compared to one-time murderers is one of the proposed explanations for this difference. While murders are often the result of arguments that escalate to physical aggression, serial killing is usually more planned and targeting a specific type of victim. Thus, if serial killers wish to attack a specific target (e.g., children) they must travel to a location where the target is available (e.g., primary schools), which may not always be close to their home. Furthermore, hard-to-solve crimes, which usually require a lot of planning and preparation from the offender, have been linked to longer

journey to crime distances (Santilla, Laukkanen & Zappalà, 2007; Warren et al., 1998). Finally, serial killers' motivation may also play a role in the long distance traveled. These offenders are often sexually motivated and single sexual murderers have been found to travel very long distances to commit their crimes (nearly 30km on average), while sex offenders in general travel short distances (under 4km on average) (Martineau & Beauregard, 2016).

The longer distances traveled do not imply that geographical profiling of these offenders is impossible or even inaccurate. Serial killers have been found to have similar decision-making when moving around an area's environmental backcloth. As a result, they have similar patterns to other violent criminals as proposed by the Circle Hypothesis. Hodge and Canter (1998), for example, found that 86% of 126 US serial killers were marauders, Lino, Calado, Belchior, Cruz and Lobato (2018) identified that 66.7% of a sample of Brazilian serial killers were marauders, and Barreda's (2021) sample of 41 serial killers included 77.6% of marauders.

Tests of Dragnet's applicability on samples of serial killers have also shown good results. Canter et al. (2000) found that 51% of the serial killers analyzed had their home/base within 5% of the area suggested by Dragnet. Lino et al. (2018) found that in 66.7% of the serial killer cases analyzed, the offender's home was within one of the top two highest probability areas predicted by Dragnet. These findings suggest that Dragnet may be a useful solution to assist hard-to-solve serial killing cases.

Methods

Data was collected from two Brazilian cities: Salvador, the state capital of Bahia, which has approximately 2,857,000 habitants (around 3,900 habitants/km²), and Belo Horizonte, the state capital of Minas Gerais, with approximately 2,500,000 habitants (around 7,000 habitants/km²). In Salvador, there were 1,289 murders in 2016, while in Belo Horizonte there were 615 in the same year (Fórum Brasileiro de Segurança Pública, 2017). Regarding murder investigative success, there is no information about the cities, only

about their state. 58% of the murders committed in Minas Gerais in 2019 were solved, while in Bahia only 24% of them were solved (Instituto Sou da Paz, 2022). These differences may be because the largest criminal organizations in Brazil were created in the southeast area (where Minas Gerais is situated) but have recently moved to other areas of the country (such as Bahia) (Fórum Brasileiro de Segurança Pública, 2022). However, it could also be the result of financial investment, since Minas Gerais' Gross Domestic Product is more than twice that of Bahia, which directly influences the amount of money available to invest in better policing and to improve habitants' quality of life (Instituto Brasileiro de Geografia e Estatística, n.d.).

Police and court records were searched to identify serial killers. There are several proposed definitions for serial killers, however, the present study considers a serial killer as a person who unlawfully killed at least three victims in separate events, with a cooling-off period between them. This definition is in line with both the classical proposal by Douglas, Ressler, Burgess, and Hartman (1986) and recent developments in the field as proposed by Fridel and Fox (2018). The period considered for data collection varied according to each city due to the reliability of data and access granted by the institutions. As a result, data collected from Salvador ranged between 2011 and 2017, while in Belo Horizonte it ranged from 1999 and 2017.

A data collection protocol was created to ensure that every relevant information was extracted and considered for future analysis. Considering that the focus of the paper is on the effectiveness of a geographical profiling software, considerable emphasis was given to the geographical coordinates and information, such as the street address of where the crime occurred and where the offender lived. Independent variables that could provide greater insight into the applicability and effectiveness of Dragnet's performance were included in this protocol: offenders' gender, race, how many murders the offender committed, age at first murder, and the distance between crime location and offenders' home as measured by a straight line (as the crow flies).

Using the information about where the crimes took place for each series of murders, Dragnet was used to generate a heatmap for each one of them. The standard negative exponential function of the software was used since there

were no significant differences to other functions when tested on a sample of serial killers (Canter, et al., 2000; Canter & Hammond, 2006). After the results from this software were available, the home location for each serial killer was manually added using an image editor software. This allowed for verification of whether the home of the offender responsible for that specific series of crimes was within the area predicted by Dragnet, and how close it was to the top priority area.

Considering that Dragnet has eight different colors that range from grey to red (least to most likely area to find offender's home/base), the effectiveness of the software was categorized into four types, equal to that proposed by Lino et al. (2018): Ideal (offender's home within the red area), Fit (offender's home within the pink area), Weak (offender's home within the green, navy blue, light blue, yellow or dark blue area), Harmful (offenders' home within the grey area). However, due to the small sample size expected in each of the four groups, a new dependent variable named "Dragnet's Effectiveness" was created from these results to allow for more robust analyses. It was a dichotomous variable where a value of "0" was given when Dragnet was either Weak or Harmful, and a value of "1" was given when the result was Fit or Ideal.

Following this process, two types of statistical analysis were conducted. First, descriptive analyses were used to characterize the sample of serial killers and how well Dragnet could predict their home base. Second, Spearman's Rho correlations were conducted to analyze the association between the dichotomous variable "Dragnet's Effectiveness" and the independent variables. This research was submitted and approved by the Ethics Committee of the State University of Paraíba.

Results

In total, 66 serial killers were identified, which had enough information about the offender and crimes committed to allow the use of a geographical profiling software such as Dragnet. There were 20 serial killers in Salvador,

who had murdered 86 victims, the remaining 46 serial killers were identified in Belo Horizonte, and they were responsible for the murder of 248 victims. The mean age when these serial killers started their series was 20.47 (SD = 4.24) and only one of them was a female. A considerable part of the data regarding race was missing (43.9%) but analyses of the information available showed that 56.8% were black, 27% were brown-skinned (*pardo*, in Brazilian Portuguese), and 16.2% were white. Information about formal education was even more lacking, only 28.8% of the files had details of whether offenders had finished elementary or high school. Detailed information on sociodemographic data is presented in Table 1.

Table 1: Sociodemographic variables

Variable	n	Valid Frequency
Serial Killers per City		
Belo Horizonte	46	69.7%
Salvador	20	30.3%
Gender		
Male	65	98.5%
Female	1	1.5%
Race[a]		
Black	21	56.8%
Brown-skinned	10	27%
White	6	16.2%
Formal Education[b]		
Unfinished Elementary School	4	21.1%
Finished Elementary School	12	63.2%
Finished High School	3	15.8%

a: 43.9% of missing data.
b: 71.2% of missing data.

Regarding their crime series, offenders usually committed four murders (45.5%). Only 9.1% had killed the minimum number of victims to be considered a serial killer (3 victims), while 2 offenders were each responsible for the murder of 12 people (3%). In total, only 9.1% had killed at least eight victims and could be considered "prolific" serial killers according to the classification proposed by Fridel and Fox (2018). The serial killers traveled

on average 2.36km (median = 0.65km) from their home to the crime scene, with a minimum distance traveled of 0.03km and a maximum of 21.74km. Table 2 and Figure 4 present detailed data on serial killers' crime information and distance traveled.

Table 2: Serial killers' crime information

Variable	Mean (SD)	Median	Minimum	Maximum
Number of victims	5.06 (1.86)	4	3	12
Age of first murder	20.47 (4.24)	20	14	34
Distance travelled	2.36km (4.33)	0.65km	0.03km	21.74km

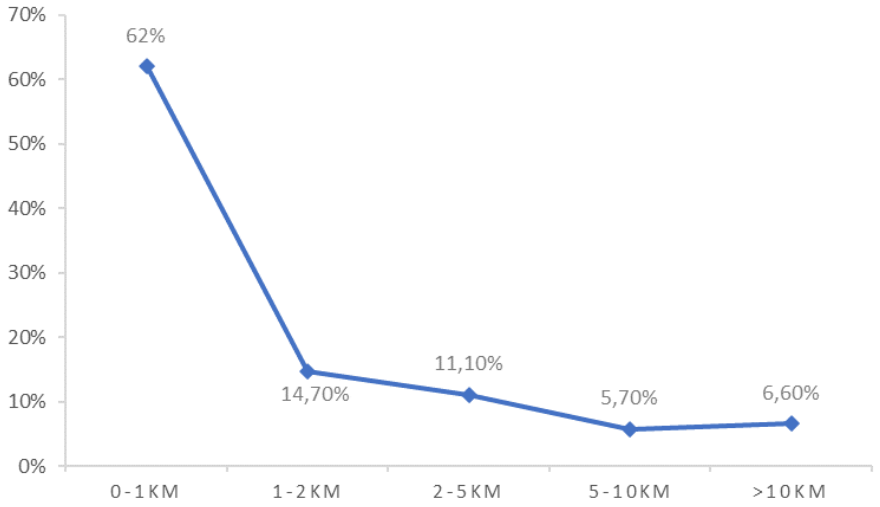

Figure 4: Distance traveled from offenders' base to commit murder.

Most of the serial killers displayed a marauder offending pattern (66.7%). Finally, Dragnet's results were as follows: 45.5% of serial killers had their home base within the red area, thus being categorized as an Ideal result, 18.2% were identified as a Fit result, while 21.2% of the results were Weak and 15.1% were considered Harmful. As a result, Dragnet achieved high effectiveness in 63.6%

of the cases and low effectiveness in 36.4% of the cases. Figures 5 and 6 provide examples of Dragnet's High Effectiveness and Low Effectiveness, respectively. In those figures, the offender's base is represented by the white circle. Table 3 details offenders' geographical movement patterns and Dragnet's results.

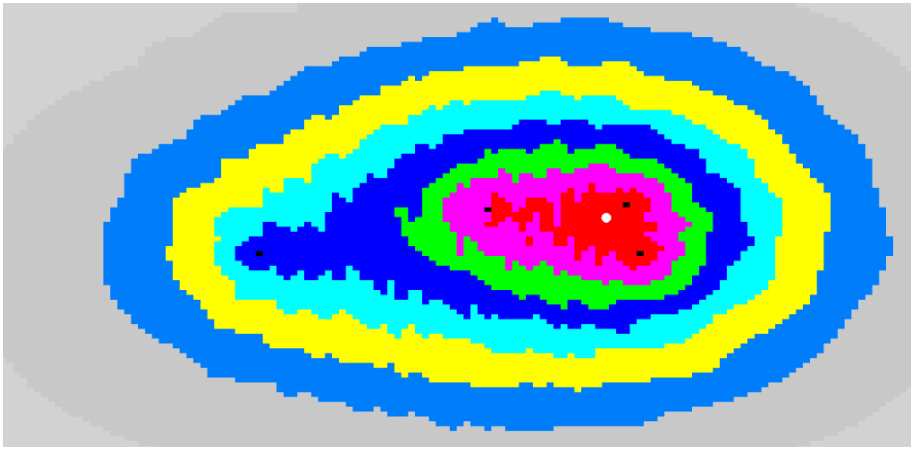

Figure 5: Example of Dragnet's High Effectiveness.

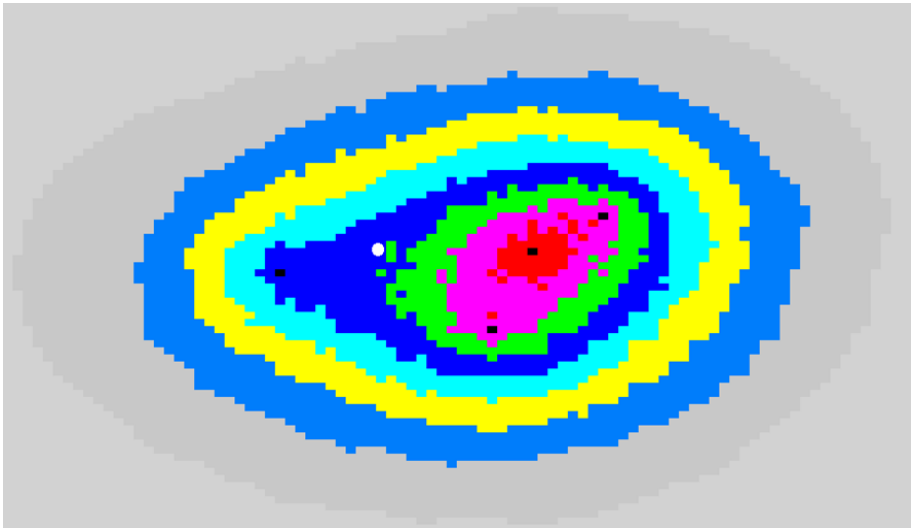

Figure 6: Example of Dragnet's Low Effectiveness

Table 3: Serial killers' movement pattern and Dragnet's results

Variable	n	Valid Frequency
Movement pattern		
Commuter	22	33.3%
Marauder	44	66.7%
Dragnet's results		
Ideal	30	45.5%
Fit	12	18.2%
Weak	14	21.2%
Harmful	10	15.2%
Dragnet's effectiveness		
High effectiveness	42	63.6%
Low effectiveness	24	36.4%

Correlation analyses were conducted to measure whether the dependent variable "Dragnet's Effectiveness" was related to any of the independent variables. A significant and positive correlation was found between Dragnet's results and the marauder offending pattern ($r = 0.535$, $p < 0.01$), with a negative correlation of equal strength to the commuter offending pattern ($r = -0.535$, $p < 0.01$). A negative significant correlation was found between Dragnet's results and the mean distance traveled to commit a murder ($r = -0.250$, $p < 0.05$).

There were no other significant correlations ($p > 0.05$) when analyzing "Dragnet's Effectiveness" and the other independent variables, such as gender, race, age on the first murder, and number of victims. Offenders' formal education was not considered for correlation analysis because more than 70% of the data was missing, which could lead to inaccurate results (Fraenkel & Wallen, 2009). A new dichotomous variable was also created to allow for the analysis of prolific serial killers (i.e., those who had killed at least eight victims). It was named "Prolific" with the following values: 0 = "non-prolific offender" and 1 = "prolific offender". However, there were no significant correlations identified between this new variable and the dependent variable "Dragnet's Effectiveness" ($p > 0.05$). Table 4 details the full correlation matrix.

Table 4: Full correlation matrix

	1	2	3	4	5	6	7	8	9	10	11
1. Dragnet's Effectiveness	1										
2. Marauder	.535[a]	1									
3. Commuter	-.535[a]	-1.000[a]	1								
4. Mean distance travelled	-.250[b]	-.438[a]	.438[a]	1							
5. Number of victims	.058	.220	-.220	.082	1						
6. Prolific	.020	.112	-.112	.111	.525[a]	1					
7. Male	-.094	-.088	.088	-.029	-.120	.039	1				
8. Black	.057	-.119	.119	.164	.162	-.191	[c]	1			
9. Brown-skinned	-.117	.098	-.098	-.097	-.159	.274	[c]	-.697[a]	1		
10. White	.065	.041	-0.41	-.103	-.026	-.073	[c]	-.504[a]	-268	1	
11. Age at first murder	.004	-.057	.057	.083	-.150	-.206	.114	-.098	.132	-.028	1

a: Correlation is significant at the 0.01 level (2-tailed)

b: Correlation is significant at the 0.05 level (2-tailed)

c: Unable to calculate because at least one of the variables is constant. There was no data on the single female participant.

Discussion

Studies on Brazilian serial killers are extremely scarce. The available information on the biggest database in the world on serial killers (Radford/FGCU Serial Killer Database) includes only 29 Brazilian serial killers, even though it considers any time or location where the crimes took place in Brazil, and a minimum victim threshold of two, instead of three (Aamodt, Leary & Southard, 2020). This is less than half of the serial killers that have been analyzed in the present study, even though only two cities were considered, and the definition of serial killers was much stricter. Therefore, it is extremely likely that a country as big as Brazil has at least as many serial killers as the USA, widely known as the country with the most serial killers.

Comparing the data from Brazil and that of the Radford/FGCU Serial Killer Database, allow us to verify up to which point international details on

serial killers are also found in Brazil. Worldwide, serial killers appear to be mostly men, with only 10.7% of them being women (Aamodt, Leary & Southard, 2020). In Brazil, this is also true, but the proportion seems to be much more prominent, considering that out of the 66 serial killers identified, only one of them was a woman, equivalent to 1.51% of the sample, or around 10x less than the proportion of female serial killers worldwide. While this information may lead us to think that Brazilian females are less likely to commit serial murder than females from other countries, it is also possible that the explanation for this difference resides in investigative results. Female serial killers are more likely than their male counterparts to kill using poison. Male serial killers, on the other hand, are more likely to kill using firearms and have unusual behaviors, such as necrophilia, torture, rape, and mutilation of the body (Aamodt, Leary & Southard, 2020). These differences may make it more likely for police forces to identify male perpetrators because they would leave more forensic evidence (e.g., sperm, DNA on victim's body), while women serial killers would be more difficult to detect since they would leave less identifiable traces that could link them to the murders.

Race of serial killers is another topic usually considered when characterizing these offenders. In the USA, half of the serial killers are white, while 40.4% are African American (Aamodt, Leary & Southard, 2020). The sample analyzed in the present study did not have information on the ethnicity of nearly half of the serial killers, preventing an accurate comparison. However, the available information points to a significantly different direction, given that 16.2% of the offenders were white, and over half were black. These results should be considered with caution, not only due to the lack of representative data but also due to cultural differences.

Brazil is known to be a country with mixed races, with less clear differences between White, Black, and Brown-skinned people than other countries from North America or Europe. Furthermore, black people in Brazil are more likely to live in areas where infrastructure, formal education, and basic human rights are lacking (Instituto Brasileiro de Geografia e Estatística, 2021; Oliveira & Souza, 2015). This could be linked to increased involvement with criminality, including crimes against the person such as homicide. A

national report showed that the proportion of white victims of murder caused by firearms was 10.6/100,000 white habitants, while for black victims it was 27.4/100,000 black habitants (Waiselfisz, 2016). Therefore, it is probable that the high proportion of black serial killers in this sample is a symptom of much deeper socioeconomic problems in Brazil.

It appears that Brazilian serial killers begin their crime series much younger than in other countries. The average age for a serial killer at the start of their series was 28 when looking at the serial killer database (Aamodt, Leary & Southard, 2020), while in Brazil they started 8 years earlier. The high levels of criminality, especially homicide, in Brazil may serve as a catalyst for earlier involvement in crime. There were around 47,000 murders in Brazil in 2021, there are geographical areas dominated by drug traffic cartels where dispute for territory leads to dozens of murders in the area (Fórum Brasileiro de Segurança Pública, 2021; 2022). This exposure to violence likely affects people from a very young age, desensitizing them to acts of aggression and resorting to violence to solve interpersonal conflicts. Three other factors may also be influencing this young age of offending. Aamodt, Leary, and Southard (2020), found that male and Black serial killers, as well as those that killed in relation to organized crimes, were younger at the beginning of their murder series. The sample analyzed in this paper consisted mostly of men and (possibly) black offenders, and the high number of drug-related murders in Brazil suggests that this motivation is also prevalent among Brazilian serial killers, a fact already identified by Lino and Lobato (2019).

The number of victims each offender killed shows that there were "regular" serial killers as well as "prolific" serial killers, those that killed more than seven victims (Fridel & Fox, 2018). These were only a small part of the sample, which indicates that the police have been able to prevent future murders from happening by arresting these individuals early in their series. While this is a fact to be praised, since serial killers cause terror and are responsible for taking multiple lives, it is likely that many more serial killers have not yet been identified by the police. Recent reports show that only 37% of the murders in Brazil are solved by the police, which means that around 29,600 of them remain unsolved each year (Instituto Sou da Paz, 2022). If we

consider, hypothetically, that merely 1% of the unsolved murders are due to serial killers (296 murders per year), and that each of them killed four people (the average number of victims identified in the present study), there would be 74 serial killers active in a year in Brazil. Whilst it is important to praise police for their work in the capture of these serial killers, it is also necessary to identify the perpetrator of the thousands of other murders that happened and correctly verify how many serial killers are active in a year in Brazil.

In this sense, Dragnet showed promising results that it could work as an effective decision-support tool in the investigation of serial killers in Brazil. It could accurately direct police resources in around 63% of the time (when the offender's base was within the first or second most likely area predicted by the software). Although one can argue that this percentage of accuracy is not good enough to defend its use in active investigations, in only 15% of the cases the offender's home was not within the area predicted by Dragnet. Even though the offender's home was not always within the highest area of probability predicted, should police forces work their way through the other areas suggested by Dragnet, they would find the home of the offender in 85% of the cases.

The results found in the present study are similar to those with another sample of Brazilian serial killers, where Dragnet accurately predicted the offender's home in 66.67% of the cases (when the offender's base was within the first or second most likely area predicted by the software) and had the offender's base within any of the predicted area 86.67% of the time (Lino et al., 2018). Faria (2020) found similar results testing the Rigel Analyst software using a sample of Brazilian serial offenders in general. In 85% of the cases, a known address of the serial offender was present in an area predicted by the geoprofiling software. These findings suggest that any geographical profiling software currently available would have around 85% accuracy in identifying a Brazilian serial offender's base within the heatmap generated, with a decrease in accuracy when considering the highest probability area suggested by the software.

For that reason, it is important to improve the software's effectiveness. Identifying which factors could contribute to a higher level of accuracy is one

possible way of improving Dragnet's effectiveness. Attempts to identify these factors using the data collected in the present study were less promising than expected. Correlation analyses identified only two factors that were significantly related to Dragnet's accuracy: offenders' movement pattern (marauder vs commuter) and offenders' short journey to crime distances. Other independent variables collected and discussed earlier, such as race, gender, age of first murder, and number of victims were not correlated to Dragnet's effectiveness.

Considering that Dragnet uses an exponential distance decay function to measure and create the heatmap, it is not surprising that the farther offenders travel from home, the less likely the software is to identify where they live. This was expected because the environmental theories that support the geographical offender profiling (and consequently Dragnet's calculations) propose that offenders do not travel far from home because of their awareness space, routine activities, and decision-making focused on minimum effort (Brantingham & Brantingham, 1984; Cohen and Felson, 1979; Cornish & Clarke, 2016). This theoretical perspective has also proven to be true under empirical scrutiny, given that most offenders travel short distances to commit their crimes (Martineau & Beauregard, 2016), which has also been found to be true for serial offenders in Brazil (Faria & Diniz, 2020; Lino et al., 2018)

This finding further suggests that if police forces have reason to believe that the offender would not travel far from home, Dragnet could be even more reliable. There are numerous studies on journey to crime that have established links between offender characteristics or offending behavior and distance traveled. Lino et al. (2018) have found that serial killers who use surprise as the method to approach/attack their victims are more likely to travel shorter distances. Andresen, Frank, and Felson (2014) have identified an inverted "U" shaped relationship between age and distance traveled. In other words, very young and older adults tend to travel shorter distances to crime when compared to young adults between 18 and 29 years of age. This type of information can be collected directly or inferred from the crime scene and could help police better discern when and how to use Dragnet, increasing its effectiveness. Therefore, it is not simply a matter of knowing simple "rules of

thumb" but understanding the underlying principles and theories of geographical profiling, the cognitive and social constraints on offender's decision-making, and being in touch with the available evidence to make the most of a geoprofiling software (Knabe-Nicol and Alison, 2011).

The link between offenders' movement patterns (marauder/commuter) and Dragnet's results found in the present study had already been identified by Lino et al. (2018), which suggests that this software's applicability is constrained depending on how the offender searches for his victims and uses his base/home. In Brazil, most of the serial killers are marauders. However, it is not as dominant as it has been found in other countries, such as the USA (86% of marauders serial killers; Hodge & Canter, 1998) or from an international sample of multiple countries (77.6% of marauders; Barreda, 2021). If the link identified in the present research is also present in international samples, it is possible that Dragnet could have reduced accuracy in Brazil when compared to other countries.

The fact that Dragnet is more suitable for marauder offenders is not surprising due to what is already known about offenders' decision-making and movement patterns. When Canter and Larkin (1993) first proposed the Circle Hypothesis, they based their assumptions on environmental criminology research, which suggested that offenders would act somewhat close to their homes due to the security provided by their familiarity with the area. In other words, offenders will act close to their homes because it is the least effort required but also because they are familiar with the area due to their routine activities. Furthermore, as Canter and Larkin (1993) suggest, the marauder model has a closer relationship between his home and crime locations when compared to the commuter model. Thus, Dragnet, which has been created as a computerized development of the Circle Hypothesis, is more effective when analyzing the most common offending model identified in previous research: the marauders (Canter, et al., 2000).

This connection between Dragnet's good results with marauders raises the question if police forces should invest in acquiring and training police officers to use geographical profiling software, or whether they should simply teach them the circle hypothesis. In other words, train them to look for

suspects living within the criminal range of the series of crimes. Bennell, Snook, Taylor, Corey, and Keyton (2007) tested this using a sample of police officers who were tasked with identifying the home location of serial burglars. They found that officers who were taught about the circle hypothesis were significantly better at predicting the offender's home base when compared to CrimeStat's results. Considering that Dragnet follows the same underlying principles as CrimeStat, it is possible that the results would be similar if Dragnet were the chosen geoprofiling software used for analysis by the researchers.

On the other hand, as Knabe-Nicol and Alison (2011) highlight, the work of producing a geographical offender profiling is more than putting "Xs" on a map. It consists of being able to identify the most relevant information collected in the investigation that could have inferential or predictive value, an attempt to identify criminal behavior and offenders' choices throughout their criminal act, such as how they chose the victim or location or why they decided to attack at a specific time. Another important piece of expertise required to produce a geoprofile is knowledge of the available scientific evidence on geographical offender profiling. It would make investigators aware of situations when software may not be favorable or how to best interpret its findings. This necessary knowledge is directly linked to the results of the present study, which has identified some situations where Dragnet has its best results.

Practical Implications

The need for better investigative practices in Brazil when it comes to murder, and serial murder is clear. The clearance rates for these types of crimes are far from ideal. The present research provides scientific evidence for the use of a new investigative tool to assist in the investigation of serial killings. Dragnet's accuracy was not perfect, but it was suitable for use in most cases. Therefore, during an active serial killer investigation, where police either have no suspects or too many suspects, knowledge of where this offender may live can prove fruitful. If there are currently no suspects, police

can use the heatmap generated by Dragnet to conduct house-to-house inquiries and identify anyone who could be linked to the killings. In a situation where there are too many suspects, the ones that live in high-probability areas predicted by Dragnet could be prioritized. Therefore, it allows police to use their resources more effectively, using science and evidence-based practices to increase their chances of apprehending the suspect faster while spending less money. It is important to note that a geographical profile produced from Dragnet is not supposed to be used as evidence of guilt or innocence but as a decision support tool to help police direct their efforts. It is not meant to replace traditional investigations but to act as another tool in the investigators' toolbox.

On the other hand, some precautions must be taken to ensure that Dragnet's use is optimal. Dragnet will have the best results when the offender is a marauder or when the journey to crime distances are shorter. Thus, officers must consider other factors when deciding whether and how to use this software. For example, if the police have reason to believe that an offender travels short distances because he is a teenager, Dragnet is more suitable. However, if the police have reason to believe that the offender is not from the area (e.g., the offender stands out from the people that circulate in the area where the crimes are committed), they are advised to use Dragnet with caution, since it is likely that the offender is not a marauder, and Dragnet's effectiveness is suboptimal.

Considering these issues, it is suggested that a geographical offender profiling software (Dragnet) can be used in active serial killer investigations in Brazil. However, any investigators who wish to produce geographical profiles need to go through proper training, since it requires thorough knowledge of the underlying theories, principles, and empirical evidence on the subject. Even though it may seem like a big effort, the results can have a cascade effect and improve murder clearance rates and public safety. First, if a serial killer is identified and Dragnet is used, the police will have more chances to conclude the investigation more quickly and spend fewer resources. Second, if this serial killer is arrested, multiple murder investigations will have been solved, increasing clearance rates, and there will probably be fewer

homicides because a serial offender has been stopped. Third, because of more effective investigations, police forces will have more resources (e.g., number of investigators available, quicker forensic analyses) and, therefore, more chances to solve other murders that may or may not have been committed by serial killers. Fourth, arresting serial killers and improving murder clearance rates will also lead to better perceptions of public safety by the community, improving quality of life and the relationship between police and the community.

Limitations and Future Directions

Despite the promising findings and potential applications, the present research also had limitations. One of those is outside of researchers' grasp, which relates to the low murder clearance rates and inaccuracy of police crime data. Less than half of the homicides in Brazil are solved, Minas Gerais had better clearance rates than Bahia, but it still fell below 60%. As a result, there is a plethora of data that is inaccessible and could represent a different group of serial killers, those that are not caught. This is a common limitation to any research in Investigative Psychology and Offender Profiling, which is constrained by what the police and courts have available. Similarly, out of those cases in which the serial killer was caught, some data that could prove useful to better understand Dragnet's effectiveness were missing, such as offenders' race, previous convictions, previous home addresses, etc. The fact that only one of the serial killers was a female also prevented detailed analyses of how gender could be related to offenders' movement and Dragnet's effectiveness.

Another limitation refers to research generalizability. The sample consisted of serial killers from only two cities, although the results were similar to studies in another Brazilian city, Brazil is a massive country, with many states and regions, each with its own culture, police force, and movement patterns. Further, considering the method used to assess Dragnet's accuracy in the present paper, it was possible to compare to other studies conducted in Brazil, but it did not directly compare to studies in other

countries.

Identifying those limitations is an important step to direct future research. Colleagues who wish to further explore the subject are invited to seek other independent variables that were unavailable or missing and could prove useful. Those include but are not limited to offenders' criminal history, past home addresses, work address, modus operandi, and victimology. It would also be beneficial to verify Dragnet's applicability on a sample of female serial killers to compare with the results presented in this paper and other research conducted in Brazil. One of the main findings of the present paper refers to Dragnet's improved accuracy when the offender is a marauder, thus, research that builds on current knowledge to identify whether the offender is a commuter or marauder based on crime scene evidence and criminal behavior will greatly advance the field. Finally, Dragnet was developed to assist in the investigation of serial crimes, it is important to test its applicability on other types of crimes, such as serial rape or serial burglary, which could potentially provide evidence of its use in different investigative scenarios.

Conclusion

The present study set out to verify the effectiveness of Dragnet, a geographical profiling software, in the identification of Brazilian serial killers' homes. Results showed promise as in most of the cases the offender's home was within the area predicted by the software, and in 6 out of 10 cases, it would be within the most likely areas predicted. This supports the use of such software in assisting police investigations when searching for serial killers. However, it is important to note that it should not be used without a qualitative analysis and interpretation that considers other aspects of the crime and offender that may increase or decrease the software's effectiveness.

The data collected also allowed for an analysis of Brazilian serial killers that had not yet been done and published in English. This study has shown that Brazilian serial killers start their crimes much younger when compared to international ones, fewer women are involved in this type of criminal activity,

and the race of these offenders is quite different in proportion. Explanations of these discrepancies are suggested according to the specificities of criminality and police investigation in Brazil.

Although these findings encourage the use of Dragnet to assist investigations of serial killings, there is still much that can and needs to be improved as we expect greater accuracy to optimize even further police efforts. It has been shown that there are individual differences among Brazilian and foreign serial killers, but do they also affect how offenders move, and how effective geographical profiling software are? It is important to generate as much evidence as possible on influencing factors of Brazilian serial killers' movement patterns and how these may impact Dragnet's efficacy.

References

Aamodt, M. G., Leary, T., & Southard, L. (2020). *Radford/FGCU Annual Report on Serial Killer Statistics: 2020.* Radford, VA: Radford University.

Ackerman, J. M., & Rossmo, D. K. (2015). How far to travel? A multilevel analysis of the residence-to-crime distance. *Journal of Quantitative Criminology*, *31*, 237-262.

Andresen, M.A., Frank, R., & Felson, M. (2014). Age and the distance to crime. *Criminology and Criminal Justice*, *14*(3), 314–333.

Barreda, D. S. (2021), The application of Newton and Swoope's geographical profile to serial killers. *Journal of Investigative Psychology and Offender Profiling*, *18*, 68-78.

Beauregard, E., Proulx, J., & Rossmo, D. K. (2005). Spatial patterns of sex offenders: Theoretical, empirical, and practical issues. *Aggression and Violent Behavior*, *10*(5), 579–603.

Bennell, C., Snook, B., Taylor, P.J., Corey, S., & Keyton, J. (2007). It's No Riddle, Choose the Middle: The Effect of Number of Crimes and Topographical Detail on Police Officer Predictions of Serial Burglars' Home Locations. *Criminal Justice and Behavior*, *34*(1), 119-132.

Berezowski, V., MacGregor, D., Ellis, J., Moffat, I. & Mallett, X. (2021). More than an offender location tool: Geographic profiling and body deposition sites. *Journal of Police and Criminal Psychology*, *38*, 3–19.

Brantingham, P. L., & Brantingham, P. J. (1984). *Patterns in crime*. New York, USA: Macmillan.

Butorac, K., & Marinović, J. (2017). Geography of crime and geographic information systems. *Journal of Forensic Sciences & Criminal Investigation*, *2*(4), JFSCI.MS.ID.555591

Canter, D., & Hammond, L. (2006). A comparison of the efficacy of different decay functions in geographical profiling for a sample of US serial killers. *Journal of Investigative Psychology and Offender Profiling*, *3*(2), 91-103.

Canter, D., & Larkin, P. (1993). The environmental range of serial rapists. *Journal of Environmental Psychology*, *13*(1), 63-69.

Canter, D., Coffey, T., Huntley, M., & Missen, C. (2000). Predicting Serial

Killers' Home Base Using a Decision Support System. *Journal of Quantitative Criminology*, *16*(4), 457-478.

Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: A routine activity approach. *American Sociological Review*, *44*, 588-608.

Cornish, D.B., & Clarke, R.V. (2016). The Rational Choice Perspective. In R. Wortley & M. Townsley (Eds.), *Environmental criminology and crime analysis*. (pp. 29-61). New York, USA: Routledge.

Douglas, J., Ressler, R., Burgess, A., & Hartman, C. (1986). Criminal profiling From Crime Scene Analysis. *Behavioral Sciences & The Law*, *4*(4), 401-421.

Faria, A.H.P. (2020). Perfil Geográfico (Geographic Profiling): Metodologia e Estudo de Caso de Criminosos em Série Atuantes em Belo Horizonte. *Revista Caminhos De Geografia*, *21*(74), 51-67.

Faria, A.H.P., & Diniz, A.M.A. (2020). Jornada para o crime: Análise das distâncias percorridas por criminosos para o cometimento de crimes. *REBESP*, *13*(1), 9-19.

Fórum Brasileiro de Segurança Pública. (2017). *11º Anuário Brasileiro de Segurança Pública*. São Paulo: Fórum Brasileiro de Segurança Pública.

Fórum Brasileiro de Segurança Pública. (2021). *14ª Anuário Brasileiro de Segurança Pública*. São Paulo: Fórum Brasileiro de Segurança Pública.

Fórum Brasileiro de Segurança Pública. (2022). *15ª Anuário Brasileiro de Segurança Pública*. São Paulo: Fórum Brasileiro de Segurança Pública.

Fraenkel, R. J., & Wallen, E. N. (2009). *How to Design and Evaluate Research in Education* (7th ed.). San Francisco, USA: McGraw-Hills.

Fridel, E.E., & Fox, J.A. (2018). Too few victims: Finding the optimal minimum victim threshold for defining serial murder. *Psychology of Violence*, *8*(4), 505–514.

Hodge, S., & Canter, D. V. (1998). *Predatory Patterns of Serial Murderers*. Internal Report, Centre for Investigative Psychology, Liverpool.

Instituto Brasileiro de Geografia e Estatística (2021). *Tabela 2.1 - Rendimento domiciliar per capita médio e mediano, por sexo e cor ou raça, com indicação dos coeficientes de variação, segundo as Grandes Regiões e as Unidades da Federação - Brasil – 2020.* Instituto Brasileiro de Geografia e Estatística.

Instituto Brasileiro de Geografia e Estatística (n.d.). *Produto Interno Bruto*. Retrieved from https://www.ibge.gov.br/explica/pib.php

Instituto Sou da Paz. (2022). *Onde Mora a Impunidade? Porque o Brasil precisa de um Indicador Nacional de Esclarecimento de Homicídios. Edição 2022*. Retrieved from https://soudapaz.org/wp-content/uploads/2022/08/OndeMoraAImpunidade.pdf.

Knabe-Nicol, S., & Alison, L. (2011). The cognitive expertise of Geographic Profilers. In L. Alison & L. Rainbow (Eds.), *Professionalizing offender profiling* (pp. 126-159). New York, USA: Routledge.

Levine, N. (2000). *CrimeStat: a spatial statistics program for the analysis of crime incident locations (version 1.1)*. Annandale, USA: Ned Levine & Associates; Washington, USA: National Institute of Justice.

Levine, N., & Lee, P. (2012). Journey-to-crime by gender and age group in Manchester, England. In M. Leitner (Ed.), *Crime modeling and mapping using geospatial technologies* (pp. 145-178). Dordrecht: Springer Netherlands.

Lino, D., & Matsunaga, L. H. (2018). Perfil criminal geográfico: novas perspectivas comportamen-tais para investigação de crimes violentos no brasil. *Revista Brasileira de Criminalística*, *7*(1), 7-16.

Lino, D., Calado, B, Belchior, D., Cruz, M., & Lobato, A. (2018). Geographical offender profiling: Dragnet's applicability on a Brazilian sample. *Journal of Investigative Psychology and Offender Profiling*, *15*(2), 149-161.

Lino, D., & Lobato, A. (2019). Vitimologia Forense: As Vítimas de Assassinos em Série. *Revista Eletrônica de Direito Penal e Política Criminal*, *7*(1), 93-115.

Lino, D. (2021). *Criminal Profiling/Perfil Criminal: Análise do Comportamento na Investigação Criminal*. Curitiba, PR: Editora Juruá.

Lundrigan, S., & Canter, D. (2001). Spatial patterns of serial murder: An analysis of disposal site location choice. *Behavioral sciences & the law*, *19*(4), 595-610.

Martineau, M., & Beauregard, E. (2016). Journey to murder: examining the correlates of criminal mobility in sexual homicide. *Police Practice and Research*, *17*(1), 68–83.

Meaney, R. (2004). Commuters and marauders: An examination of the spatial

behavior of serial criminals. *Journal of Investigative Psychology and Offender Profiling*, *1*(2), 121–137.

Morrison, S., & O'Donnell, I. (1996). An analysis of the Decision-Making practices of armed robbers. In R. Homel (Ed.), *The Politics and Practice of Situational Crime Prevention*. New York, USA: Criminal Justice Press.

Oliveira, J.R., & Souza, R.M. (2015). Direito à moradia: reflexões sobre território e compromisso com o maior contingente populacional brasileiro. *Cadernos De Ciências Sociais Aplicadas*, *11*(17), 207-222.

Rich, T., & Shively, M. (2004). *A methodology for evaluating geographic profiling software*. Retrieved from https://www.ojp.gov/pdffiles1/nij/grants/208993.pdf.

Rossmo, D.K., & Rombouts, S. (2016). Geographic profiling. In R. Wortley & M. Townsley (Eds.), *Environmental criminology and crime analysis.* (pp. 162-179). New York, USA: Routledge.

Rossmo, K. (2000). *Geographic Profiling*. Boca Raton, USA: CRC Press

Santtila, P., Laukkanen, M., & Zappalà, A. (2007). Crime behaviours and distance travelled in homicides and rapes. *Journal of Investigative Psychology and Offender Profiling*, *4*(1), 1-15.

Snook, B., Cullen, R. M., Mokros, A., & Harbort, S. (2005). Serial murderers' spatial decisions: Factors that influence crime location choice. *Journal of Investigative Psychology and Offender Profiling*, *2*(3), 147-164.

van der Kemp, J.J. (2021). The modus via of sex offenders and the use of geographical offender profiling in sex crime cases. In N. Deslauriers-Varin & C. Bennell (Eds.), *Criminal Investigations of Sexual Offenses: Techniques and Challenges*. (pp 33–48). Gewerbestrasse, Switzerland: Springer International Publishing.

Waiselfisz, J.J. (2016). *Mapa da Violência 2016: Homicídios por armas de fogo no Brasil.* Brasília, BR: Flacso Brasil.

Wang, L., Lee, G., & Williams, I. (2019). The Spatial and Social Patterning of Property and Violent Crime in Toronto Neighbourhoods: A Spatial-Quantitative Approach. *ISPRS International Journal of Geo-Information*, *8*(1), 51–69.

Warren, J., Reboussin, R., Hazelwood, R. R., Cummings, A., Gibbs, N., & Trumbetta, S. (1998). Crime scene and distance correlates of serial

rape. *Journal of Quantitative Criminology*, *14*(1), 35-59.

White, R.C. (1932). The relation of felonies to environmental factors in Indianapolis. *Social Forces*, *10*(4), 498–509.

Willmott, D., Hunt, D., & Mojtahedi, D. (2021). Criminal Geography and Geographical Profiling within Police Investigations–A Brief Introduction. *Internet Journal of Criminology, 2021*, 1-24.

Xiao, L., Liu, L., Song, G., Ruiter, S., & Zhou, S. (2018). Journey-to-Crime Distances of Residential Burglars in China Disentangled: Origin and Destination Effects. *ISPRS International Journal of Geo-Information, 7*(8), 325.

Zipf, G.K. (1949). *Human Behavior and the Principle of Least Effort*. Menlo Park, USA: Addison-Wesley.