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Exploring Directional Consistency in Offending: The Case of Residential Burglary in The Hague

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ABSTRACT
Many aspects of human behaviour are remarkably stable across times, places and situations. Repetition and predictability also characterises our geographical behaviour. Prior research has confirmed that criminal behaviour is no exception. Offenders tend to recidivate, and recidivists tend to be behaviourally consistent in many aspects, including geographical ones. The present study assesses directional consistency in offending. It reviews the literature on directional consistency. It proposes an improved measure of directional consistency, and empirically uses this measure to explore directional consistency amongst a set of 268 burglars in The Hague. Copyright © 2012 John Wiley & Sons, Ltd.

Key words: journey-to-crime; behavioural consistency; spatial analysis; directional statistics; burglary

INTRODUCTION

Human geographical behaviour is remarkably stable and predictable. Research that followed the spatial tracks of a sample of mobile phone users concluded that ‘there is a potential 93% average predictability in user mobility, an exceptionally high value rooted in the inherent regularity of human behaviour’ (Song, Qu, Blumm, & Barabasi, 2010, p. 1021). Thus, if we know a person’s whereabouts in the recent past, we can correctly predict their future whereabouts most of the time. Behavioural consistency also applies to criminal behaviour. Not only do many offenders recidivate, but also, features of their target choices and modus operandi often recur in subsequent crimes (Davies, 1992; Salfati & Alicia, 2005; Tapper, 2008; Woodhams, Hollin, & Bull, 2007).The strong predictability of human geographic behaviour raises the question whether this finding also holds for geographic offending behaviour, in particular to the journey-to-crime. To what extent is the journey-to-crime characterised by consistency?

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Three aspects of the journey may be characterised by consistency: destination, distance and direction. The present study focused on *directional consistency*, which can be defined as a serial offender's tendency to commit offences at places that are located in the same direction from his or her anchor point (but not necessarily at the same distance). People's behaviour is largely determined by routines and habits (Gärling & Axhausen, 2003; Golledge, 2002; Golledge & Stimson, 1997; Schlich & Axhausen, 2003). The routes between places that are regularly visited, for example work or school, influence the locations of other activities in two distinct ways. First, because they are time-constrained, people will decide to perform other activities along these routes (Hanson & Hanson, 1981; Hanson & Huff, 1988). For example, to save time, many people go shopping on the way home from work. Second, during their daily routines, they develop mental maps (e.g. Gould & White, 1974; Tobler, 1976; Tuan, 1975) and knowledge about the areas they cross. When they become familiar with these areas, the area becomes part of their awareness space. For some, this includes knowledge about criminal opportunities, such as attractive potential targets (Brantingham & Brantingham, 1981, 1993). The concept of a criminal awareness space may be narrowed down further to the concept of criminal 'search space', the part of the awareness space that contains only those places that are viewed as being above the minimum threshold of profitability and safety (Rengert & Wasilchick, 1985).

When people repeatedly visit the same places, they also tend to repeatedly travel along the same routes (Gärling & Axhausen, 2003). If it can be assumed that individuals are aware of their routes and the areas within visual range of their routes, one may expect the area between their homes and their habitually visited places, belonging to their mental map and awareness space. This leads to the expectation of directional consistency in offending behaviour: criminals tend to offend near their homes, near regularly visited places and on the routes between these nodes.

The objectives of the study were to review the prior literature on directional consistency in crime (Section 2), to develop an improved measure of directional consistency (Section 3) and a method to test it against random directionality (Section 4) and to assess levels of directional consistency in a sample of residential burglars in The Hague, The Netherlands (Sections 5 and 6). Section 7 discusses the findings against the background of what we know about the geography of crime and its perpetrators, including linkage analysis and geographic profiling.

JOURNEY-TO-CRIME AND DIRECTIONAL CONSISTENCY

Offenders who commit two or more crimes can display spatial consistency in their journey-to-crime. Like other studies that investigate the journey-to-crime, this study did not record actual travel behaviour, but was confined to measuring the distance between the homes of offenders and the locations of their offences. As long as the offender's home is a fixed anchor point, three aspects of geographic offending behaviour can be distinguished that may be characterised by consistency: destination, distance and direction.

The *destination* of an offence is the geographic location where it takes place. The *distance* is the Euclidian or straight-line distance between the offender's home and the destination. The *direction* is the angle between the home-offence line and a baseline reference (e.g. the equator). The destination is the most informative aspect as it implies both the distance and the direction from home.

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Destination consistency occurs if offenders repeatedly choose the same location to commit an offence. For example, a car thief may one week steal from a car in a parking lot and return to the same parking lot to steal another car the week after. A street robber who attacked his previous victim at a train station may return to the same train station next time to rob another traveller. The repeat incident may represent a repeated attack against the same victim, but the essence of location consistency is that the offender returns to the same place where he offended before. Some research findings suggest destination consistency. Bernasco (2008) and Bowers and Johnson (2004) demonstrate that the large majority of repeat and near repeat burglary victimisations are perpetrated by the same offenders who return to the locations of their prior burglaries, especially those repeat and near repeat victimizations that take place during the first days and weeks after the initial event. Additional support comes from case linkage studies that concluded that spatial and temporal proximity of offences are better predictors for involvement of the same offender than other measures of behavioural consistency (Goodwill & Alison, 2006; Tonkin, Woodhams, Bull, Bond, & Palmer, 2011).

Distance consistency occurs if offenders repeatedly commit offences at approximately the same distance from their homes. Although there are many dozens of studies that address the home-offence distance, there are only three studies that actually investigate distance consistency in serial offenders (Smith, Bond, & Townsley, 2009; Townsley & Sidebottom, 2010; Van Daele, 2010). The three studies are remarkably similar in their conclusion that offenders are much more distance consistent than had been assumed by those who interpreted the aggregated distance decay function as an individual phenomenon. Indicative of distance consistency, within-offender distance variation appears to be much smaller than between-offender distance variation.

Directional consistency is the third type of spatial consistency and a central focus of the research described here. Directional consistency occurs if a serial offender repeatedly commits crimes at locations that are situated in the same direction from his or her main anchor point. This may occur if all his habitual travelling occurs in the same direction from his home, for example if the individual lives at the outskirts of a city and all professional and leisure activities require inbound travel. Directional consistency may also occur if the individual habitually travels in several directions, but only one route offers attractive criminal opportunities. Finally, it may be that other aspects contribute to an offender showing directionally consistent behaviour, for example the location of the accomplice's residence or another convergence setting (Andresen & Felson, 2010; Bernasco, 2006; Felson, 2003).

Clearly, destination consistency implies distance consistency as well as directional consistency, but distance consistency or directional consistency alone is not enough to imply destination consistency.

An extensive literature search identified four studies that address directional consistency. Lundrigan and Canter (2001) investigate the disposal site locations of serial murders. They find that murderers dispose the bodies of their victims precisely in the opposite direction from the preceding one. Goodwill and Alison (2005) study serial murder, rape and burglary and compare the angles between two subsequent offence sites targeted by the same criminal. They find the angle between two consequent murders being consequently larger than it is for rape and burglary. Both these studies use sequential angulation to define directional consistency. In sequential angulation only the angles between pairs of consecutive offences are taken into account.

In two other studies, the directional consistency is calculated as the largest angle between any pair of crimes in the series. Kocsis *et al.* (2002) find evidence for directional consistency

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because they establish that multiple burglaries lie in a rather narrow 'corridor'. Lundrigan and Czarnomski (2006) find similar results, demonstrating that the majority of offenders follow a rather narrow spatial corridor in their crime series. In sum, we found two different measures of directional consistency and mixed evidence for its existence.

One other study (Costanzo, Halperin, & Gale, 1986) investigated whether criminals living nearby each other travelled in similar directions. This study is excluded here because it concerns the offence locations of different offenders and not crime series involving the same offender.

In the next section, we will argue that both measures of directional consistency that have been used in the literature—the average angle between pairs of consecutive offences in a series and the largest angle between any offence pair in a series—fail to fully capture the nature of directional consistency. We propose an improved measure.

A NEW MEASURE OF DIRECTIONAL CONSISTENCY

Although directional data are not very common in the social sciences, they are frequently analysed in the natural and medical sciences such as biology and geology. For example, they occur in bird migration research and in pollutant transport research in biology (e.g. Helbig, 1991). In the social and behavioural sciences, they sometimes appear in the form of circular data, in particular in the representations of daily, weekly, monthly or yearly temporal cycles. Directional and circular data have properties that require a separate branch of statistics called directional statistics or circular statistics (Fisher, 1993; Jammalamadaka & SenGupta, 2001; Mardia & Jupp, 2000). For example, 0° (or equivalently 360°) would suffice as a measure of central tendency for an angle of 2° and one of 358°, but 180° would certainly not qualify (as it is approximately the opposite direction), although it is the mean of 2° and 358°. Circular statistics suits circular data, but fortunately, very little circular statistics is required to support our argument for an improved measure of directionality.

Of the four studies that have investigated directional consistency in offence series, two have measured directional inconsistency as sequential angulation (Alasdair. M. Goodwill & Alison, 2005; Lundrigan & Canter, 2001) and two others as maximal angulation (Kocsis *et al.*, 2002; Lundrigan & Czarnomski, 2006).

We believe both measures fail to capture directional consistency sufficiently and propose an improved measure. Before describing the advantages of the new measure, we address the weaknesses of the sequential and the maximal angulation measures.

First, however, we discuss the definition of the 'angle' between two offences, a definition that is used in all three measures. In all three measures, the angle between two offences is defined by the offender's home (the vertex) and the two rays connecting the vertex to the two offences. The angle between the offences is defined to be always the absolute value of the smallest angle that can be formed by the three points. For example, in Figure 1, the circle labelled 'H' represents the offender's home, and the other two circles labelled '1' and '2' represent the locations of two offences. Both α and β form an angle between offences 1 and 2, but α is the smallest angle.

Mathematically, the smallest angle between two offences is calculated as follows using Cartesian geometry:

$$\alpha = \left| \left| \tan^{-1}\left(\frac{y2 - y0}{x2 - x0}\right) \right| - \left| \tan^{-1}\left(\frac{y1 - y0}{x1 - x0}\right) \right| \right|$$

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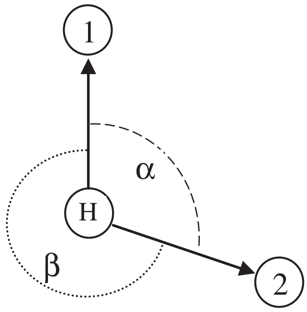

Figure 1. Smallest angle (α) and largest angle (β) between two offences.

In which α is the angle expressed in radians, ($x0$, $y0$) are the coordinates of the offender's home, and ($x1$, $y1$) and ($x2$, $y2$) are the coordinate pairs of the two offences, respectively. To convert radians to degrees, simply multiply by 180/π. Because most non-mathematicians are more familiar with degrees than with radians, we will express in the remainder angular quantities in degrees.

To calculate *sequential angulation* in a series, one calculates the mean angle between all pairs of consecutive crimes. In a series of *n* crimes, there are *n*-1 pairs of consecutive crimes.

Consider, for example, panel 2a in Figure 2. The circle with an 'H' at the centre represents the offender's home, the other circles represent the locations of the offences committed by the offender and the numbers represent the order in which they were committed. As four offences were committed, there are three pairs of consecutive offences (1 and 2, 2 and 3, and 3 and 4). All three pairs are 90° apart so that the average angle, the sequential angulation, equals 90°.

Panel 2b in Figure 2 displays a different pattern, one in which the offender alternates between two directions only. This series also consists of four offences, again all three consecutive pairs are 90° apart, and therefore, its sequential angulation measure also equals 90°.

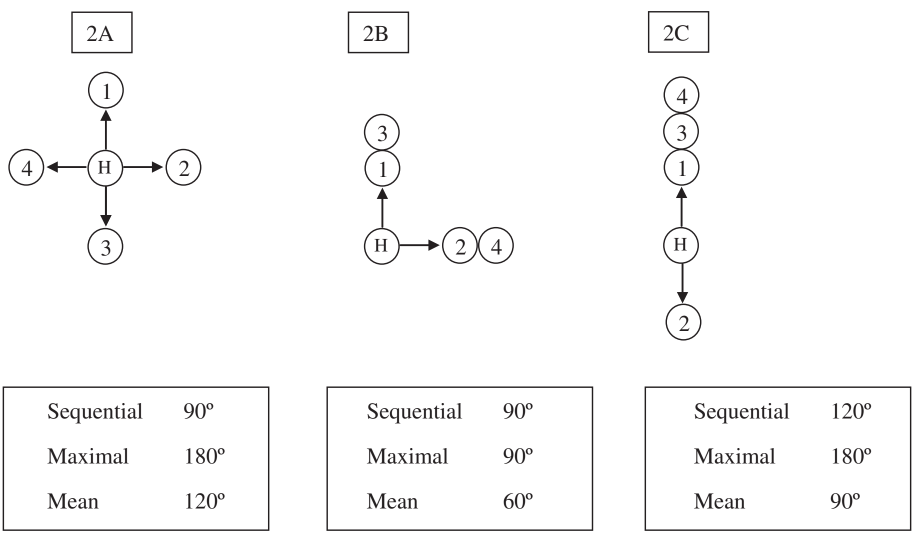

Figure 2. Sequential, maximal and mean angulation in three crime series.

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The weakness of the sequential angulation measure is that it myopically focusses on the angles between consecutive offences and thereby ignores angles between non-consecutive offences. As a result, the sequential angulation measure rates the patterns in panels 2a and 2b both as 90°, despite the fact that offence pair 1 and 3 and offence pair 2 and 4 are perfectly directionally consistent (have zero angle) in panel 2b but not in panel 2a. A better measure would rate the pattern in panel 2b as more directionally consistent than the pattern in panel 2a.

To calculate *maximal angulation* in a series, one calculates the largest angle between any pair of directions in the series.

Consider again panel 2a in Figure 2. The maximal angulation is 180°, which is the angle between offences 1 and 3 and also between offences 2 and 4. Panel 2c displays a different pattern, in which offences 1, 2 and 4 are in the same direction, whereas offence 2 stands out because it is in the opposite direction. The maximal angulation of this pattern is also 180°, just as in panel 2a. The weakness of the maximal angulation measure is that it myopically focuses on the largest angle and ignores all other pairs of offences. As a result, maximal angulation rates the patterns in panels 2a and 2c as equal, despite the fact that offence pairs 1–3, 1–4 and 3–4 are perfectly directionally consistent in panel 2c but not in panel 2a. A better measure of directional consistency would rate the pattern in panel 2c as more directionally consistent than the pattern in panel 2a.

To calculate the measure we propose, *mean angulation*, one calculates the average angle α_{av} between all $n(n-1)/2$ possible pairs of offences in the series. In panel 2a, mean angulation is 120°. This is the average of the angles between the offence pairs 1 and 2 (90°), 1 and 3 (180°), 1 and 4 (90°), 2 and 3 (90°), 2 and 4 (180°) and 3 and 4 (90°). In panel 2b, mean angulation is 60°, the mean of pairs 1 and 2 (90°), 1 and 3 (0°), 1 and 4 (90°), 2 and 3 (90°), 2 and 4 (0°) and 3 and 4 (90°). In panel 2c, it equals 90°, the average of the angles between the offence pairs 1 and 2 (180°), 1 and 3 (0°), 1 and 4 (0°), 2 and 3 (180°), 2 and 4 (180°) and 3 and 4 (0°). Mean angulation better captures directional consistency than both sequential angulation and maximal angulation. It is able to differentiate between the three patterns in Figure 2-2a, 2b and 2c- whereas the two alternative measures can each only differentiate between two of the three patterns.

TESTING DIRECTIONAL CONSISTENCY

Smaller mean angulation α_{av} indicates greater directional consistency as it implies that the offender tends to always travel in approximately the same direction to crime locations. Thus, directional consistency is maximal if $\alpha_{av} = 0$ and all offences are located exactly in the same direction (but not necessarily at the same location). Directional consistency is minimal if $\alpha_{av} = 180°$, a situation that can only occur in a series of two crimes that are in opposite directions from the anchor point.

For any measured level of directional consistency, it may be necessary to test whether it differs significantly from the level of directional consistency that would be observed if the directions had been randomly chosen, that is, if for every offence the offender randomly chooses a direction from the uniform distribution between 0 and 360°. In order words, in evaluating the specific pattern of angles in an offence series, a first indication of directional consistency is the test of whether α_{av} is smaller than the expected value of α_{av} under the H_0 hypothesis of completely random directional choices. This test must take into account the number of offences n in the series because the sampling distribution of α_{av} under randomness depends on the number of offences n in the series.

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Because in directional statistics many (sampling) distributions cannot be analytically derived, we used a simulation to approximate it. To calculate the sampling distribution of α_{av} under random direction choice, for each offence series length n between 2 and 25, we simulated 1 million series by first drawing random directions from a uniform distribution between 0° and 360°, and subsequently calculating the average angle between the directions of all $n(n-1)/2$ offence pairs. Figure 3 graphically displays the densities of these sampling distributions, with angles on the horizontal axis expressed in degrees.

For series of two offences, this distribution is completely flat because any angle between 0° and 180° is equally likely, and angles lower than 0° and larger than 180° cannot occur. For a series of three offences, the minimum angle is again 0° but the maximum is only 120°, and the distribution is strongly left-skewed.

For each value of n, the expected value of α_{av} is 90°. Thus, in case of random direction choices, the expected value of α_{av} is always 90°, independently of the number of offences in the series. Thus, every pattern with α_{av} being smaller than 90° may be considered directionally consistent, whereas patterns with α_{av} being larger than 90° are anti-directional and patterns with α_{av} being equal to 90° may be called adirectional. The standard error, however, decreases with n. The skewness also decreases (becomes more negative) with n, indicating it is getting more left-skewed as n increases. Using these simulated sampling distributions, it is easy to verify whether any particular observed α_{av} should be considered as a significant level of directional consistency. The value of α_{av} of a series of n offences should be amongst the 1% (or in case of a less conservative threshold, 5%) lowest α_{av} values in the sampling distribution calculated for size n.

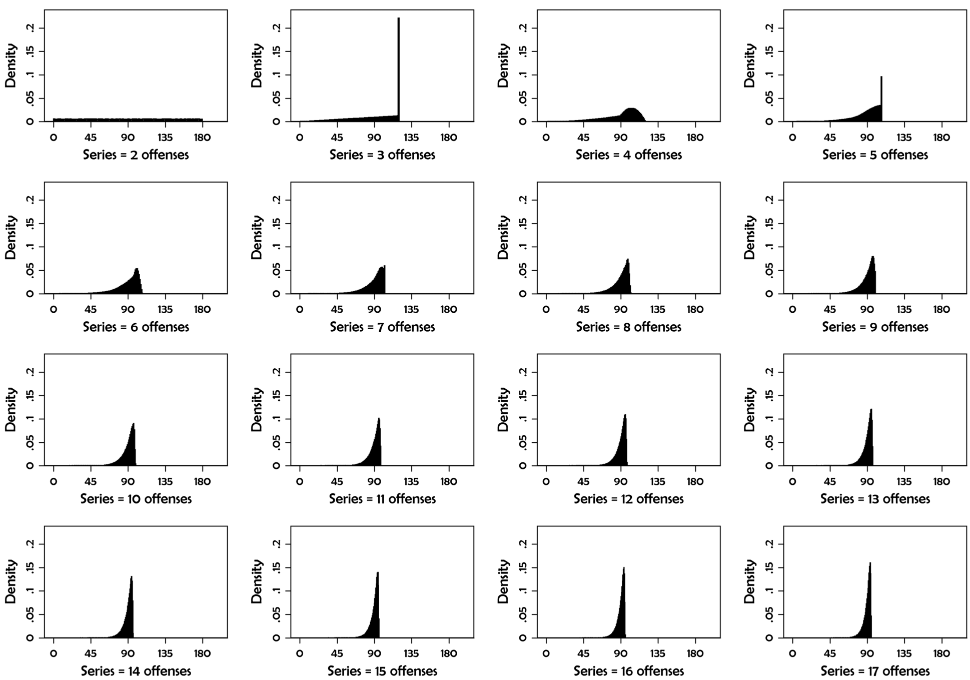

Figure 3. Distributions of mean angulation of crime series under uniform randomization of angles by size of the crime series.

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Table 1 lists for offence series of sizes 2–26 the number of offence pairs it contains and the threshold values for significance (at $p < 0.05$ and $p < 0.01$). When a series comprises only two offences, significant directional consistency requires that $\alpha_{av} < 1.8°$ (for $p < 0.01$) or $\alpha_{av} < 9°$ (for $p < 0.05$). For series of 15 crimes however, the directional consistency requires only that $\alpha_{av} < 72.36°$ (for $p < 0.01$) or $\alpha_{av} < 79.92°$ (for $p < 0.05$).

DATA

Our data set consists of a sample of police recorded and detected residential burglary series ($n > 1$) in the Greater The Hague area (that is served by the 'Haaglanden' regional police force) in a 7-year period (2001–2006). All burglary addresses and offender home addresses were geocoded on the basis of their six-digit postal code. The six-digit postal code is a fairly small area containing approximately 20 residential properties on average (e.g. one side of a small street segment or part of a terraced multi-household dwelling). The centroid of this postal code area was assigned to the burglary targets and burglars' homes located inside it.

An additional selection criterion applied was that only offenders who had not changed their residence during the series were included. This selection was applied because moving causes a change in the anchor point of the directional consistency calculations. Although in

Table 1. Significance thresholds (in degrees) for testing against random directionality

# offences (n)	# offence pairs $n(n-1)/2$	$p < 0.05$ (degrees)	$p < 0.01$ (degrees)
2	1	9.0	1.8
3	3	31.0	13.9
4	6	45.9	26.6
5	10	55.8	37.4
6	15	62.5	45.4
7	21	67.0	51.5
8	28	70.2	56.5
9	36	72.5	60.1
10	45	74.3	63.4
11	55	76.0	65.7
12	66	77.2	67.9
13	78	78.1	69.7
14	91	79.0	71.1
15	105	79.9	72.4
16	120	80.5	73.4
17	136	81.0	74.3
18	153	81.5	75.2
19	171	82.1	76.0
20	190	82.4	76.7
21	210	82.8	77.4
22	231	83.2	77.9
23	253	83.5	78.5
24	276	83.7	79.0
25	300	84.1	79.4
26	325	84.2	79.7

Simulation results. Read example (row 3): A series of four offences involves six pairwise comparisons. If the average angle across those six pairs is below 45.9°, there is significant directional consistency at $p < 0.05$; if it is below 26.6°, there is significant directional consistency at $p < 0.01$.

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principle an acceptable alternative would have been to split these series into a part 'before the move' and another part 'after the move', this would have resulted in a double hierarchical data structure (offences nested in series that are nested in offenders) and associated analytical complications. We decided to exclude them for two reasons. Theoretically, it may be expected that when offenders move, their spatial awareness changes in complex ways that are difficult to model without knowledge of their old and new routine activities (Bernasco, 2010). For example, they may still attend the same school as before or shift to another school. Statistically, the increased number of observations that would be won by including movers would not outweigh the increased statistical complexities of modelling three hierarchical levels.

The result is a data set of 268 burglars each of whom had been involved in two or more burglaries and for whom measures of directional consistency can be calculated. Together, the 268 burglars committed 1,116 detected residential burglaries. The crimes committed by each offender vary between 2 and 26. Table 2 specifies how many offences had been committed by how many offenders.

FINDINGS

The present section applies the improved measure of directional consistency in the The Hague burglary series data. Figure 4 displays a histogram of the distribution of α_{av} in the sample, where each bar represents a width of 10°. The shaded parts of the bars represent the proportion of the cases for which α_{av} is statistically significant ($p < 0.01$), whereas the unshaded parts represent α_{av} values that are, although in the same range of magnitude, non-significant (these are generally the shorter burglary series).

Table 2. Distribution of serial offenders and offences (empirical data)

# of offences per offender	# of offenders	% of offenders	# of offences	% of offences
2	107	39.93	214	19.18
3	46	17.16	138	12.37
4	34	12.69	136	12.19
5	24	8.96	120	10.75
6	23	8.58	138	12.37
7	12	4.48	84	7.53
8	2	0.75	16	1.43
9	4	1.49	36	3.23
10	2	0.75	20	1.79
11	3	1.12	33	2.96
12	1	0.37	12	1.08
13	3	1.12	39	3.49
14	1	0.37	14	1.25
15	1	0.37	15	1.34
16	1	0.37	16	1.43
17	1	0.37	17	1.52
19	1	0.37	19	1.70
23	1	0.37	23	2.06
26	1	0.37	26	2.33
Total	268	100	1116	100

Source: Police registration, *Haaglanden* Police Force.

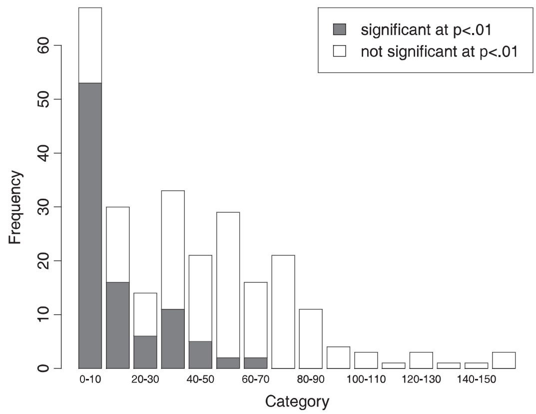

Figure 4. General directional consistency and significant directional consistency.

Figure 4 indicates that the vast majority of offenders (242 out of 268 or 90.3%) have a pattern that shows directional consistency to some extent. Only 26 offenders (9.7%) have an anti-directional pattern ($\alpha_{av} > 90°$). A closer examination of Figure 4 suggests two groups of offenders with directional consistency. First, 97 offenders (36.2%) have a strong directional consistency ($\alpha_{av} < 20°$). Another substantial part (120 offenders or 44.8%) shows α_{av} values between 30° and 80°, a more moderate form of directional consistency but still smaller than 90° and therefore directionally consistent.

Clearly, α_{av} and significance are related, but the relation is confounded by the numbers of crimes in the series. Table 3 presents an alternative view of the relation. For each series size, it presents the number of offence pairs involved (i.e. $n(n-1)/2$), the threshold value necessary for significance at $p < 0.01$ and the number and percentage of series that have an α_{av} value below the threshold. The last three columns are repeated for $p < 0.05$.

In general, 98 out of 268 burglars (36.6%) demonstrate a significant ($p < 0.01$) level of directional consistency, 140 burglars (52.2%) have directional consistency at significance level $p < 0.05$. This shows that many offending patterns are characterised not only by directional consistency but also by directional consistency that is unlikely to result from the combination of coincidence and the law of small numbers. This shows that within reasonable margins of likelihood, a considerable number of offence series, but certainly not all, are characterised by directional consistency. Table 3 represents the amount of

Table 3. Significant directional consistency in relation to crimes

		$p < 0.01$			$p < 0.05$		
Crimes	n	Value (degrees)	n	%	Value (degrees)	n	%
2	107	1.76	31	29.0	8.96	45	42.1
3	46	13.82	13	28.3	30.98	18	39.1
4	34	26.66	11	32.4	45.88	13	38.2
5	24	37.37	6	25.0	55.84	17	70.8
6	23	45.41	12	52.2	62.46	17	73.9
7	12	51.52	6	50.0	67.00	10	83.3
>8	22	varying	19	86.4	varying	20	90.9
Total	268	varying	98	36.6	varying	140	52.2

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significant directionally consistent patterns in relation to the numbers of offences in the series and the number of offence pairs that the measure is based on.

Next, two correlations are considered as one may expect them to influence offenders' directional consistency. First, the correlation between directional consistency and size of the crime series is considered. We observe no substantial correlation ($r = 0.08$) between the number of crimes in a series an offender's directional consistency.

We do find a slight negative correlation ($r = -0.23$) between the average home-offence distance in a crime series and its mean angulation α_{av}. Thus, offenders who perpetrate further from their anchor point are more directionally consistent and have a more narrow 'corridor' to their crime locations than those who perpetrate closer to home. Our calculation of α_{av} makes no reference to distance. Still, we find a relationship, be it an inverse one. This means that offenders' operational ranges (the distances between their two widest offences) may be similar and independent of the distance they travel.

DISCUSSION

Proposing a new measure for calculating directional consistency in offence series, we find two main groups of offenders. A first offender type has a very strong directional bias, that is, a small average angle between his offence pairs. Ninety-seven offenders (36.2%) have a strong directional consistency ($\alpha_{av} < 20°$). Second, 120 offenders, or 44.8%, show α_{av} values between 30° and 80°, a pattern that is still directionally consistent (as $\alpha_{av} < 90°$) but to a lesser extent. Only a small minority of offending patterns (26 offenders or 9.7%) shows no directional consistency.

The results are quite similar to the findings of Lundrigan and Czarnomski (2006). Using the angle between the two widest offences, they also found a large proportion of offenders operating in a corridor of less than 45° and a second group of offenders operating in a wider corridor of between 136° and 180°. As they only use the angle between the two widest offences and the method in the present paper calculates the average angle between all offence pairs, the exact sizes of the angles are obviously different. Yet, the existence of both groups is largely the same.

Such findings are largely in line with the marauder–commuter dichotomy as developed by Canter and also tested by others (Canter, 2000; Canter & Alison, 2000; Canter & Gregory, 1994; Canter & Larkin, 1993; Canter & Youngs, 2008; Meaney, 2004; Paulsen, 2007). In contrast, there are offenders who are characterised by a high level of directional consistency. As all their offences are located at the same side of their anchor point, they are classified as commuters. However, offenders with weaker directional consistency commit crimes in many different directions around their anchor point and are therefore classified as marauders.

Through calculating average angles, our measure of directional consistency is mathematically independent from distance. Consequently, we expect no relationship between average travelled distance and directional consistency. Empirically, however, it is found that that larger distance is positively related to directional consistency (i.e. to smaller α_{av}). First of all, this means that directional consistency measures another component of the journey-to-crime than distance does. Second, it demonstrates that the mean angulation does not increase with distance. Such a finding may be interpreted to support the concept of awareness space, as developed by Brantingham and Brantingham (1981, 1993). In this concept, certain activity areas—work, leisure and so on—are called nodes, and it is assumed that offenders operate in the area that covers such nodes. The area around a certain node may be consistent

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(e.g. visual range), independent of how far this node is located from the offender's residence. Figure 5 demonstrates that such an assumption makes the angle smaller if offenders operate further away from home (right picture) than closer to home (left picture).

In this picture, two crimes are committed each at one extreme side of the awareness space node (presented by the grey circle). The crime trips are referred to as the white arrows. Although the size of the awareness space remains the same, the angle formed by the location of both crimes and the home is much smaller, that is, strong directional consistency, in the right situation than it is for the left one. Thus, assuming that the area around certain activity nodes remains constant, larger travelled distances lead to smaller angles and hence stronger directional consistency.

The observation of directional consistency suggests that offending patterns are shaped by daily routines and habitual behaviour. Furthermore, it suggests that not only regularly visited places may be relevant but also that the routes towards these places may shape crime patterns. From an investigative point of view, the observation of directional consistency might inform police investigations. Over 90% of offenders in our sample demonstrate directional consistency to some extent, making it a reasonable assumption for offending patterns in general. Thus, if on a 'pin map' of a crime series, we would be able to identify (sub)sets of points that are located approximately on a line; we might expect this line to point, in either direction, to the offender's anchor point.

As an alternative to the hypothesis of circular offending behaviour that underlies geographic offender profiles based on distance decay patterns, the focus on directional consistency helps investigators to develop a geographic profile for non-circular patterns and might even locate a probable anchor point outside the criminal activity area.

A few caveats and weaknesses concerning the present study have to be mentioned. First, the sample used is rather small and only considers burglars. Therefore, more extensive and future research on directional consistency may include larger samples and different crime types. Second, cut values to judge whether patterns demonstrate significant directional consistency vary with the size of the crime series. This makes it less straightforward to judge the significance level of a certain pattern (see also Figure 4); one needs to calculate the random pattern first and only in a later stage can the empirical pattern be compared to this pattern. Third, and this is relevant for every research in this area, we only work with caught offenders. If we consider it possible that more mobile offenders are less probably to get caught (Eck & Weisburd, 1995; McIver, 1981), it may as well be that offenders operating on a smaller area, and thus showing stronger directional bias, get caught more easily. Fourth, the present study did not take into account the presence of potential mobility frictions other than distance. For example, although the study area generally consists of flat land with a good mobility infrastructure for travel by foot, bicycle, motor bicycle, car and public transport, for some anchor points, directionality is restricted by natural (e.g. the sea-shore) or constructed (e.g. railway and highways that obstruct cross-traffic) barriers. Fifth,

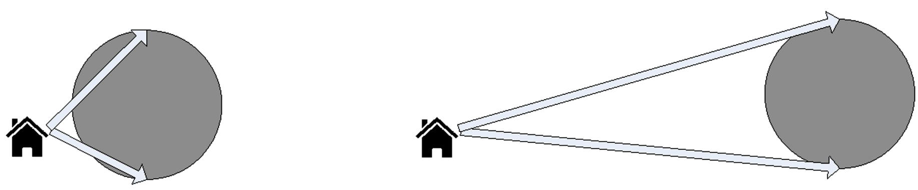

Figure 5. Directional consistency related to distance.

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assessing the directional consistency of offenders who have changed homes during their crime series is problematic as the directionality of their habitual travelling may shift. Finally, this method has the potential to develop geographic profiles of non-circular patterns and may even locate anchor points outside the criminal range. Yet, this brings along the question when to assume a circular offending pattern, and, accordingly, minimal distance, or a non-circular pattern with directional consistency.

Nevertheless, we have demonstrated that a large percentage of offending patterns show strong levels of directional consistency. Therefore, and taking into account the fact that directionality is an underrepresented area in the study of crime trips, this paper demonstrates the usefulness and importance of directionality research. We hope to see future journey-to-crime studies take their analysis a step further in this direction.

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