

CO-OFFENDERS' CRIME LOCATION CHOICE: DO CO-OFFENDING GROUPS COMMIT CRIMES IN THEIR *SHARED* AWARENESS SPACE?

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This study examines the influence of co-offending on crime location choice: the extent to which awareness spaces of co-offenders overlap and whether co-offended crimes are more likely committed in this overlap in awareness space. In total, 4,654 offenders from the greater The Hague region in The Netherlands were studied. They committed 6,283 crimes; of which, 3,612 were co-offended. The data were analysed using a discrete spatial choice model. Results show that most co-offending groups share 50 per cent or less of their awareness space. Offender groups are significantly more likely to commit crimes in areas known to multiple offenders in the group (the shared awareness space of the group) than in areas known to one offender or none of the offenders.

Keywords: crime location choice, co-offending, discrete spatial choice model, awareness space, crime pattern theory

Introduction

‘There is substantial evidence for the incorporation of co-offending into any criminological analysis’ (Andresen *et al.* 2012: 496). Two decades ago, Kleemans (1996) concluded that there is a lack of knowledge on the influence of co-offending on choices made by offenders when committing crimes, including the choice for a crime location. While the role of co-offending in other aspects of criminality, e.g. the onset of criminal behaviour (Andresen and Felson 2009) or offending versatility (McGloin and Piquero 2009), has been studied since, studies on the geography of crime, and more specifically crime location choice, have largely neglected co-offending. Ten years after the study of Kleemans (1996), Bernasco (2006) was the first to study the influence of co-offending on crime location choice in burglaries. To date, no other studies have directly evaluated the role of co-offending in crime location choice, although some authors have wondered whether their results would have been different if co-offending was controlled for (Bernasco and Block 2009) and others have excluded crimes in which two or more offenders were involved (Clare *et al.* 2009). However, most crime location choice studies do not mention co-offending at all, indicating that crimes that are possibly committed by multiple offenders are analysed as being committed by a single offender (e.g. Lammers *et al.* 2015). This raises concerns about the validity of conclusions drawn regarding crime location choice, as different studies show that a significant percentage of crimes are committed by two or more offenders (e.g. Carrington 2009; Van Mastrigt and Farrington 2011).

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The current study will take a next step in gaining insight into the relationship between co-offending and crime location choice, by using one model to analyse previous and current home locations of all offenders involved, as well as previous crime locations and measures of attractiveness of targets. More specifically, this article will study *shared* awareness space of co-offenders and whether crimes are more likely to be committed in this shared awareness space than in otherwise comparable areas. To do this, a discrete spatial choice model is used.

In the following first theory and previous research on co-offending, crime location choice and the relationship between these two phenomena are discussed. After that, the research questions studied in this article are formulated, the data and methods are explained and the results are shown. The article ends with a discussion of these results.

Theory and Previous Research

Co-offending

Co-offending can be defined as a criminal act involving direct and simultaneous cooperation between at least two offenders (Felson 2003). This is the definition of co-offending used in this study, although a broader definition also exists (Tremblay 1993). According to Warr (2002) criminal behaviour is predominantly social behaviour and one of the strongest predictors of criminal behaviour is the number of delinquent friends a person has. Reiss (1988) stated that criminal histories of offenders are characterized by a combination of co-offending and solo offending. Indeed, empirical studies have shown that a significant percentage of crimes are committed by more than one offender. Carrington (2009) reported that 45 per cent of the offences in his sample were committed by more than one offender, in the sample of Van Mastrigt and Farrington (2009) this was 10.4 per cent of offences and of the burglaries Bernasco (2006) studied, a little over 30 per cent were committed by at least two offenders.

Another conclusion, from the perspective of the offender, is that most offenders have committed crimes together with others. Van Mastrigt and Farrington (2009), e.g., have found that in their sample of over 61,000 offenders (Van Mastrigt and Farrington, 2009; 2011), 30 per cent had at least one co-offender during a 3-year period. In their sample of 400 offenders, McGloin *et al.* (2008) found that 84 per cent has co-offended at least once. About 64 per cent of the offender population Carrington (2009) studied had committed at least one joint offence in their 10-year delinquent careers. Most offenders are not exclusively group offenders or solo offenders, but commit some crimes alone and others with co-offenders (Reiss 1988; Warr 2002).

Most studies on co-offending offer insight into co-offending as independent variable. These studies have, e.g., investigated the influence of co-offending on onset, maintenance and desistance of criminal behaviour (McGloin and Piquero 2009). Co-offending has been found to be a significant factor in delinquency onset (Andresen and Felson 2009), and it decreases as offenders get older and more experienced (Reiss and Farrington 1991; Stolzenberg and D'Alessio 2008; Carrington 2009). Some studies have examined the consequences of co-offending, such as the influence of co-offending as an independent variable on crime events (Tillyer and Tillyer 2015). For example, the benefits co-offending offers such as knowledge and skills for future crimes (Felson, 2003), or the risks that come with co-offending such as betrayal by co-offenders (McGloin and Nguyen 2012).

In short, co-offending is not an exception and it is 'a rather fluid, varying, and dynamic phenomenon' (Weerman 2003: 401). Still unexplored, however, is how co-offending influences offender's decisions (McGloin and Piquero 2009), including the decision on where to commit a crime.

Crime location choice

According to crime pattern theory, crimes take place where attractive criminal opportunities overlap with the awareness space of offenders (Brantingham and Brantingham 2008). Offenders, like everybody else, learn about their environment during their daily routine activities. They develop routine activity spaces, consisting of activity nodes (e.g. a home or work location) and the paths between these nodes. The activity space and all areas within visual range constitute a person's awareness space. An offender will search for an attractive target within his or her awareness space (Brantingham and Brantingham 2008; 1993).

Research on crime location choice has focused on two important nodes in an offender's awareness space: (1) residential locations: the area in which the offender lives at the time of the offence and areas where the offender has previously lived and (2) areas where the offender has previously offended. Results of multiple studies show that offenders tend to offend near their current and previous homes (Bernasco and Nieuwbeerta 2005; Bernasco 2010b; Bernasco and Kooistra 2010; Baudains *et al.* 2013; Johnson and Summers 2015) and their previous crime locations (Bernasco *et al.* 2015; Lammers *et al.* 2015).

Co-offending and crime location choice

To examine how co-offending has been taken into account in previous crime location studies, all 16 studies (that the author is aware of) that have used the discrete spatial choice approach have been studied. These studies were chosen because the discrete spatial choice approach is the current state of the art in crime location choice studies. The current study uses the same approach, which will be explained in the following paragraph on the analytic strategy.

Six of the 16 studies have analysed all crimes as if being committed by a single offender and have not made any remarks on their discussion about co-offending (Bernasco 2010b; Baudains *et al.* 2013; Lammers *et al.* 2015; Townsley *et al.* 2015; Chamberlain and Boggess 2016; Menting *et al.* 2016), which could indicate that they have not taken co-offending into account by, e.g., controlling for it or removing co-offended crimes from their samples. Three studies have also analysed possible co-offended crimes as being committed by a single offender, but did discuss the possible implications of this in their report (Bernasco 2010a; Bernasco *et al.* 2012; 2015). Five studies have excluded crimes committed by more than one offender from their sample: Townsley *et al.* (2015) had to remove 25 per cent of their sample for this reason, Bernasco and Kooistra (2010) removed 75 per cent and Bernasco and Nieuwbeerta (2005), Clare *et al.* (2009) and Vandeviver *et al.* (2015) have not described how many cases were excluded in their studies. Two studies have randomly selected one offender for each offence that was committed by more than one offender (Bernasco and Block 2009; Johnson and Summers

2015). So, some crime location choice studies do take co-offending into account to a certain extent, but only by removing co-offenders or co-offended crimes from the sample.

As stated before, [Bernasco \(2006\)](#) has been the only author who studied crime location choices of co-offenders specifically and separately. In his study, he compared solitary offenders with group offenders and concluded that solitary offenders and group offenders seem to agree on the criteria that are important for choosing a target area. These criteria were, however, mostly area characteristics and not measures of the awareness space of the offender(s). Also, he did not analyse how awareness spaces of co-offending groups overlap or how these multiple awareness spaces influence the choice for a crime location when offending together.

A number of other studies on the geography of crime or offender mobility shed light on how co-offending might influence crime location choice. [Reiss and Farrington \(1991\)](#) have found that 60 per cent of co-offenders lived in the same postal district or within about a mile away from each other, and that co-offenders tend to commit crimes close to their homes. [Andresen et al. \(2012\)](#) studied what they call the offender mobility polygon, which is the area covering the offender's residence, the victim's residence and the crime location. They found that the size of this polygon increases when the number of offenders involved in the crime increases. This could indicate that co-offenders' crime location choice is influenced by the home locations of both offenders. [Van Daele \(2008\)](#) concluded that criminals who co-offend travel slightly further from their home location to the offence locations than solo offenders. However, [Snook \(2004\)](#) found that co-offending burglars do not select targets further away from their homes than burglars who offend alone. [Van Daele and Vander Beken \(2011\)](#) found that co-offenders are more likely to travel further to commit crimes; however, they found no clear evidence that this is caused by co-offenders living in different regions.

According to crime pattern theory, crimes are committed at those locations where attractive targets overlap with the awareness space of the offender ([Brantingham and Brantingham 2008](#)). [Bernasco \(2006\)](#) has stated that the notion of the attractiveness of criminal opportunities does not distinguish between solitary offenders and group offenders. However, co-offenders probably have different awareness spaces, although they might overlap to a certain extent ([Kleemans 1996](#)). No studies to date (that the author is aware of) have studied to what extent awareness spaces of co-offenders overlap.

Research questions

When multiple offenders are involved in the commission of a crime, there are multiple residential areas as well as multiple previous crime locations that possibly influence the choice for a crime location. These areas might overlap between co-offenders, e.g., when they live in the same area. These areas constitute the shared awareness space of co-offenders. [Figure 1](#) shows a schematic representation of the shared awareness space of three offenders who offend together. The figure shows six areas. The awareness space of offender A consists of areas 1, 2 and 3, the awareness space of offender B consists of areas 2, 3 and 4 and the awareness space of offender C consists of areas 3, 5 and 6. This means that areas 2 and 3 are known to more than one offender in the group and belong to the *shared* awareness space of this group.

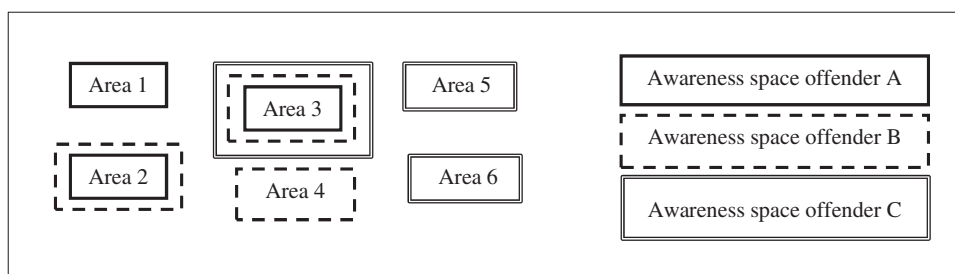


FIG. 1 Schematic representation of shared awareness space

The first research question addressed in this study is: What is the percentage of shared awareness space between co-offenders?

Awareness space is defined here as current and former home locations and previous crime locations, and these locations are represented as postal code areas. Previous studies have shown that these locations influence crime location choice and that the postal code is an appropriate representation of areas known to people (Bernasco and Nieuwebeerta 2005; Bernasco 2010b; Bernasco *et al.* 2015; Lammers *et al.* 2015). The unit of analysis for answering the first research question is the co-offending group responsible for one co-offended crime, and areas are determined as being shared when more than one offender of this co-offending group has lived, lives, or has committed a previous crime in that area. Offender groups can be fluid over time, and offenders can commit crimes in different group compositions. In this study, the starting point is always a co-offended crime, the group responsible for that specific crime, and thus the (shared) awareness space of that specific group. If some of the offenders have also committed crimes in a different group, then that group and their (shared) awareness space is measured.

The second research question of this study is: Are co-offended crimes more likely to be committed in the shared awareness space of co-offenders or in other, comparable areas?

Here, the unit of analysis is the crime committed by a group of offenders. Figure 2 shows a schematic representation of the data and the different units of analysis used to answer both research questions.

Data and Methods

In this section, the data used for the study are described, as well as how the study and control variables are defined. Subsequently, the analytic strategy, discrete spatial choice modelling, is explained. The dependent variable in this study is the choice of an area j from a geographical set of alternatives J to co-offend in. This co-offended crime had to be committed between 2006 and 2009 in the greater The Hague region. This region consists of a total of 142 four-digit postal code areas, which have an average size of 2.96 km² and an average population size of 7,000. Since the four-digit postal code areas were designed to have minimal travel restrictions for postal delivery services travelling by bike or foot (Bernasco 2010b), it is plausible that those living in or frequently visiting such an area will be familiar with it.

Awareness space in this study is defined as the home location of the offender at the time of offence, the previous home locations of the offender and the locations where the offender has committed a crime before. These locations have been found to

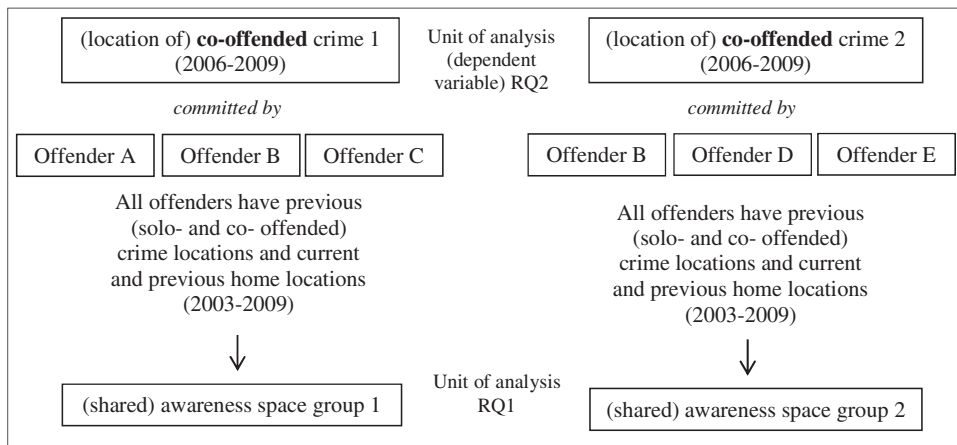


FIG. 2 Schematic representation of the data and unit of analysis

influence crime location choice (e.g. [Bernasco and Nieuwbeerta 2005](#); [Bernasco 2010b](#); [Lammers et al. 2015](#)) and can be measured using registration data, the only data available for the current study. All crime locations and residential locations had to be in the greater The Hague region and are measured as four-digit postal code areas.

Offenders and co-offenders

The starting point for the sample of offenders was the sample used in previous reports of the same project ([Lammers et al. 2015](#); [Menting et al. 2016](#)). This sample consisted of 10,000 offenders with at least one crime they had committed in the greater The Hague area between the years 2006 and 2009. From this group, 2,090 offenders were excluded for a number of reasons: (1) 92 offenders were only involved in crimes that did not meet the criteria of a felony; (2) 5 offenders were under the age of 12 years in 2009 and the Dutch law does not allow prosecution of children younger than 12; (3) the crime(s) of 308 offenders did not have a valid address in the greater The Hague region; and (4) 1,685 offenders did not have a valid address in the greater The Hague area in the time they committed the 2006–09 offence. This leaves a sample of 7,910 offenders.

For those offenders, additional data were collected on whether they co-offended and if so, with whom. This was done by matching every offender to possible other offenders using the police report number of each of their crimes (crimes receive a unique police report number, and every person who is suspected of committing the crime has this number in his/her police records). The crimes with the same police report number had to be committed on the same day, at the same address. This led to including new offenders (not part of the original 10,000 offenders). As the focus of this study is on co-offending and *shared* awareness space and the dependent variable is the choice for an area of a *co-offended* crime, offenders who only offended alone (no offences committed together with another offender) were removed from the sample. Groups consisting of more than three offenders were also removed from the data, as group sizes of two or three offenders are sufficient to answer the research questions in this study without further complicating the analyses. Also, most criminal acts are committed in pairs or

small groups of offenders, as nearly all studies on group offending have shown that group sizes typically vary between two and three members (Reiss and Farrington 1991; Kleemans 1996; Warr 2002; Farrington 2003; Felson 2003; Weerman 2003).

Lastly, to measure awareness spaces, it is necessary to have current and previous residential addresses of all offenders in the sample. However, this residential history was not available for all offenders. Offenders without a residential history were removed from the sample. The final sample consisted of 4,654 offenders with at least one co-offended crime in a group of two or three offenders. There were a total of 2,926 groups of offenders: 2,420 groups of two offenders and 506 groups of three offenders.

Measuring awareness space: offence locations and residential locations

For all offenders, their criminal history and their residential history were retrieved using registration data. The offences were obtained from the police information system used by the greater The Hague Police Service. For each offence, information on the location and the date of crime were retrieved. Although each offender had to have at least one co-offended crime committed between 2006 and 2009, all their previous crimes (also those who were committed alone) committed in the greater The Hague area were taken into account. These prior crimes are used to create the independent variable that measure whether an offender has committed a crime in a specific area before. Of the 6,394 crimes committed by 4,654 offenders, 3,720 (58.2 per cent) were co-offended. Of these co-offended crimes, 3,037 were committed between 2006 and 2009 and will be analysed as a dependent variable in the discrete spatial choice model. The other crimes will be analysed as independent variables as being part of the awareness space, to the extent that they were committed *before* the crime that is analysed as the dependent variable. Various crime types are included in the study, the most common crime types are burglary, theft, public disorder crimes and assault.

The residential history of the offenders was derived from population registration data held in a nationwide information system (Dutch acronym is BRP). This system is continuously updated and holds records of all Dutch citizens, including their residential addresses. Major status changes (e.g. moving house, marriage or childbirth) are registered and updated while keeping all historical information like residential histories. For each offender, his or her home location at the time of the offence was established, as well as all previous home locations back until 2003 within the greater The Hague area. All crime and residential locations were geocoded and allocated to one of the 142 four-digit postal code areas.

Control variables: area characteristics

The discrete spatial choice model testing whether co-offended crimes are more likely committed in the shared awareness space of the co-offending group includes a number of control variables measuring area characteristics known to influence crime location choice. These variables are indicators of crime attractors and crime generators (Brantingham and Brantingham 1995) and of guardianship (Cohen and Felson 1979). Several studies have found that these characteristics influence crime rates in an area

(Bernasco and Nieuwbeerta 2005; McCord *et al.* 2007; Nieuwbeerta *et al.* 2008; Bernasco and Block 2011; Reynald 2011).

Statistics Netherlands records socio-demographic and socio-economic information for each postal code area in the Netherlands. For the current study, information was obtained for each of the postal code areas in the study region on the total number of residents, the number of residents with a non-Western ethnic background and the number of single-person households. This information, combined with information on the surface of the postal code areas (Ministry of the Interior and Kingdom Relations 2014), was also used to calculate the population density of each area.

The LISA database (see Steenbeek *et al.* 2012 for more information on the LISA database), a database containing information on businesses, was used to obtain year-postal code area-specific information on the number of retail stores, hotels, restaurants, bars, schools, cultural facilities, health care institutions and sport and leisure facilities.

One could argue that these control variables have a difference in influence on the crime location choice of a group of offenders opposed to the influence they have on the crime location choice of a solitary offender. For example, the risk of an offender standing out in an area as not belonging there might be higher in areas with higher social control. This risk might increase even more for a group of offenders, as a group of unknown people might stand out more than a single person (Bernasco 2006). However, Bernasco (2006) has shown that these area characteristics do not significantly differ in their influence on crime location choices of solitary offenders and group offenders.

Analytic strategy

This first research question is descriptive in nature and results will show three graphs: one for the percentage of shared *criminal* awareness space (overlap in areas where previous crimes were committed), one for the percentage of shared *residential* awareness space (overlap in areas of previous and current home locations) and one for the *total* awareness space, consisting of the criminal and residential awareness space combined. To calculate the overlap in awareness spaces, the total number of four-digit postal code areas known to the group as a whole was calculated (G), as well as the number of four-digit postal codes known by at least two group members (S). The percentage of shared awareness space was then calculated as $(S/G) \times 100$. The following example shows this in more detail.

Group	Offender	Areas in the offenders' awareness space				
1	1	a	b	c	d	e
1	2		b	c		
1	3	a				e
						f

The group in this example consists of three offenders. The total number of areas known to this group as a whole: $G = 6$ (areas a, b, c, d, e and f); the number of areas shared by at least two offenders in this group: $S = 4$ (a, b, c and e). So, the percentage of shared awareness space in this group is $(4/6) \times 100 = 67\%$. This calculation is the same for the shared criminal awareness space and the shared residential awareness space. For the residential awareness space, the offenders did not have to live at the same area at

the same time. For an area to be part of the shared awareness space, it just has to be known to two or more group members.

The second research question of this study is 'are co-offended crimes more likely to be committed in the shared awareness space of co-offenders or in other, comparable areas?' This question is answered using a discrete spatial choice model. [Bernasco and Nieuwbeerta \(2005\)](#) have introduced this model in criminology to study crime location choice. Discrete choice models are used to explain why an individual chooses a specific single alternative when presented with a distinct number of alternatives ([Ben-Akiva and Bierlaire 2003](#)), given characteristics of the alternatives and characteristics of the decision maker. Applied to *location* choice, the alternatives from which the individual has to choose are spatial entities, e.g. postal code areas. When applied to *crime location* choice, the choice faced by the offender (the decision maker) is where to commit a crime. Discrete choice models are statistically tested with a conditional logit model ([McFadden 1974; 1978](#)). In the case of crime location choice, the model implies that a motivated offender (the decision maker) evaluates the utility of each of the possible choice alternatives, and selects the alternative with the largest utility and gain (for a comprehensive explanation of this model applied to crime location choice, see [Bernasco 2010b](#)).

The dependent variable in this model is the choice of an area j from a geographical set of alternatives J to commit a co-offended crime. The set of alternatives J in this study contains the 142 four-digit postal code areas of the greater The Hague area. The postal code area in which the co-offended crime was committed received a score of 1, and all other 141 postal codes in the choice set a score of 0. The independent variables *home location*, *previous home location* and *previous crime location* were constructed in a similar way: these variables received a score of 1 when an offender had committed a crime in this postal code area, or was living in the area at the time of the offence, or had lived in the area before. All other postal code areas received a score of 0. These three independent variables were constructed two times: one time for areas only known by one of the offenders of the group and one time for the areas known to at least two offenders in the group. These last variables represent the shared awareness space locations.

Results

Shared awareness space

The first research question of this study is 'what is the percentage of shared awareness space between co-offenders?' The results are based on 2,926 groups of offenders: 2,420 groups of two offenders and 506 groups of three offenders. Awareness space is defined as the current and former home locations and previous crime locations, measured as four-digit postal code areas. The total number of four-digit postal code areas in the data is 142. To answer this first research question, all crime and residential locations of the offenders between 2003 and 2009 are taken into account.

The criminal awareness space consists of the areas of previous crimes, both solo- and co-offended crimes. The number of previous crime areas covered by the offender groups in the data ranges between 1 and 16 and is on average 4 (SD = 2.6). [Figure 3](#) shows the percentage of criminal awareness space that the co-offending groups in the data share. From this figure it becomes clear that around 75 per cent of the offending groups share 50 per cent of their criminal awareness space or less. So, most of the

groups share less than half of their criminal awareness space. This result also indicates that co-offenders have a larger combined criminal awareness space than the separate offenders do.

The residential awareness space consists of the previous and current home locations. The current home location is the home location at the time of the offence, and the previous home locations are those locations the offender resided in before the current home location. The number of residential areas covered by the offender groups ranges between 1 and 16 (mean: 3.8; SD = 2.2). Figure 4 shows the percentage of residential awareness space that the co-offending groups in the data share. The graph shows that around 40 per cent of the offender groups in this study do not share any residential

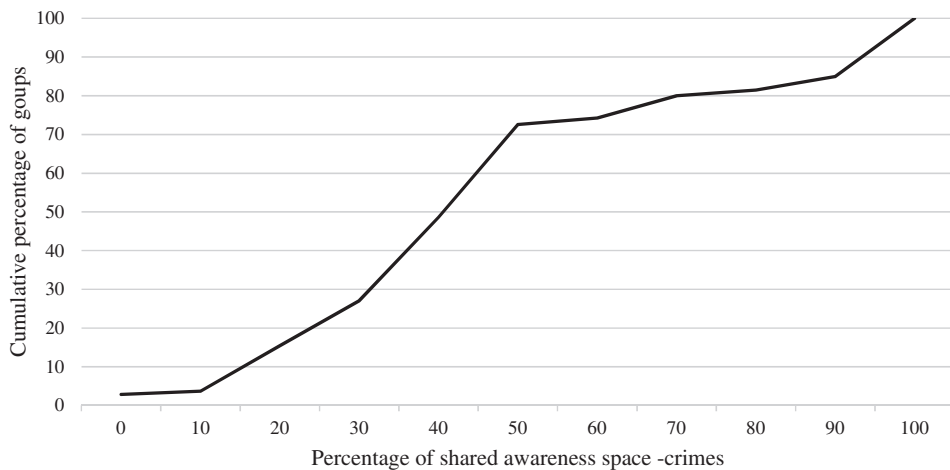


FIG. 3 Cumulative percentage of co-offending groups and the percentage of shared criminal awareness space

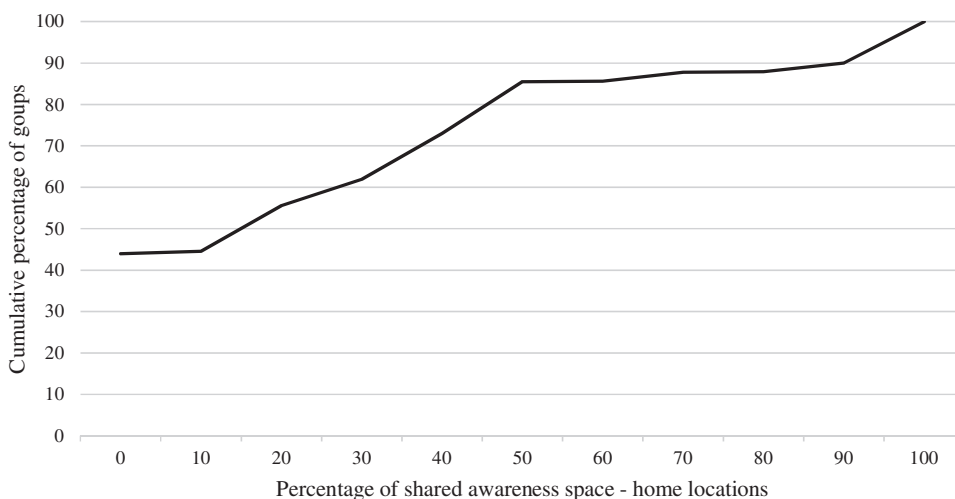


FIG. 4 Cumulative percentage of co-offending groups and the percentage of shared residential awareness space

awareness space, meaning that the offenders of these groups have never lived in the same area(s). Similar to the criminal awareness space, around 85 per cent of offender groups share 50 per cent of their residential awareness space or less. This result again also shows that the awareness space of a group is larger than the awareness space of a separate offender.

The total awareness space as defined in this study consists of previous and current residential locations and previous crime locations (of both solo- and co-offended crimes). The number of total awareness space areas covered by the offender groups ranges between 1 and 24 and is on average 6.8 (SD = 3.4). Figure 5 shows the percentage of the total awareness space that the groups of offenders in the data share. In line with the two previous graphs, the figure clearly shows that most groups of offenders (around 75 per cent) share 50 per cent or less of their awareness space.

Crimes committed in the shared awareness space

The above-shown figures indicate that awareness spaces of co-offenders overlap to a certain extent, but that most offender groups share only 50 per cent of their awareness space or less. The second research question of this study is whether groups of offenders commit their co-offended crimes in those areas of the awareness spaces that they share. Of the 6,283 crimes committed by 4,654 offenders, 3,612 (57.5 per cent) were co-offended. Of these co-offended crimes, 2,926 were committed between 2006 and 2009 and were analysed as a dependent variable in the analysis, all the other crimes serve only as independent variables as their locations are part of the awareness space (to the extent that they were committed *before* the crime that is the 'dependent' crime). As explained above, the choice set consists of 142 four-digit postal code areas in the greater The Hague region.

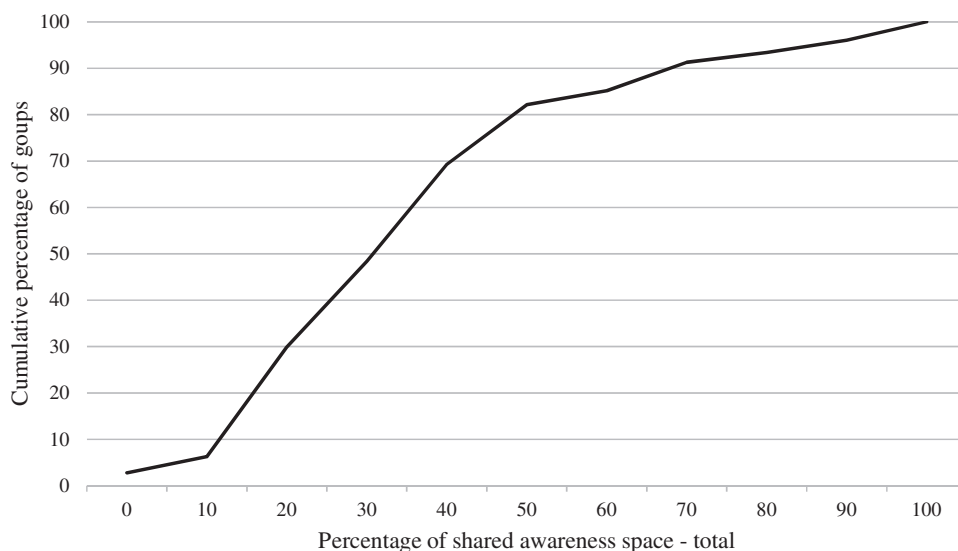


FIG. 5 Cumulative percentage of co-offending groups and the percentage of shared total awareness space

All the awareness space variables were analysed in one model. When presenting the results of the model, odds ratios (ORs) will be shown. These should be interpreted as the multiplicative effect of a one-unit increase of the independent variable on the odds of choosing a particular target area. The independent variables measure the different areas of the awareness space, a one-unit increase means an increase from 0 (area is not part of the awareness space) to 1 (area is part of the awareness space). The same holds for the variables measuring whether the area is part of the shared awareness space. An area is part of the shared awareness space when more than one offender of the group is familiar with this area, so 0 means that the area is not part of the shared awareness space and 1 means that the area is part of the shared awareness space. The reference category is an area where none of the offenders were familiar with and is thus not part of the (shared) awareness space.

Table 1 shows the results of the conditional logit model. In this model, all three areas measuring the offenders' awareness space (current home location, previous home location and previous crime location) were analysed simultaneously. All described control variables were also analysed in this model. The results show that the area where one of the offenders lives at the time of the offence has 11.7 times higher odds of being targeted than an otherwise comparable area where none of the offenders live at the time of the offence. When two or three offenders live in that area, the odds of it being targeted is 44.05 times as large as the odds that an area where none of the offenders lives is being chosen. The difference between these two ORs is also statistically significant ($p < 0.001$), which means that the odds of a co-offending group targeting an area where most of them live in is significantly higher than them targeting an area where only one of them lives.

TABLE 1 *Results of the conditional logit model*

	OR	Z
Current home location		
One offender	11.70***	33.23
Two/three offenders (shared awareness space)	44.05***	35.74
Previous home location		
One offender	3.01***	11.29
Two/three offenders (shared awareness space)	8.41***	9.81
Previous crime location		
One offender	4.80***	18.76
Two/three offenders (shared awareness space)	15.08***	21.90
Control variables		
Density of residents (per 1,000)	0.99	-0.70
Number of one-person households	1.01***	7.00
Percentage of non-Western residents	1.00***	3.93
Number of employees (per 1,000)	1.00**	3.07
Retail businesses (per 10)	1.01***	9.36
Hotel, restaurants and bars (per 10)	0.99*	-2.21
Schools (per 10)	1.00	1.02
Healthcare facilities (per 10)	0.99	-0.56
Cultural facilities (per 10)	0.99	-1.03
Sport facilities	1.02*	2.20

Pseudo- $R^2 = 0.26$.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Both the areas of previous home locations and previous crime locations show similar results: when one offender lived or offended before in an area, the odds that this area will be targeted increases (3.01 times and 4.8 times, respectively). Moreover, when more offenders of the co-offending group have lived or have committed crimes in that area before, the odds increase significantly to 8.41 times ($p < 0.01$) and 15.08 times ($p < 0.001$) those of an area where none of the offenders has lived or has offended before.

In this model, all crime types are combined. Only for burglary and theft, the samples were big enough to test them separately. For both crime types the results are mostly similar to those shown in Table 1. Effect sizes of the variables of interest are somewhat smaller, but the direction of the effects and level of significance remain the same. Only previous home locations of one offender had no significant OR in the model testing burglary. For both the models testing burglary and theft, the difference in ORs between 'previous home location—one offender' and 'previous home location—two/three offenders' was not statistically significant.

Discussion and conclusion

While the phenomenon of co-offending has been studied to some extent, studies on the influence of co-offending on criminal decision making are scarce. Following Bernasco (2006), this article is trying to get more insight into the influence of co-offending on the decision on where to commit a crime. Similar to other crime location choice studies, the theoretical background of this study is crime pattern theory, which states that crimes take place on locations where attractive targets overlap with the awareness space of the offender (Brantingham and Brantingham 2008; 1995). When multiple offenders are involved in the commission of a crime, multiple awareness spaces influence the choice for a crime location. The current study focused on the locations where the awareness spaces of co-offenders overlap: the *shared* awareness space of a co-offending group. In total, 2,926 groups of offenders were studied: 2,420 groups of two offenders and 506 groups of three offenders. The total of 4,654 offenders had committed 6,283 crimes between 2003 and 2009, 3,612 of which were co-offended. Of these 3,612 crimes, 2,926 were committed between 2006 and 2009 and serve as 'dependent crimes' in the analysis.

First of all, this study has given insight into the extent in which awareness spaces of co-offenders overlap. It has been stated before that it may well be that co-offenders share (at least some of) their awareness space (Kleemans 1996), this article is the first to empirically study that. When awareness space is defined as the home location of the offender at the time of the offence and previous home and crime locations, most offender groups share around 50 per cent of their awareness space or less. The extent of overlap is therefore not as large as was assumed before. Moreover, it shows that offender groups have a larger combined awareness space than the awareness space of a single offender. Another remarkable finding is that although a high percentage of offender groups do not share any residential awareness space (around 40 per cent), almost all offender groups share at least some of their criminal awareness space (consisting of crime locations). This could indicate that regardless of where an offender lives, certain areas are more attractive as crime location, as they apparently draw multiple offenders. Subsequently, these areas become part of many offenders' awareness spaces.

The second research question of this study was whether crimes are more likely to be committed in this shared awareness space of the offender group or in other areas, e.g. areas where only one of the offenders is familiar with. The analysis showed that areas where one of the offenders lives at the time of the offence, or where one of the offenders has lived or offended before, have an increased odds of being targeted compared with an area that is not part of the group's awareness spaces. More important, however, is the finding that when two or three of the offenders of the group lived in an area at the time of the offence, or had previously lived or offended in an area, the odds that that specific area was targeted is significantly greater than an area that is not part of the groups' awareness space. Also, the difference between these two findings is statistically significant. This means that the odds that offender groups offend in their *shared* awareness space is significantly greater than the odds that they offend in an area known to only one of the offenders of the group. As stated, offender groups have a larger combined awareness space than a single offender. However, co-offenders tend to commit crimes in those areas that they share and are thus already familiar with, instead of exploring areas unknown to them yet known to a co-offender. The results of the current study therefore might indicate that the awareness spaces of offenders are not extended with areas unknown to them, yet known to co-offenders. Additional research is needed to ratify this conclusion.

The findings of this study are in line with crime pattern theory: the locations where offender groups commit their crimes are more probably locations known to multiple offenders in that group, or in other words locations that are part of the shared awareness space of the group. These results also have important implications for crime locations studies. It reiterates the importance of taking co-offending into account. First of all, a large proportion of crimes are committed by two or more offenders. When offenders co-offend they tend to do so in areas that they are all, or at least most of them, familiar with. However, the percentage of overlap in awareness spaces of co-offenders is not 100 per cent. Actually, for most offender groups it is less than 50 per cent. This means that when co-offended crimes are analysed as being committed by one offender, results are biased towards those areas that are in the shared awareness space of the co-offending group.

Limitations

A number of limitations of this study have to be mentioned. First, some remarks about the data used in this study need to be made. The data were not specifically sampled to study co-offending, which led to a large number of offenders and offences being removed from the sample. A new co-offending study could benefit from sampling specifically on offenders who have co-offended. Also, only police arrest data on cleared offences were used for this study, which means that only arrested offenders and their arrested co-offenders were studied. According to McGloin and Piquero (2009), data from official records are potentially vulnerable to over-represent co-offending because law enforcement agencies focus on capturing group offenders. Therefore, the data used in this study might over-represent offender groups compared with solo offenders. This is not problematic as this study does not compare groups of offender to solo offenders. The use of arrest data could be problematic if a large number of groups used

in this study are 'incomplete' in these data, i.e. if some of the offenders of the group are arrested while others are not. Not having all offenders of the group present in the data could influence the amount of shared awareness space, most likely the percentage of shared awareness space is overestimated when not all offenders of the group are taken into account. Another downside of using police arrest data is that they might be biased because arrested offenders differ in their crime location choices from not arrested offenders, e.g. because offenders who commit crimes in the area where they live have a greater probability of being caught. However, two studies suggest that this detection bias is not likely. [Lammers \(2014\)](#) has found that the inter-crime distances of arrested and non-arrested offenders do not differ significantly, and [Johnson *et al.* \(2009\)](#) showed that unsolved and solved crimes display similar spatio-temporal crime patterns. The results from these studies suggest that it is not very likely that findings from this study would differ significantly when non-arrested offenders were also taken into account.

Second, the data are limited to the greater The Hague region (offenders from the sample were excluded if they did not reside in this region). Areas outside this region could be part of the offenders' awareness spaces, e.g. because they lived there in the past or they regularly visit the area for work. This could have consequences for the amount of shared awareness space. In reality, the shared awareness space of an offender group could be even smaller than found in the current study.

Third, some remarks need to be made about the measurement of the (shared) awareness space. Awareness space in this study is measured as the current and previous home locations of the offenders, as well as previous crime locations. However, a person's awareness space consists of more areas, e.g. a work location and/or a school location. These unmeasured locations could cause more overlap between co-offenders' awareness spaces. Young offenders, e.g., could know each other from school but live in different areas, or they met at the gym or another leisure activity. The registered data used in this study (and many others) do not provide any information regarding these locations and they could, therefore, not be taken into account. The percentage of shared awareness space found here could thus be an underestimation of the actual percentage.

Furthermore, the spatial unit of analysis that was used in this study is a four-digit postal code area. Most studies on crime location choice have used areas of similar or larger size for their analyses. However, the four-digit postal code area could be considered a large unit of analysis. A smaller measurement could have been used, e.g. a six-digit postal code area. These areas contain on average 18 residential units and 40 residents. However, using small spatial units of analysis has its downsides. For example using smaller areas increases the issue of spatial interdependence between observations. This means that models that take spatial interdependence into account need to be used to properly analyse the data. This problem of choosing the right level of aggregation and the influence that has on study result, the modifiable areal unit problem, are discussed extensively in [Ouimet \(2000\)](#).

A last remark in this regard concerns the calculation of the shared awareness space. In the current study, it is defined and measured as more than one offender being familiar with an area. However, this can also be done in other ways. For example shared awareness space can be defined as all offenders of an offender group being familiar with an area, which would result in an even lower percentage of shared awareness space. In [Figure 1](#), this would mean that the shared awareness space of this group of

offenders does not consist of areas 2 and 3, but only of area 3 (with the percentage of shared awareness space dropping from $(2/6) \times 100 = 33\%$ to $(1/6) = 17\%$).

Future Research

The above-described limitations offer some pointers for future research. Data could be collected closer to the source by interviewing offenders on their awareness space and crime locations, but also on who their co-offenders are. These co-offenders could then subsequently be interviewed. When using registered data, sampling could be done specifically focused on co-offending. Also, to be able to generalize findings it would be necessary to study a larger area.

Furthermore, as this is one of the first studies that examines the influence of co-offending on criminal decision-making, there are numerous ideas for future studies to gain more insight into this process. For example how does co-offending influence other decisions such as which type of crime to commit? But also when focusing on crime location choice, there are many more questions that need to be answered in order to better understand how co-offending influences that decision. For example whether it is true that offenders do not extend their awareness space with locations unknown to them yet known to a co-offender. Or, does an offender who commits crimes solo and in a group make other choices when he offends alone versus when he co-offends? And, does the composition of the group of offenders (by age or gender for example) influence crime location choices?

Lastly, an offender's awareness space consists of more locations than just his or her home location, and previous home and crime locations. As explained above, these locations might cause the percentage of overlap to increase. Therefore, it is important to gain information about these locations, to expand the awareness space of offenders and with that to study whether shared awareness space extends to those locations as well.

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