ARTICLES

Formal Evaluation of the Impact of Barriers and Connectors on Residential Burglars' Macro-Level Offending Location Choices

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Previous research evaluating burglars' offending location choices has produced mixed findings about the influence of physical barriers and connectors on offender movement patterns. Consequently, this article utilises the discrete spatial choice approach to formally evaluate the impact of barriers and connectors on residential burglars' macro-level offending location choices. Data from Perth, Western Australia, demonstrated that physical barriers and connectors exert significant influence on offender decision-making at this level, and that the influence of impermeable barriers increases with proximity of these obstacles to the offender's point of origin. These findings provide formalised evidence for the independent importance of physical barriers and connectors in offender movement and are discussed with respect to current environmental criminology theory.

An extensive body of research indicates that offenders' choice of burglary location is influenced by distance from offender residence, individual characteristics of offenders, and a range of environmental factors. However, little attention has been given to the potential mediating effects of physical barriers and distance-decreasing connectors on macro-level offender location choice. To address this situation, the current research utilises a discrete spatial choice approach to investigate the influence of physical barriers (such as rivers, and major roadways) and connectors (such as train lines) on macro-level residential burglary target selection in Perth, Western Australia.

Previous Approaches to Investigating Target and Location Vulnerability

The first major type of research methodology investigating burglary choice has focused on target vulnerability. These studies have made use of a diverse range of techniques and the geographic resolution of analysis has ranged from the micro to the macro. For example, at a micro-level, some studies have made use of offender

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interviews or ethnomethodology to investigate how burglars choose particular targets (as summarised by Nee & Taylor, 2000). On the other hand macro-level studies have (a) focused on broader target characteristics (such as the suburb affluence, social cohesion, etc.); (b) examined individual household, dwelling, and block characteristics within neighbourhoods (e.g., Smith & Jarjoura, 1989) and (c) also utilised increasingly sophisticated analyses of victimisation surveys that have simultaneously incorporated individual and area-level factors (e.g., Tseloni, Osborn, Trickett, & Pease, 2002). These approaches to understanding burglary choice are not without their limitations. Ethnomethodological studies have provided insight into the decision-making process that leads to discrimination between targets within a local area, but they have largely ignored the question of broad location choice (spatially and temporally). On the other hand, victimisation survey analyses have provided valuable information about general target vulnerability, but they have not been able to include offender information in the modelling process (e.g., Rountree & Land, 2000; Sampson & Groves, 1989; Simcha-Fagan & Schwartz, 1986).

These limitations are at least partially addressed through the *journey-to-crime* studies that utilise official records of apprehended offenders to model movement and broad area selection (e.g., Gabor, 1984; Hesseling, 1992; Rhodes & Conly, 1981; Smith, 1976; Turner, 1969). This class of studies examines distances between burglary targets and offender residence and has established the existence of patterns of *distance-decay* (such that the likelihood of offending decreases as the distance away from the point of origin increases) and has demonstrated this factor interacts with characteristics of the offender, the target, and victim–offender relationship (e.g., Rhodes & Conly, 1981; Wiles & Costello, 2000; Wright & Decker, 1994). The major weakness of this approach is its inability to examine the importance of potential targets that were not selected by the offenders. As noted by Bernasco and Nieuwbeerta (2005, p. 301), an examination of why offenders choose certain targets over others 'should use distance as an explanatory variable; whereas [in journey to crime studies], distance is used as the dependent variable'.

This weakness is countered to an extent through *gravity* models. Such models utilise the same official data sources as journey-to-crime studies to examine the number of crime trips between neighbourhoods as a function of the distance separating them, as well the *push* factors from area of origin and *pull* factors to the target area. While these models are able to examine variation in frequency of victimisation across areas (e.g., Elffers, Reynald, Averdijk, Bernasco, & Block, 2008; Peeters, 2007; Rengert, 1981; Smith, 1976), this is achieved through reliance on aggregated crime data for areas. As a result, gravity models can only examine individual offender and target characteristics by developing separate, more limited submodels.

More recently, Bernasco and Nieuwbeerta (2005) applied a discrete spatial choice model to burglary victimisation. The model was originally developed by McFadden (1974) to study the motivation, frequency and methods involved with urban travel, but Bernasco and Nieuwbeerta used it to investigate residential burglary target selection in The Hague, the Netherlands. In particular, the authors examined how the perceived utility of a target suburb varied as a function of four factors: target affluence, the perceived likelihood of successfully completing a burglary (as influenced by factors such as residential mobility, ethnic heterogeneity, and so on), the number of potential targets in an area and the distance between an offender's origin and each potential target in an artificially constrained choice-set. They found that the discrete spatial choice approach provided an advance in analysing criminal location choice at a macro level, combining the strengths of previous models in the absence of associated weaknesses. Their findings provided further confirmation of the importance of offender proximity to target neighbourhood selection. Importantly, this model enabled the researchers to establish that other risk factors for burglary were dependent on specific offender characteristics. For example, while macro-level ethnic heterogeneity was a positive risk for burglary victimisation, this influence was diminished for native-born offenders relative to offenders not born in the Netherlands. Furthermore, there were indications that the proximity between the point of origin and a potential target was more important for juvenile burglars than adult burglars in the selection of target neighbourhoods.

Theoretical Frameworks for Understanding Offender Movement and Offending Location Choice

Rengert (1981, p. 191) suggested that any optimal analysis of offending must consider the offender's residence, the target area and the relationship between these two areas because '… opportunities for crime do not operate in isolation from potential criminals any more than potential criminals operate in spatial isolation of opportunities in creating crimes'. A broad range of opportunity theories exist that stress the importance of the environment and the spatial and temporal interaction between offenders and targets for the actualisation of criminal behaviour. First, a rational choice account of offender decision-making (e.g., Clarke & Cornish, 1985; Cornish & Clarke, 1986) provides a framework for understanding how offenders make decisions when a crime opportunity arises. The assumptions underlying this perspective are that offenders make rational decisions to offend and to select targets, but that these decisions are bounded by logistical constraints (such as time, knowledge and ability) that operate to limit the effectiveness of these decisions (Clarke, 1997; Clarke & Felson, 1993).

Routine activity theory is another opportunity theory that can assist in understanding how elements of bounded rationality operate in the real physical world. It proposes that the minimum components required for a crime to occur are for a motivated offender and a suitable target to coincide temporally and spatially in the absence of a capable guardian (Cohen & Felson, 1979). One major implication of this perspective is to emphasise that the rational choice of targets cannot overcome the tyranny of distance into places that are beyond the consciousness and daily routines of offenders; a limitation that constitutes an often unacknowledged condition of action (Giddens, 1984, p. 282).

Based on these perspectives, it is unsurprising that the likelihood of a typical offender committing a residential burglary decreases as they move away from the area they live in. Despite some claims that distance-decay emerges as a consequence of faulty analysis (e.g., Van Koppen & De Keijser, 1997), subsequent modelling research (e.g., Bernasco & Nieuwbeerta, 2005; Rengert, Piquero, & Jones, 1999) has demonstrated good support for the assumption that this pattern is not simply an artefact of aggregating crime journeys across offenders. Instead, Bernasco and Nieuwbeerta suggested that a distance-decay pattern may result from any one (or a combination) of the following reasons: increased unfamiliarity in novel areas, fear of standing out as a stranger in these areas, a lack of knowledge about the physical infrastructure and the residents in such areas and the increase in effort required to travel to and from these places.

Chainey and Ratcliffe (2005, p. 96) discuss how crime pattern theory (as proposed by Brantingham & Brantingham, 1984) provides a 'helpful convergence' for routine activity theory and a rational choice perspective. Essentially, this perspective predicts that willing offenders are likely to find offending opportunities in areas about which they have knowledge. Crime pattern theory makes predictions about the importance of offender's cognitive 'awareness space' (Brantingham & Brantingham, 1991, p. 35) based on 'the parts of the city [offenders] have some knowledge about' composed of the pathways of their normal activity (such as the movement between home, work and leisure activities). Essentially, this theory divides the offender's world into: (a) *nodes*, which are the locations where offenders regularly find themselves; (b) *pathways*, which are the routes frequently chosen between nodes; and (c) *edges*, which label the physical and psychological/perceptual boundaries that define the limits of the offender's functional space. Fundamentally, this theory proposes that offending is most likely to be operationalised when an offender's awareness space intersects with a suitable opportunity (from both a rational choice and routine activity perspective). Building on these general theories of offender movement and the role of distance and opportunity, the following section provides an overview of previous research specific to the issue of the influence of physical barriers and connectors on offending.

The Influence of Barriers and Connectors on Offending Patterns

The Influence of Physical Barriers

Quite clearly, as is addressed by all of these theoretical frameworks, movement through space and time is not random or irrational and is more complicated than simply evaluating straight-line distance between two points: instead, it is influenced by the physical and social constraints placed on the individual. Despite good reason to believe impermeable barriers will contribute to these movement patterns, the impact of this factor lacks conclusive formal evaluation. Across offence types, the micro-level influence of physical barriers has been investigated in a number of previous studies. For example, with respect to burglary, Bowers, Johnson, and Hirschfield (2005) assessed the impact of closing rear-access laneways, and when examining violent and drug crime, Zavoski et al. (1999) explored the impact of a single barrier. From a macro level, the theoretical and empirical work of the Brantinghams (e.g., 2000; 2003) and Felson (e.g., 2002) is relevant with respect to the potential influence of natural features such as rivers or forests or man-made features such as roads or bridges.

At present, current research provides mixed support for this hypothesised influence of barriers on offender movement and area target selection. It is clear from Sampson's work (e.g., Sampson, 1985; Sampson & Groves, 1989) that offenders are bounded to an extent by socioeconomic variations between areas (arguably reflective of perceived social barriers and the estimated likelihood of successfully completing an offence). However, it remains uncertain how large, physically fixed barriers between an offender and their surrounding suburbs influences the movement they are prepared (and able) to undertake. On the one hand, Ratcliffe (2001, 2003) conducted an examination of the impact of suburb boundaries on movement patterns of residential burglars in the Australian Capital Territory, and found no significant inhibitory influence of factors such as additional vegetation, wider roadways or limited suburb entry points. However, other examples of research do demonstrate a relationship between barriers and offending. Greenberg et al. (1984) found that barriers (which they termed *boundaries*) in low-crime neighbourhoods restricted outside access, relative to barriers in high-crime areas, which were much more permeable. Further insight into these mixed findings was provided by a recent study conducted by Peeters (2007). Through use of a gravitational model to analyse movement patterns of residential burglars in The Hague, Peeters initially found that, once distance was included in the model, the overall explanatory capacity of barriers was found to be negligible. However, further exploration exposed two important patterns. First, not all barriers had the same impact on movement, with factors such as crossing water bodies decreasing the likelihood of travel while parklands did not. Second, the influence of these barriers varied with increased distance, such that over a shorter distance the barriers were more influential deterrents on travel.

These findings suggest that at least part of the confusion surrounding the influence of barriers may stem from the fact that, within the framework of current terminology, there is broad variation surrounding what constitutes a *barrier*, and what are sometimes termed barriers may actually be more like *obstacles* that exert a much more limited deterrence. From a theoretical perspective, a barrier is only influential to the extent that it inhibits movement in that direction, thereby reducing the likelihood of an area becoming part of an offender's routine movements and cognitive awareness space. Furthermore, this again demonstrates the importance of identifying the level of analysis that is being used: where macro-level factors such as wide rivers may prevent selection of areas for offending, while micro-level factors such as laneways will influence individual target selection between dwellings.

The Influence of Connectors

Just as barriers may reduce access between areas, connectors can facilitate access by minimising the impact of distance. At the micro-level, Beavon, Brantingham, and Brantingham (1994) examined the influence of street networks in providing differential access to dwellings. Furthermore, Swartz (2000, p. 39), in summarising aspects of the Brantingham's work, suggested that, 'researchers must better understand the effects of different types of transportation, such as cars, buses, and trains, on the spatial distribution of crime'. As Chainey and Ratcliffe (2005, p. 105) point out, 'from an aggregate perspective, [these types of] pathways provide an opportunity to go past and assess new criminal opportunities'. Brantingham et al. (1991) provided evidence for the influence of public transportation on offending opportunity and proposed that such networks enable potential offenders to coincide spatially and temporally with novel targets. This hypothesis was further supported by the outcome of the crime prevention exercise investigating automobile-related thefts from a 'Skytrain' commuter parking facility in Vancouver (Barclay, Buckley, Brantingham, Brantingham, & Whin-Yates, 1997). However, the relatively few studies that have investigated the impact of public transport connectors have focused mainly on the short-term impacts of introducing new lines and have not examined offender travel patterns. In summarising research prior to 2003, Sedelmaier (2003, p. 36) stated that 'Thus far, there is little evidence that transit expansion "infects" neighborhoods with crime'. Sedelmaier's own research was able to examine offender travel patterns before and after the introduction of a new light rail system in Newport and found evidence for a increase in distance travelled to crime in only one of four service areas, and this was not for offences against property. The lack of uniformity in prior research on the crime redistribution impact of new transit routes is underlined by Smith and Clarke (2000, p. 219) who note that public fear of attracting crime can delay the introduction of new services.

Nevertheless, in direct contrast to the expected role of impermeable barriers on inhibiting offender movement, appealing to the theoretical perspectives discussed previously leads to expectations that connectors should simultaneously fulfil two roles. They act to decrease the significance of distance for movement, thus increasing access, first, by reducing travel effort and second, by integrating them into offender's daily routines and thereby their cognitive awareness space

Aims and Hypotheses

Based on the framework provided by opportunity theories discussed above for understanding the role of the environment in the interaction between offenders and targets, the aim of this research is to build on Bernasco and Nieuwbeerta's (2005) findings and utilise a discrete spatial choice approach to formally evaluate the influence of barriers and connectors on target selection at a macro level. To this end, a number of hypotheses were proposed. First, it was anticipated that effective barriers should reduce the perceived utility of separated areas. Second, it was predicted that connectors should increase the utility of linked areas. Third, it was expected that distance would have an impact on offender movement and target area selection, in addition to the impact of barriers and connectors. Finally, it was hypothesised that the perceived likelihood of successfully completing a burglary (as a consequence of sociological, area factors) would influence offender decision-making.

Methodology

DATA SPECIFICATIONS

Representativeness of the Burglary Data

The residential burglary data analysed here were provided by the Western Australian Police. The information provided for each burglary incident contained details on the nature of the burglary (attempted or actual) and the broad location of the burglary (in this case, the suburb). In those instances where an offender was identified, the burglary incident data could be linked to offender information including age, sex, Indigenous status,[1] and location of home suburb. In 2002, the estimated prevalence rate for break-in and attempted break-in in Western Australia was 9.6%, and of these incidents approximately 84% of actual break-ins were reported to police (Australian Bureau of Statistics [ABS], 2006). Police were able

TABLE 1

Frequency, Mean Age plus Standard Error (s.e.) and Percent of Sample for Offenders by Age, Indigenous Status, and Sex*

Age	Indigenous status	Sex	Frequency	Mean age	s.e.	Per cent of sample
Adult	Indigenous	Female	54	25.06	0.88	3.07%
		Male	168	24.87	0.57	9.54%
	Total		222			12.61%
	Non-Indigenous	Female	164	27.76	0.66	9.31%
		Male	994	26.42	0.24	56.45%
	Total		1,158			65.76%
Juvenile	Indigenous	Female	21	14.62	0.46	1.19%
		Male	122	14.66	0.19	6.93%
	Total		143			8.12%
	Non-Indigenous	Female	24	15.46	0.31	1.36%
		Male	214	15.43	0.10	12.15%
	Total		238			13.52%
Total			1,761			100.00%

Note: *Statistics were calculated on the basis of burglary incidents rather than individual offenders since the dataset did not permit the unique identification of offenders.

to identify an offender for approximately 5.5% of burglaries (actual and attempted) reported during 2001 and 2002. Of these cases, 49.7% were included in the final data set for analysis here. Cases were removed if: (a) there were multiple offenders identified for a single incident, or (b) the offender's area of residence was located outside the Perth metropolitan area. The final dataset contained 1,761 single-offender (actual or attempted) residential burglaries committed between January 1, 2001, and December 31, 2002, where the offender resided in the city of Perth.

The descriptive statistics for the characteristics of the offenders involved in this analysis are displayed in Table 1 disaggregated by age, Indigenous status, and sex. Age here captured the offender's age at the time of apprehension, with individuals below 18 years categorized as juvenile and those 18 years and over considered to be adult. Of the 1,761 burglary incidents examined here, 21.6 per cent involved juvenile offenders and 20.7 per cent of the selected offenders were classified as Indigenous by the processing officer.

The Geography of Perth, Western Australia

The city of Perth is located in the south-west of Western Australia at the coast of the Indian Ocean. The estimated residential population of Perth in 2001 was 1,381,298 people. Perth is the largest city in Western Australia, with suburbs that sprawl along the coast for approximately 100 km and extend inland from the coast by up to 40 km. A total of 291 residential suburbs were selected as members of the possible choice set for the residential burglaries examined here. The summary

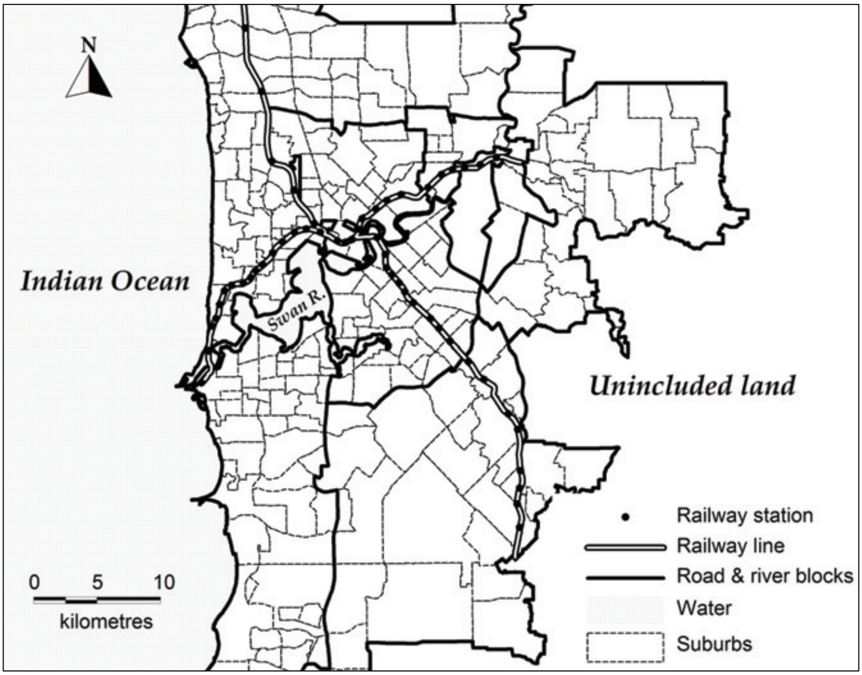

FIGURE 1

Perth, Western Australia, with suburb boundaries, major roads, railway lines, and the Swan River identified.

statistics for this set of suburbs show that they have an average size of 6.76 km^2 with a mean population of 4,669 residents and 1,791 dwellings (ABS, 2003). It is important to note here that the term *suburb* as used in Western Australia has a different meaning to other parts of the world (particularly the United States and Canada), and is more akin to a *neighbourhood* in these areas. The overall geographic placement of these suburbs in relation to the Swan River, selected major roads, and the location of the railway line are displayed in Figure 1.

Some summary characteristics for Perth suburbs are displayed in Table 2. Because the weekly income for suburbs was categorically defined within the census data, it was not meaningful to talk about the average weekly income (ABS, 2004). However, the median weekly income bracket was \$800–\$999 and the interquartile range demonstrated that 50% of the suburbs had a weekly household income that ranged from \$600–\$699 to \$800–\$999. Distance between suburbs was calculated by creating a distance matrix based on distance between suburb centroids estimates and adjustments were made to correct for zero distances (when the offender resided in the target suburb) under the assumption that the suburb was approximately circular (Dunbar, 1997).[2]

Initial analysis of the suburb victimisation demonstrated an uneven distribution of burglary across the suburb set. Thirty suburbs (10.3% of the 291 examined) experienced nearly 37% of the 1,761 offences included in this analy-

TABLE 2

Descriptive Statistics of the Suburbs Variables (n = 291) from the 2001 Australian Census

Variable (unit)	Mean	*SD*	Min.	Max.
Proximity (kilometres)	20.37	16.12	2.10	81.04
Victim suburb advantage (SEIFA index)	1,016.11	85.84	805.44	1,230.48
Residential mobility — 5-year transience (%)	43.31	10.03	21.16	81.58
Residential mobility — Rent (%)	22.23	12.83	0.00	80.00
Percent Indigenous (%)	1.51	1.73	0.00	11.54
Residential units	1,791	1,509	10	8,455

sis. Furthermore, 54 suburbs (18.6%) included in the choice set did not experience any victimisation during the time period of interest.

Analytical Strategy and Variable Selection

The essential elements involved with the application of discrete spatial choice are: (a) defining the boundaries of the choice set, (b) capturing the unique attributes of the decision-makers and (c) modelling the interaction between the individual chooser's characteristics and choice for the whole population (McFadden, 1974). As such, the fundamental premise that underpins this framework is that the single choice an individual makes from a discrete set of spatial alternatives is driven by their evaluation of the utility of each individual alternative. Based on this logic, the general form of the discrete spatial choice is captured by Equation 1, whereby the utility (U) chooser i derives from each alternative j is determined according to the relationship between the empirically estimated coefficient β and the set of decision attributes that vary between choice options, z_{ij}. In this case, e_{ij} represents those additional factors that influence the perceived utility chooser i derives from possibility j but which have not been included in the model.

$$U_{ij} = \beta' z_{ij} + e_{ij} \tag{1}$$

The general utility formula, represented by Equation 2, included elements to simultaneously evaluate the impact of a range of factors believed to influence location choice. Most important for this modelling exercise was the formalised evaluation of the influence of selected barriers and connectors on the perceived utility of all suburbs in the choice set. The first barrier parameter, W_{ij}, captured whether the large dividing water body (the Swan River) acted as a natural divide between the burglar's home suburb and each target suburb. As can be seen from Figure 1, this river is wide with very few bridges: over 4 kilometres wide at some points and large sections (over 15 km in some cases) where there are no bridges between the north and south sides. As a consequence, line distances between suburbs' centroids do not always reflect the actual distance required to journey between areas. This variable was coded such that if the river was placed between two suburbs, W_{ij} was allocated a value of 1, with W_{ij} given a value of 0 otherwise. The second barrier parameter, F_{ij}, examined the influence of major roads that divided suburbs, and was allocated a value of 1 if at least one of the major roads displayed in Figure 1 divided the victim suburb and the offender's home suburb, and a value of 0 if no major road divided the two areas. The influence of connectors on burglary suburb target selection was examined through inclusion of a parameter capturing the train network, T_{ij}, such that a value of 1 was given if both the burglar's home suburb and the target suburb had a train line running through them, and a value of 0, otherwise.

$$U_{ij} = \beta_T W_{ij} + \beta_W F_{ij} + \beta_F T_{ij} + \beta_{AD} A_i D_{ij} + \beta_{JD} J_i D_{ij} + \beta_V V_j + \beta_S S_j + \beta_M M_j + \beta_R R_j + \beta_H H_j + \beta_{IE} I_i E_j + \beta_{NE} N_i E_j + e_{ij} \quad (2)$$

As suggested previously, in addition to examining the impact of barriers and connectors on perceived utility of suburbs, it was also expected that line distance between suburbs would provide further explanatory capacity. As such, the distance between each victim suburb and the offender's suburb was captured by the D_{ij} parameter, where *i* and *j* were included in combination, because this distance value varied according to the home suburb of each individual burglar. Furthermore, previous research has demonstrated that distance impacts on movement differentially as a function of age, this parameter was entered into the model separately for adult (A_iD_{ij}) and juvenile offenders (J_iD_{ij}).[3] The varying influence of proximity for adults (A_i) and juveniles (J_i) was coded such that if the burglar was an adult, A_i had a value of 1 and J_i had a value of 0, with the inverse true if the burglar was a juvenile.

In accordance with other previous research modelling offender movement patterns and target selection, other parameters captured the target suburb affluence and the perceived likelihood of successfully completing an offence in a specific area. Affluence was measured by victim suburb weekly income, V_j (calculated based on a dollars ($AU) per week classification resulting from the 2002 Census, [ABS 2004]) and the Socio-Economic Index for Areas (SEIFA) value for Advantage–Disadvantage of the target suburb (S_j).[4] Perceived likelihood of completion was captured in the model by three parameters: (a) victim suburb 5-year residential mobility rates, M_j, (b) victim suburb percentage of rental properties, R_j and (c) victim suburb ethnic heterogeneity for Indigenous and non-Indigenous burglars, E_j (determined by the percentage of Indigenous residents in each suburb).[5] The final parameter in the model, H_j, captured the total number of residential units in the victim suburb.

Equation 2 summarises the structure of the logic that underpins the discrete spatial choice approach. However, in order to apply and test this theoretical construct, a *statistical* technique called conditional logit modelling is required. These models, which take the general form shown in Equation 3, are based on the assumption that a burglar selects the member of the choice set that they consider has the greatest utility. Thus, Y_i is the actual choice offender *i* makes from the overall choice set based on an evaluation of all available alternatives (captured by z_{ij}). The conditional logit model draws its versatility from its capacity for z_{ij} to capture variation between choice options and individual's perceptions of the utility of choice options simultaneously, with the model able to: (a) acknowledge the influence of distinct characteristics of all choices available in the choice set, (b) estimate the importance of variable factors such as distance between suburbs and (c) examine the influence of individual chooser characteristics for the outcome of the decision-making process. In the form summarised by Equation 3, e^{β} represents the multiplicative effect a unit increase in the attribute z_{ij} has on the odds of that element of the choice set being selected by the chooser. Bernasco and Nieuwbeerta (2005, p. 304) described this process as follows: 'if z_{ij} represents the distance in kilometres between a potential target and the offender's home, and if the corresponding $\beta = -0.70$, then the odds of the targets being attacked by the offender inflates by a factor of $e^{-0.70} = 0.50$ for every kilometre further away it is located from the offender's home base'.

$$\mathrm{Prob}(Y_i = j) = \frac{e^{\beta' z_{ij}}}{\sum_{j=1}^{J} e^{\beta' z_{ij}}} \tag{3}$$

Parameters are estimated by conditional logit models through maximum likelihood methods and, as such, care must be taken to ensure that the estimated standard errors are robust to the probability that the data set contains instances of multiple burglaries committed by the same offenders (*clustering* of cases). Given no unique offender identifier linking offenders between burglary cases was available within this dataset, the extent of clustering in this data was estimated by considering every common occurrence of offender age, offender sex, offender race and offender home suburb to be the same person (following personal communication with Bernasco and Nieuwbeerta). This resulted in an estimated clustering of 37%, which is comparable to the measured 46% clustering observed in a similar data set from the Netherlands (Bernasco, 2006). All results presented were calculated utilising this estimate for clustering of offences.

Results

Overall Model Fit

The parameter odds ratios and information about model performance are displayed in Table 3. The model tested here makes the assumption that all parameters are of equal importance to all burglars. As such, the odds ratios reflect the multiplicative factor that alters the odds of a target suburb being selected by an offender for a one unit increase in the relevant variable. The conditional logit model tested here contained 12 parameters and provided an acceptable fit of the burglary target selection data, with McFadden's $\rho^2 = 0.27$.[6] As displayed in Table 3, nine of the twelve parameters significantly contributed to the predictive capacity of this model.

Prior to focusing on the influence of barriers and connectors on the perceived utility of target suburbs, the general trends for the other parameters are briefly discussed. Given the similarity of this analysis with the previous application of a conditional logit model to residential burglary target selection (Bernasco & Nieuwbeerta, 2005), loose comparisons will be drawn between the perceived utility of comparable parameters for Perth and The Hague.[7]

First, the expected distance-decay pattern was observed in the model, with a reduced likelihood of selecting a target as distance increased overall, and a differential effect on offender decision-making as a consequence of age (with a greater negative influence for juveniles, $\chi^2(df = 1) = 4.90$, $p < .03$, Wald test). Second,

TABLE 3

Odds Ratios plus Standard Error (s.e.) for Parameters Influencing Utility of Target Suburbs for Burglary (Choice Set: 1,761 Offenders and 291 Suburbs)

Parameter	Variable (unit)	e^{β}	Robust s.e.
β_W	Barrier — River (offender to victim, Boolean)	0.71**	0.06
β_F	Barrier — Road (offender to victim, Boolean)	0.42**	0.04
β_T	Connector — Train (offender to victim, Boolean)	2.08**	0.21
β_{AD}	Distance — Adults (km)	0.87**	0.01
β_{JD}	Distance — Juveniles (km)	0.81**	0.03
β_V	Affluence — Income (victim–suburb $/week category)	1.04	0.04
β_S	Affluence — SEIFA index	1.00	< 0.01
β_M	Success — Transience, 5 year (10%)	1.01	0.04
β_R	Success — Rent (10%)	1.11*	0.04
β_{NE}	Success — Ethnic heterogeneity, Percent Indigenous (1%) — Non-Indigenous Offenders	1.07*	0.03
β_{IE}	Success — Ethnic heterogeneity, Percent Indigenous (1%) — Indigenous Offenders	1.25**	0.04
β_H	Targets — Residential units (•100)	1.03**	< 0.01
	Wald χ^2	1,564	
	df	12	
	McFadden's ρ^2	0.27	

Note: $^*p < .05$ for $e^{\beta} = 1$ two-tailed.
$^{**}\ p < .001$ for $e^{\beta} = 1$ two-tailed.

both measures for target suburb affluence failed to make a significant contribution to the predictive capacity of the model. Next, there were mixed findings for the influence the offenders' expected likelihood of successfully completing a burglary. Although the 5-year transience in the target suburbs was not predictive, a 10% increase in rental properties in the target suburb did increase the likelihood of victimisation. Furthermore, the separate analysis of ethnic heterogeneity for Indigenous and non-Indigenous offenders revealed that, while all offenders were significantly more likely to target suburbs as the percentage of Indigenous people increased by 1%, this effect was smaller for non-Indigenous offenders than for Indigenous offenders ($\chi^2(df = 1) = 22.42$, $p < .001$, Wald test). These findings are consistent with assertions that these types of ethnic heterogeneity measures are probably indicative of various other types of disadvantage (e.g., Sampson & Groves, 1989). Finally, a 100 unit increase in the number of targets in a potential victim suburb, translated into a moderately increased likelihood of that suburb experiencing a burglary. Overall, these findings for the various different proxy measures paralleled those of Bernasco and Nieuwbeerta (2005), strengthening the case for extrapolating these findings across geographical contexts.

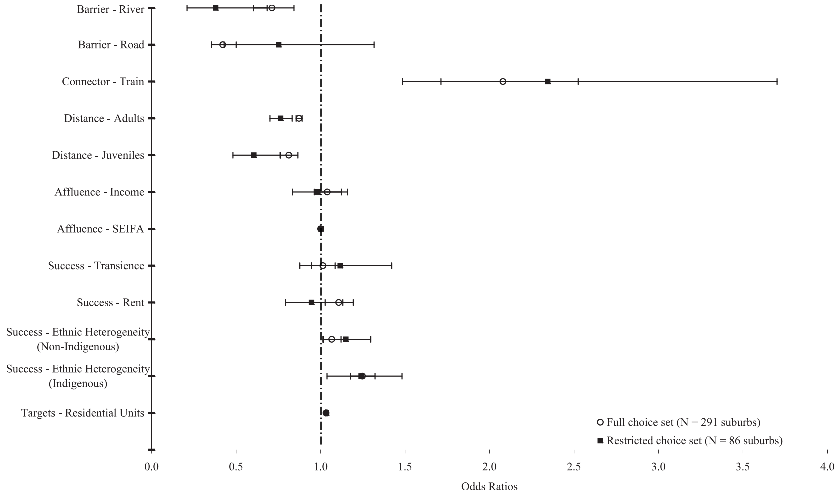

FIGURE 2

Relative odds ratios and error bars for the full sample (choice set: 1,761 offenders and 291 suburbs) and the restricted sample (choice set: 416 offenders and 86 suburbs).

Physical Barriers and Connectors

Physical barriers. Both of the selected barrier parameters performed as predicted. When the offender's home suburb was separated from a possible target suburb by the river, the likelihood of selecting that target for burglary decreased. The same pattern was observed for suburbs separated by a major road, with a decrease in the chances of victimisation if the offender was required to cross a major road divide to reach the target. At first glance it is surprising that the river seemed to have less impact as a barrier than did the major roads. However, a possible explanation of this result is that major roads separate suburbs that are close together and still accessible because distance decay has not made them inaccessible from each other. Conversely, suburbs separated by the river may already be effectively classed as remote from each other in the model because of the pre-existing impact of distance decay. These ideas were explored by repeating the model on a subset of the suburbs, selecting only those that bordered the river. The expectation here was that once the suburbs directly influenced by the river boundary were examined in isolation the impact of the river barrier factor on perceived utility would be even greater. The model involved 86 suburbs all within approximately 4 km of the river. This distance was chosen based on the estimated impact of distance in isolation from the full model fit, which suggested an odds ratio of 0.50 for adults and 0.43 for juveniles travelling 4 km. This restricted choice set resulted in 416 offences being included for analysis. The fit for this restricted model was acceptable, McFadden's $\rho^2 = 0.29$. As is displayed in Figure 2 (the full choice set represented by the white circles and the restricted choice set captured by the black squares), the odds ratios for individual parameters were highly comparable across models (the presentation style for these odds ratios was motivated by work by Gelman, Pasarica, & Dodhia, 2002; and Kastellec & Leoni, 2007). Importantly, the likelihood of crossing the river was found to be significantly reduced for the subset of suburbs that were bounded by this physical barrier, thus supporting the hypothesis that motivated this additional analysis.

Connectors. As predicted, when an offender lived in a suburb that contained a train line, the likelihood of offending in a suburb that also had a train line increased (by factor of 2.08 in the full choice set model and 2.34 in the restricted sample). This provides good support for a crime pattern approach to understanding offending locations, with the railway line facilitating access to more remote areas (reducing the impact of wheel distance in this case) thus enabling further-reaching areas to exist in offender's cognitive awareness space.

Discussion

Overview of Main Findings

Overall, the results for the barriers and connecters examined here were all statistically significant and demonstrated good support for the assumptions that connectors such as train lines, and physical barriers such as rivers and roads, do significantly influence target suburb utility. As anticipated, this finding occurred in addition to the traditionally observed distance-decay effect and was demonstrated to vary depending on how the choice set was defined. Furthermore, the influence of comparable parameters largely paralleled Bernasco and Nieuwbeerta's (2005) findings in a novel environmental context, which makes a positive contribution to alleviating concerns about the relevance of a discrete spatial choice approach to modelling residential burglary target selection in non-European cities with very different physical geography to The Hague.

Implications of these Findings for Barriers, Connectors, Distance, and Intervening Opportunities

This pattern of results for the impact of barriers (both social and physical), connectors, distance and the number of targets was simultaneously supportive of rational choice perspectives, routine activity theory, sociological accounts of movement and the importance of intervening opportunities on decision-making. In addition to supporting assumptions that ethnic heterogeneity (which is likely to be acting as a proxy for broader senses of disadvantage related to social disorganisation and a lack of social cohesion) influences the perceived likelihood of successfully completing a burglary, these findings also add support to the position that such factors act as perceived social barriers that, in turn, influences travel patterns. However, these results also demonstrate that these sociological parameters operate in parallel with physical barriers to influence movement; a pattern that gets more pronounced the closer the offender's origin is to a major, impermeable physical barrier. Furthermore, these factors were shown to influence perceived utility in addition to the influence of distance between areas and any impact of increased numbers of residential targets in each suburb. Future research into the influence of barriers must analyse types of barriers separately, and consider their varying impact over different distances (variations in choice set). Furthermore, following from Peeters's (2007) and Ratcliffe's

(2001, 2003) findings, subsequent research needs to consider the permeability of these factors to help define the characteristics that differentiate obstacles from barriers. The significance of the connector examined here was also consistent with crime pattern theory and the expectations of previous research (e.g., Brantingham et al., 1991) as the facilitative influence of a train link on suburb target selection was pronounced. Future research should examine the generalisability of this finding, particularly with a view to transferability across crime type, and to consider how this pattern relates to physical and social characteristics of specific train stations. Note that the findings of this research do not necessarily imply that burglary is directly linked with rail connectors. Research involving burglar interviews in Perth revealed that very few burglars used either train (1.3%) or bus (1.3%) to travel to their most recent burglary (Clare & Ferrante, 2007). Over the long-term, however, it may be that offenders' awareness space is altered by routine rail travel. Furthermore, while burglary patterns in Perth are evidently affected by rail links, the 'stretching' of distance along lines may have little net effect on crime rates in a burglary target suburb because burglar 'immigration' may be balanced by 'emigration' of local burglars.

As discussed previously, the models tested here enabled the impact of distance to be evaluated separately for adults and juveniles, and simultaneously with impact of barriers and connectors. The patterns of findings pose some interesting questions for an explanation that simply relies on distance as a single causal mechanism underlying target choice. Barriers were seen to inhibit choice and connectors acted to facilitate selection; additionally, the impact of distance overall was found to vary depending on offender age. As Bernasco and Nieuwbeerta (2005, p. 300) discussed, juvenile burglars are typically more impulsive and more likely to be motivated by thrill-seeking tendencies. Therefore, one potential explanation for the different ranges of adults and juvenile offenders is a variation in willingness to seize opportunities to offend. Perhaps the decision to offend closer to home is moderated less by the restrictions on mobility for juveniles (due to a lack of a driver's licence) and more by their overall lower threshold of acceptability when evaluating targets. Future attempts to model perceived utility of choices could explore the differential impact of these factors as a consequence of offender age.

Weaknesses and Limitations

Despite the arguable improvements a discrete spatial choice approach makes to the analysis of offender location target selection, there are still limitations to the approach presented here. First, as explained previously when discussing the representativeness of the burglary data involved, only a very small percentage of burglaries that occurred were actually included in this analysis. Unfortunately, given the need for offender characteristics to enable this modelling to operate, this was unavoidable and the researchers acknowledge that this low detection rate has possibly influenced the outcome of this research in a nonrandom way. Second, due to the artificial nature of defining an external boundary for the discrete choice set in this case, the exclusion of suburbs outside of the Perth metropolitan area has influenced the outcome of this analysis. Third, the dataset did not permit the researchers to uniquely identify offenders and to precisely determine the influence of prolific offenders on target choice. Nevertheless, the analytic approach adopted provided conservative estimates of the accuracy of odds ratios and allowed us to be confident about the significance of those variables included in the final model. Fourth, it must be acknowledged that the discrete spatial choice model presents researchers with the outcomes of 'practical consciousness' (Giddens, 1984, p. 375), and that despite the success of this 'choice' approach, the extent to which offender behaviour is accounted for by rational choices rather than unconscious routine remains uncertain. However, these limitations are realities across this type of criminological research and are not unique to this study.

A further issue concerns the selection of the spatial scale for burglary analysis in this case. This is a complex problem and there may be no solution that is applicable across the ecology of different cities. There is evidence, however, that rates of burglary and other crimes can exhibit large variations across very small populations and areas that in some cases are smaller than neighbourhoods (Bottoms, Mawby, & Walker, 1987). Furthermore, a relatively large degree of variation in surface size remained within and between the suburbs contained in the choice set modelled in this case. Future research could seek to minimise the impact of this limitation by using more artificially constructed and uniform areas for this type of analysis.

Conclusion

The advantage of the discrete spatial choice approach is that it places realistic constraints on those 'bounded rational choices' that rational choice theorists discuss (Cornish & Clarke, 1986). This type of formalised modelling approach allows researchers to begin to understand what influences a burglar's presence in a neighbourhood of interest and draws attention to the 'tyranny of distance' against which burglar choices are made. Such research also (partially) reveals the factors that contribute to a burglar feeling comfortable in a neighbourhood and the effect of physical or perceived social barriers on (literally) *bounded* rationality. Furthermore, this strategy has the potential to model individual differences in perceived utility of situational characteristics across individual offenders, while also formally testing modern interpretations of rational choice perspectives (e.g., Ward, Stafford, & Gray, 2006, who posit that offenders are imperfect processors of information and pursue satisfaction rather than maximum utility). Although none of these factors are necessarily excluded from rational choice models, they all have the capacity to be formally examined within the framework provided by conditional logit models.

Furthermore, this approach has the potential to integrate elements of routine activity theory and the rational choice approach to understanding criminal behaviour. Current applications of the model have provided an analysis of choice that was not dealt with by studies that examined target attractiveness in an abstract way, such as burglar interview studies (e.g., see Nee & Meenaghan, 2006, for a good summary of this research). Although such research did enable burglars to outline their decision-making processes at the micro-environmental level, other dimensions of choice could not be addressed, including: (a) offender age and experience, (b) offender ethnicity/identity in relation to the neighbourhood ethnic heterogeneity, (c) physical distance of the offender's own residence and activity space from any real neighbourhoods of interest and (d) how physical barriers and connectors interact to influence the offender.

In combination, these findings provide good initial support for the assumptions of Cusson (1986, as summarised by Clarke, 1997, p. 12), that as criminological research progresses the perceived divides between theoretical approaches may 'turn out to be mainly of historical interest and that a synthesis is inevitable and desirable'. When analysed simultaneously within this type of model it can be argued that burglar movement patterns are influenced by the physical environment, crime pattern theory (encompassing rational choice and routine activities), and aspects of social control: a parsimonious outcome that unifies the explanatory capacity of a number of the major schools of criminological thought.

Endnotes

1 As determined by a Western Australian police officer at the time of processing (Crime Research Centre, 2003).

2 Based on the findings of Dunbar (1997) that the average distance between points in a disk is captured by $64d/(45\pi)$, where the d = the diameter of the disc, derived from the suburb area (in km^2).

3 There is a range of different research findings motivating this comparison, with explanations ranging from reduced planning and preparation on behalf of younger offenders through to a reduced awareness space for juveniles resulting from constraints to their mobility resulting from an inability to drive (see Bernasco & Nieuwbeerta, 2005, p. 300, for a discussion of these issues and research citations).

4 The SEIFA index for Advantage–Disadvantage is a composite measure that relates to socioeconomic aspects of small geographic areas within Australia. It is calculated as a result of responses to a range of census questions and has the broadest coverage of area advantage/disadvantage. A high score on this index suggests, (a) that an area has a relatively high proportion of people with high incomes and has a skilled workforce, and (b) that the same area has a relatively low proportion of low-income and unskilled residents (for further discussion of the process underlying the development of this index see Trewin, 2003).

5 Differential effects of victim–suburb ethnic heterogeneity for Indigenous and non-Indigenous burglars were explored by binary coding within the model as with the influence of distance previously for adults and juveniles. The interaction between the offender's Indigenous status and the target suburb ethnic heterogeneity was captured in the model through separate parameters for Indigenous (I_i) and non-Indigenous (N_i) offenders.

6 McFadden's ρ^2 is a restricted range estimate of the proportion of variance accounted for by a model and tends to be much lower than R^2. For modelling purposes McFadden's ρ^2 values between 0.2 and 0.4 are considered to be very satisfactory (Tabachnick & Fidell, 2001).

7 Prior to discussing these findings in view of Bernasco and Nieuwbeerta's (2005) research, it is important to explain that it is incorrect to directly compare coefficients across different datasets (given the variations between U and βz_{ij} in each case). However, it is possible to compare the odds ratios of coefficients held common between the current model and the previous analysis (see Swait, 2005, for a detailed discussion of this issue).

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