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Behavioural case linkage:
Linking residential burglary offences in New Zealand

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Abstract

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This thesis aims to replicate and extend prior research on behavioural case linkage from the United Kingdom and Finland, using a sample of residential burglaries committed in New Zealand. Eighty-two solved residential burglaries, committed by 47 serial burglary offenders in Napier, New Zealand, are sampled from the New Zealand Police National Intelligence Application (NIA) database. Prior research using behavioural case linkage for residential burglary has found support for the usefulness of crime scene behaviours, inter-crime distance and temporal proximity to accurately predict offences committed by the same offender. Inter-crime distance has consistently shown higher degrees of accuracy in determining whether two crimes are linked to the same offender. Using the methodology followed by previous researchers, 41 linked crime pairs (two offences committed by the same offender) and 41 unlinked crime pairs (two offences committed by different offenders) are created. Three behavioural domains of crime scene behaviours, inter-crime distance and temporal proximity of offences committed by the same offender are compared with offences committed by different offenders. Logistic regression analysis and receiver operating curve (ROC) analysis is used to determine the ability of the three behavioural domains to accurately predict whether offences are linked or not. Similar to prior studies, all three behavioural domains showed moderate predictive ability in reliably determining the linked status of crime pairs. Contrary to prior studies inter-crime distance was found to be the least accurate predictor in

determining the linked status of crime pairs, with an optimal model combining temporal proximity with crime scene behaviours showing the greatest degree in determining whether crimes were committed by the same offender or not. These results provide support for the use of behavioural case linkage for linking residential burglary offences in New Zealand while caution is required when relying on inter-crime distance alone as a linking feature within small geographic areas.

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Introduction and Literature Review

Crime seems a constant evil in society, increasing fear and bringing harm to many, whether from being a victim of crime, knowing someone who has been victimised by crime, or through increasing levels in the fear of crime. Crime is newsworthy, negatively impacts individuals, groups and communities, and exerts a heavy cost both financially and through physical and emotional harm. The vision of the New Zealand Police is to build the communities' trust and confidence, with a key goal of reducing crime and victimisation. The operating model of New Zealand Police is Prevention First which has a focus on targeted policing to reduce offending and victimisation (New Zealand Police, 2016). The Prevention First model places prevention at the forefront and victims at the centre of policing. This is based on acting with urgency against priority and prolific offenders and includes collaboration with the justice sector in reducing crime and its harm, as well as holding offenders to account. New Zealand Police are committed to reducing the total crime rate by 20% from 2011 to 2018. Total crime has reduced in New Zealand between 1996 and 2014 by over 26%. However this reduction rate has slowed since 2011, with a 16% reduction recorded, and a slight increase from 2014 to 2015 (3%) (New Zealand State Services Commission, 2016).

A recent trend in recorded crime has been an increase in dwelling burglary offences across New Zealand (Statistics New Zealand, 2016). Dishonesty offences, of which burglary is a category, are the greatest contributor to the total crime rate with dwelling burglaries representing 12% of all recorded crime. This has increased from nine percent in 2005 (Office of the Auditor General, 2006). Burglary is one of the most common

crimes people in the developed world will experience, with the highest rates in Australia and New Zealand (Gavin, 2014). In 2013 New Zealand had the highest rate of residential or 'dwelling' burglary at 892 offences per 100,000 population, compared to 372 offences per 100,000 population for England and Wales (United Nations Office on Drugs and Crime, 2014). Burglary has steadily increased over the past 18 months in New Zealand with the highest levels recorded in the past four years. Official crime statistics released by Statistics New Zealand in October 2016 show a 36% increase in reported burglary in Hawke's Bay over the past twelve months (Statistics New Zealand, 2016).

The offence of burglary in New Zealand is defined as "the action of any person entering or remaining in a building, enclosed yard or ship, without authority and with intent to commit an imprisonable offence" (Crimes Act, 1961, s.231). This also includes vehicle crimes committed when the vehicle is parked on someone's property or on a household driveway. Although the majority of burglaries involve the theft of property from the dwelling, the commission of other offences including breaking into a vehicle whilst parked within the property boundary also constitutes a burglary in New Zealand.

There are two main categories of burglary in New Zealand namely; commercial and residential. There are additional sub-categories within the crime type of burglary including the type of property entered, but the distinction between residential and commercial burglaries is the major one and reported separately for crime reduction performance purposes. A residential burglary is defined as a burglary to any property used as a residential dwelling. Residential burglaries accounted for nearly three

quarters of all burglary offences in New Zealand in 2014 (New Zealand Police, 2015) and are of high concern for residents; ranking as the greatest perceived neighbourhood crime problem concerning adult residents in 2014 (Ministry of Justice, 2014). This reported level of community concern has increased (up 4.2%) from that reported in 2009. Respondents to the New Zealand Crime and Safety Survey (2014) reported being more worried about being a victim of burglary than any other crime, regardless of whether or not they had previously been a victim of burglary. Victims of a burglary were also more likely to define the burglary as a crime than any other offence. Burglaries exert a high cost on victims: materially, physically and emotionally.

Although categorised as an offence against property and while the majority of dwelling burglaries rarely involve a face-to-face contact between the offender and the victim, dwelling burglary is still felt as a very personal crime (Merry & Harsent, 2000). While usually involving the theft of items, namely personal property, the fact that the burglary involves an invasion into the home increases the perceived seriousness of the offence in the eyes of a victim. A person's home is a special place and is much more than just a roof over someone's head. As Merry and Harsent (2000) report, residential dwellings are chosen and decorated by occupiers and reflect their individual personal styles, tastes and choices. They are personalised with meaningful items and become a place of safety and security for occupier/s.

It is unsurprising that the home is often the subject of idioms and colloquial sayings reflecting a home's special status as a place of personal safety and security. These

sayings include 'home sweet home', 'home and dry', 'home and hosed' and 'safe as houses', perhaps stemming from the well-known phrase that a 'man's home is his castle' which rests in the English common law right for an occupier to be protected from unlawful entry into the home (Online Library Liberty Fund, n.d.). According to Beaton, Cook, Kavanagh, and Herrington (2000, p. 34) a burglary "represents an assault upon the victim's sense of security". Even if an offender is caught for a burglary and stolen property returned, the experience of being a victim can have lasting effects. As Hendery (2016) reported that even after a quick response by police and the apprehension of an offender for a burglary where a large number of electrical items and family Christmas presents were stolen, the victim later stated that "even after cleaning the house up it feels dirty and like a strange place, not a place you feel safe and at home in". The loss of a sense of security in the place where a resident should feel most safe can have long term negative physical and psychological consequences for victims and an increase in fear of further victimisation.

Negative effects on the victim

Maguire (1980) reports that victims of burglary were less worried about losing items of property than they were about the emotional harm the offences inflicted on them. Loss of property ranked third in relation to the question 'what was the worst thing about the burglary?' behind emotional upset and intrusion of privacy. Physical effects of a burglary reported by victims include the need for medication, difficulty in sleeping and other negative influences on a victim's physical health. The behaviours of an offender during the commission of the burglary can also vary greatly with a corresponding difference in

how the victim feels affected by the crime. Offending behaviours can vary from 'no search' to 'ransacking' the inside, searching personal items including underwear drawers and some offenders leave their mark by defecating and damaging property. Consequently some victims of burglary express their emotions in terms of a sexual nature including a feeling of being 'violated' by a 'dirty stranger', feelings of revulsion and also feeling like they 'have been raped' (Maguire, 1980). This supports the proposition that the emotional impact of a burglary is considerably more important to a majority of victims than any financial loss.

Resolution rates

A recorded offence is considered resolved by the Police when an offender is identified and dealt with in a number of ways; warned, formally cautioned, or prosecuted (Statistics New Zealand, 2006). Unfortunately, burglary has one of the lowest resolution rates of all reported crime, currently around 12% in New Zealand, compared to theft (22%), property damage (28%) and acts intended to cause injury (72%) (New Zealand Police, 2014). This comparatively low resolution rate has been relatively stable over a long period of time and across jurisdictions and countries. Resolution rates, termed 'clear-up' rates in the United Kingdom, for burglary in England and Wales were as high as 37% decreasing to 20% in 1992 (Evans, 2002; as cited in Thornley, 2004), and 16% from 2011 to 2013 (Home Office, 2013). The resolution rate for burglary in New Zealand is comparatively lower than other countries, ranging from 10 – 16% from 1994 to 1999 (Thornley, 2004) and reducing from 14% in 2012 to 12% in 2014 (New Zealand Police, 2015).

As burglary is classified as a property offence, it ranks lower in terms of a policing priority than offences against the person (Corboy, Gilbert, Purdie, & McKenna, 2005). This impacts policing decisions around crime scene attendance, investigative effort and resourcing. As Maguire (1980) reported, what presents itself to a Police officer as a trivial, routine offence holding out little hope of an arrest, may have a vastly different meaning to a person who is experiencing victimisation for the first time. The lack of priority given to burglary by police may explain the ongoing poor resolution rates. An additional reason for the lower resolution rates however, is the nature of the offence and the lengths an offender will go to in evading capture. Burglary is a crime of stealth and very little evidence is left at the scene linking the offender to the crime.

Burglars do not want to get caught so victims are rarely confronted by an intruder. Thornley (2004) found that from 1998 to 2003 in Christchurch, New Zealand, in almost all burglaries the offender was a stranger to the occupier (97%), and a burglar was disturbed by the occupier in only four percent of offences. The presence of occupiers inside, or other possible witnesses nearby, rated as the highest deterrent for an offender considering committing a burglary (Blevins et al., 2012) and not getting caught was stated as the most important goal when committing a burglary by a group of successful (non-apprehended) burglars (Hockey, 2016). Additionally, Blevins et al. (2012) suggest that the relatively low resolutions rates for the offence of burglary can encourage an attitude that there is little chance of apprehension. In interviews with a sample of 309 burglars in the United Kingdom, Bennett and Wright (1984) found that only 13% of those interviewed believed they had 'some chance' or 'a certainty' of being caught. In a

qualitative study involving interviews with 28 burglars in New Zealand, 60% believed the police were not getting better at stopping burglaries or catching burglars (Baker & Gray, 2005a). Napier Member of Parliament and opposition police spokesman, Stuart Nash, suggests that young offenders are losing respect for police as offenders know that burglaries in Hawke's Bay are not solved (Lock, 2016). Consequently an increase in apprehensions may act as a deterrent and result in a corresponding decrease in offending rates.

Minority of offenders commit the majority of crime

It is a well-established research finding that a small percentage of the population commit the majority of crime (Everson, 2003). In the United Kingdom, five percent of offenders are responsible for nearly 50% of all crime up to the age of 30 (Paulsen, Bair, & Helms, 2010). According to Couch (2011), six percent of the United States population is responsible for committing 60% of crime. Research from New Zealand has indicated that five percent of young males in New Zealand commit 80% of youth offences (Becroft, 2009). In a comparison of base rates of persistent and temporary antisocial behaviours in a New Zealand longitudinal cohort study, Moffitt (1993) reports five percent of the sample ($n = 1,037$) as rated very antisocial at each of the biennial assessments over a period of 18 years. In a longitudinal study in Australia, Bor, McGee and Fagan (2004) found that antisocial behaviour at age five was strongly related to antisocial behaviour at age 14, including lying, cheating and stealing.

Harvey (2005) reports that around five percent of young people in New Zealand (20% of young offenders) commit many offences over a long period of time, going on to become what Moffitt (1993) terms 'life-course persistent' offenders. Harvey (2005) suggests that the early identification and intervention with this comparatively small group of persistent serial offenders is necessary to reduce the inevitable high volume of offences these young offenders will go on to commit. Therefore the identification, apprehension and subsequent sanction of prolific offenders are effective strategies in reducing a significant proportion of crime and targeting prolific offenders may be one of the most effective use of police resources (Ratcliffe, 2008).

A burglar may be apprehended for only a fraction of the burglaries they have committed. In Napier during 2013, one offender went on a prolonged burglary spree and when apprehended for an offence admitted to committing upwards of ten burglaries each week to fund a drug habit. Of 18 New Zealand burglars who freely discussed their frequency of offending with researchers, more than half (10) admitted to committing at least one burglary a week, and 40% (seven) committing at least 2-3 burglaries per week (Baker & Gray, 2005b). In examining crime and resolution rates from 43 police force areas in England and Wales between 1992 to 2008, Bandyopadhyay (2012) reports that a one percent increase in burglary detection rates leads to an almost point one percent (0.08%) decrease in burglary offending rates. Although a very small decrease in offending percentage, in an average year this equates to a reduction of 3,500 burglary offences for a one percent increase in apprehensions in England and Wales. Therefore increasing apprehensions of a small number of burglars is likely to increase resolution

rates, lead to a reduction in offending and is a valid crime reduction goal (Bandyopadhyay, 2012; Weatherburn, Hua & Moffatt, 2006).

According to Hockey (2016), reasons for not being able to apprehend a burglar include; the majority of offences having no relationship between the offender and the victim, resulting in no avenues of enquiry; and a delay in reporting, as there is often a time delay in the offence being discovered and the absence of witnesses. An additional reason for the low clearance rates for burglary offences is the lower priority placed on the offence by police and the application of insufficient resources to thoroughly investigate each offence. Burglary in New Zealand was a 'priority 4' offence on a scale of '1 to 4', with '1' being the highest priority: an offence with actual threat to life or property, in progress with offenders present and requiring urgent police attendance. A 'priority 4' offence is a volume crime offence not requiring police attendance (Corboy et al., 2005). A burglary, with the victim returning home to find their house broken into and offenders long gone, fell into this category. Following the release of official crime statistics in 2016 indicating a 12% increase in burglary in New Zealand, and the subsequent increased public and media attention generated, the then Police Minister Judith Collins announced that the priority level of dwelling burglaries would be raised to the priority level '3' category. As a result Police would be expected to attend all dwelling burglaries within 24 hours (Collins, J., 2016).

There are a number of ways an offender is caught or apprehended for a burglary including being caught 'on the job' (a burglary in progress), through witness

identification (e.g. neighbours), and identified by occupants (if known to them) (Thornley, 2014). Offenders can also be caught through disclosure of criminal informants (or reported via a confidential crime line) or the discovery of recently stolen goods in their possession. Additionally, offences can be cleared through the admissions of an apprehended offender while in custody or being interviewed for an initial offence (Hockey 2016). The resolutions are termed 'custody clearances' in New Zealand and Taking into Consideration (the TIC scheme) in the United Kingdom (The Home Office, 2013). The most reliable method for linking an offender to a crime are forensic identifications including fingerprints, DNA from blood and other bodily fluids, shoe print impressions, and fibres lifted from a crime scene.

Linking crimes

Although forensic evidence gathered from the crime scene can identify the offender/s responsible, only a small proportion of offences are cleared by forensic identifications. Almost no burglaries were resolved by the use of fingerprints lifted from crime scenes during the 1970's in New Zealand (Davidson, 1980) and the low resolution rates have remained in spite of the advances in forensics including the introduction of Automated Fingerprint Identification System (AFIS) and DNA profiling techniques. In an examination of burglary and auto theft crimes across two police forces in the United Kingdom, Burrows and Tarling (2004) found that only 34% of offences were visited by trained scene of crime officers (SOCO) and just over 11% of those crime scenes visited resulted in a forensic match. As a result, burglary and auto crime offences cleared by forensics were approximately one third of the 10% of total offences resolved. Serial offenders also

become more forensically aware over their offending span and increase precautions, such as the wearing of gloves when committing offences (Chetwin, 2005). However, in the absence of forensic evidence or eyewitnesses, the behaviour of the offender in carrying out the crime has been shown to be useful in reliably linking one or more additional offences an offender has committed (Bennell & Canter, 2002; Bennell & Jones, 2005; Woodhams & Toye, 2007).

The ability to link two or more offences committed by the same offender has benefits including the pooling of resources during investigations of a crime series, gathering evidence across each linked crime to support a prosecution (Gavin, 2014), and increasing information relating to an offender's method of committing crimes (Woodhams & Toye, 2007). Interviewing an offender/s on multiple linked burglary offences also increases the chance of holding an offender/s accountable for a greater proportion of their total offending, increasing clearance rates, which in turn may lead to a reduction in fear of crime and increased public confidence in police (Tonkin, 2015).

Napier and Baker (2003) note trace evidence (forensics) is not the only thing left behind by an offender at a crime scene. Discernible traces of behaviour are also left behind and these behaviours can be analysed. An offender's behaviour at a crime scene include the choices an offender makes in respect of the target, where and how to break in, actions inside the house (including deciding what property to take and what to leave behind), methods of exiting the property, and avoiding detection (Gavin, 2014). Green, Booth, and Bidderman (1976, p. 388) state "The individual's operation is, in general, as

characteristic as his fingerprints". Although this is possibly an overstatement, the point being made is that offenders are generally consistent in the way they commit offences. These offending behaviours are termed *Modus Operandi* (MO), a Latin term meaning *method of operating*, comprising of the behaviours and choices made by the offender/s in the commission of the crime (Turvey, 2002).

The MO of an offender represents a recognisable preferred style of offending that has become habitual over time (Ministry of Justice, 2005). According to Turvey (2002), these behaviours are learned, developed and are changeable, and are open to influences including education, trial and error. According to Keppel (2002), the term MO is not new having been first used in literature in 1654 and became popular in the 1800s. Its use in police investigations was pioneered by Major L.W. Atcherley, Chief Constable of the West Riding Yorkshire Constabulary in England. Keppel (2002, p. 522) describes the MO list constructed by Atcherley to detail an offender's behaviour at a crime scene as follows;

- *Class word*: kind of target property (dwelling house, lodging or hotel)
- *Entry*: the actual entry point (front window, back window etc.)
- *Means*: whether instruments or tools were used to effect entry (ladder, jemmy bar etc.)
- *Object*: the type of property stolen
- *Time*: not only the time of day or night, but also whether at church time, on market day, during meal hours, etc.
- *Style*: whether the offender describes himself as a mechanic, canvasser, agent to gain entry

- *Tale*: any disclosure as to his alleged business or errand that the criminal may make
- *Pals*: whether the crime was committed with confederates
- *Transport*: whether bicycle or other vehicle was used in connection with the crime
- *Trademark*: whether the criminal committed any unusual act in connection with the crime (such as poisoning the dog, changing clothes, leaving a note for the owner, etc.).

Similar to the development of any skill or occupation, as a burglar commits more offences they develop a certain level of expertise, where many of their actions become automatic. Nee and Meenaghan (2006) interviewed 50 convicted residential burglars asking them about their level of concentration during the commission of burglaries. Over three-quarters of the sample described their search activities inside the house as automatic. Other characteristics the burglars' described included being 'speedy', 'methodical' and 'efficient'. Additionally, many described the ability to multi-task while committing a burglary, for example listening out for noises signalling the return of occupiers while continuing the searching. In an innovative study by Nee, White et al. (2015) using mock burglaries with a real house and a computer generated house, clear evidence of expertise demonstrated by the burglars was found. The experienced burglars were more efficient than a group of student research participants, spending more time in more profitable locations of the house, taking more valuable items, and the burglar's transitioning between rooms was more precise and defined;

demonstrating a higher level of practice and skill than the students. This suggest that as many experienced burglars commit their offences in a habitual, automatic way, the commission of a burglary is likely to result in increased behavioural consistency for some behaviours, which aids in linking one crime scene with another when committed by the same offender (Tonkin et al., 2008; Woodhams & Toye, 2007).

Behavioural case linkage

An increasing amount of research has found support for the ability of an offender's crime scene behaviours to be useful in linking that offender to multiple crimes (Woodhams, Hollin & Bull, 2007) and across different crime types (Tonkin & Woodhams, 2015). The process of linking crimes through an analysis of an offender's behaviours has many terms, including; comparative case analysis, case linking, case linking analysis, behavioural linkage analysis, or behavioural case linkage (BCL). For the purposes of this study the term BCL will be used, as it highlights that it is the behaviours of offenders with which case linking decisions are being made. BCL is founded in personality psychology (Woodhams, Bull, & Hollin, 2007) using principles of behavioural consistency and behavioural distinctiveness. These two key assumptions are at the core of BCL, 1) that offenders behave in a consistent manner across crimes they commit and, 2) an offender's behaviour in the commission of an offence is distinctive from other offenders (Burrell, Bull, & Bond, 2012; Woodhams et al., 2007). That is how an offender goes about committing a burglary is behaviourally similar across all the burglaries that offender commits, yet their behaviours are also unique and distinguishable in some way from how other burglars commit their offences.

There are two occasions when BCL can be useful in practice; firstly when an offender is caught for an initial crime (an index offence) and a request is made by an arresting officer or investigator to find other crimes that are similar that may have been committed by the apprehended offender. However, there is often little time to search and analyse offences that may be linked to an index offence before the offender is released on bail or taken to court. The second occasion is when, through the scanning of crime reports by analysts, several offences appearing to be similar are believed to have been committed by the same offender/s (as yet unidentified) and these offences are then considered to be part of a crime series. Analysts routinely scan crime reports and electronic crime maps, looking for offences likely to be committed by the same offender/s. However, this scanning is often done in an ad hoc fashion and sometimes limited to the past 24 hours. As Green et al. (1976) suggests, the process of identifying crimes belonging to a series is sometimes intuitive and links are made by experience and 'hunches' of the analysts. As Bennell and Canter (2002) report, case linking decisions are made in the field but are often flawed as they are subjective, prone to bias and inconsistent across analysts, investigators and jurisdictions. Green et al. (1976) argued that a statistical approach would make more accurate linking decisions than that made by the experience of analysts.

Behavioural case linking research

Research on BCL has consistently found that identifying cases that are linked (committed by the same offender) can be reliably distinguished from cases that are not linked (committed by different offenders), based on the behavioural consistency and

distinctiveness of offenders (Bennell, Gauthier, Gauthier, Melnyk, & Musolino, 2010; Bouhana, Johnson, & Porter, 2014; Woodhams & Toye, 2007). How well people perform on linking tasks is unclear as people have limited ability to process information and are subject to an array of errors, biases and illusory correlations (Bennell et al., 2010). Several studies have examined the ability of BCL to link crimes in comparison to linking decisions made by police officers, analysts, graduate students and lay people, both before and after training. The accuracy of a statistical approach to case linkage has shown to be effective and outperform people (Bennell et al., 2010; Santtila, Korpela, & Hakkanen, 2004). Results revealed that students outperformed police professionals, that additional training increased accuracy, and a statistical (logistic regression) model achieved the highest rate of success (Bennell, Bloomfield, Snook, Taylor, & Barnes, 2010). Although the accuracy of linking decisions varies across crimes and offenders, Tonkin (2012) argues that absolute consistency and distinctiveness is not necessary for BCL to be effective and reliable. Rather behaviours that are more or less consistent across offenders and crimes are able to determine whether two cases are linked or not linked. It is this behavioural similarity that identifies those cases that are more likely to be linked and therefore committed by the same offender/s. Consequently, the development of a statistical model to aid crime analysts in case linking decisions will have benefits in reducing human biases, increasing the potential for a crime series to be identified and ultimately hold serial offenders to account and increase burglary resolution rates.

Research with BCL has grown considerably over the past decade. These studies have examined BCL across a variety of crime types including car theft (Davies, Tonkin, Bull, &

Bond, 2012; Tonkin, Grant, & Bond, 2008; Tonkin, 2012), arson (Ellingwood, Mugford, Bennell, Melnyk, & Fritzon, 2013; Fritzon, 2001; Santtila, Fritzon, & Tamelander, 2004), commercial burglary (Bennell & Canter, 2002; Bennell & Jones, 2005), robbery (Burrell, Bull, & Bond, 2012; Woodhams & Toye, 2007), sexual assault (Bennell, Jones, & Melnyk, 2009), homicide (Melnyk, Bennell, Gauthier, & Gauthier, 2011) and residential burglary (Bennell & Jones, 2005; Markson, Woodhams, & Bond, 2010; Tonkin, Santtila & Bull, 2012). However, while these studies have shown support for BCL as a valid crime linking process, variation exists in the extent of usefulness of various behavioural domains used in the research across crime types and across geographical locations (Bennell et al., 2010; Tonkin 2011).

Behavioural case linkage research methodology

A common methodology used in BCL research follows that used by Bennell and Canter (2002), and is the methodology used in many case linking studies and prior BCL studies on burglary. This involves pair-by-pair case linkage, using logistic regression, and is referred to as the 'Bennell Methodology', shown in Figure 1 (Tonkin, 2015). Research replicating the study of Bennell and Canter (2002) using the Bennell Methodology for burglary include Bennell and Jones (2005), Markson et al. (2010), and Tonkin et al. (2011). The Bennell Methodology has also been used with research examining other crime types (Bennell et al., 2009; Burrell et al., 2012; Ellingwood et al., 2013; Melnyk et al., 2011; Tonkin et al., 2012; Tonkin et al., 2008; Woodhams & Toye, 2007).

Once a sample has been identified, police database records of solved burglary offences are obtained and offences within the sample timeframe committed by serial offenders (those who have committed two or more crimes within the sample period) are selected.

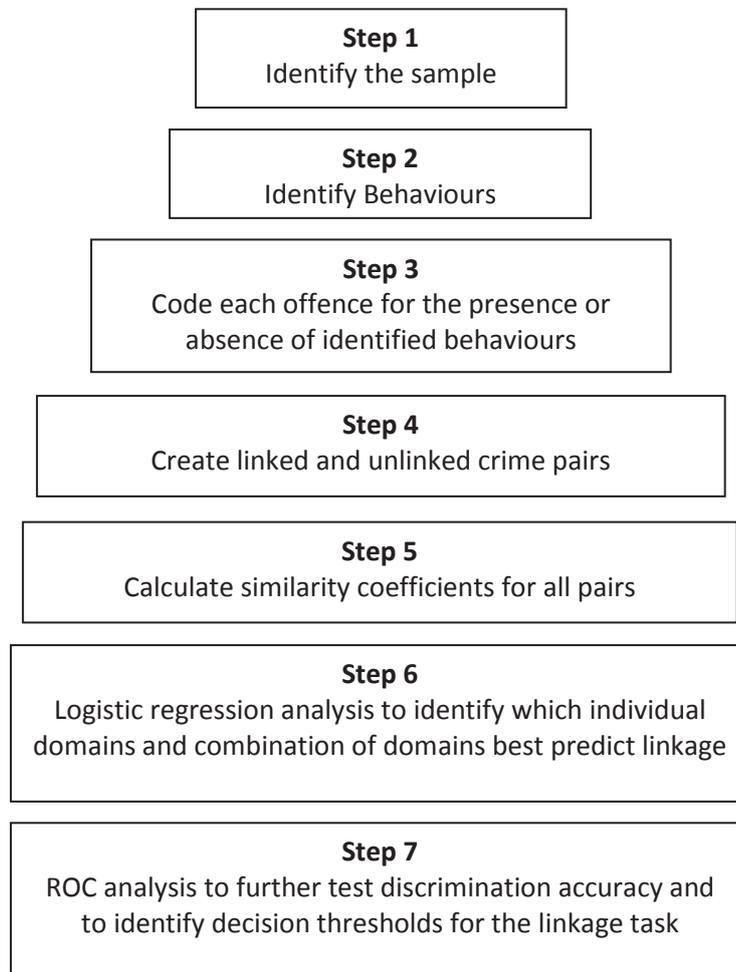


Figure 1. Seven steps of the Bennell Methodology commonly used for behavioural case linking research (Tonkin, 2015).

Using either a predefined list of behaviours based on prior research or a list of behaviours generated from the sample, each offence is dichotomously coded for the presence or absence of the identified behaviours (Tonkin, 2015). If the behaviour is present, the behaviour is coded '1', if absent it is coded '0'. Crimes committed by the

same offender are then matched, commonly limited to two of the serial offender's total crime series. These paired offences constitute the 'linked' sample of offences. An 'unlinked' sample (pairs consisting of offences committed by different offenders) are then generated. The unlinked sample can be generated by pairing every offence in the sample with every other offence, excluding pairs of offences committed by the same offender (linked pairs).

Similarity coefficients are then calculated along several behavioural domains to determine the degree of similarity between the offences in each pair, both linked, and unlinked. These behavioural domains include crime scene behaviour (target selection, point and method of entry, internal behaviour, and property stolen), inter-crime distance, and temporal proximity. For the features of inter-crime distance and temporal proximity, distance between each offence in the pair is measured in kilometres (inter-crime distance) and days (temporal proximity) respectively. The hypothesis being tested is that the linked pairs of offences (committed by the same offender) will be more similar in terms of crime scene behaviours than unlinked crime pairs, and will be closer together in time and distance than the unlinked crime pairs. Logistic regression analysis is commonly used to determine the predictive accuracy of the behaviours in correctly identifying whether the pairs are linked or unlinked.

Direct logistic regression analysis assesses each behavioural domain individually for its contribution to predictive accuracy of linked status, followed by a stepwise logistic regression analysis to determine an optimal model (combination of behavioural

domains) that maximises discrimination accuracy (Bennell & Canter, 2002). Receiver Operating Characteristic (ROC) analysis and the resulting Area under the Curve (AUC) is then used to assess the discrimination accuracy of the various behavioural domains. An AUC of 0.50 indicates no discrimination accuracy, for which the probability of making an accurate linking decision is no better than chance, and an AUC of 1.0 indicates perfect discrimination accuracy (Swets, 1988).

Although BCL researchers using the Bennell Methodology are generally consistent in following the steps outlined, there are some procedural differences across studies. The method of selecting linked and unlinked crime pairs differs with some researchers examining crime pairs containing every crime paired with every other crime, resulting in a very large sample with an unequal number of linked pairs to unlinked pairs (many more unlinked pairs) (Bennell & Canter, 2002; Bennell & Jones, 2005; Tonkin et al., 2011). Alternatively, a random sample of unlinked pairs equal in number to the sample of linked pairs can be chosen (Burrell, et al., 2012; Markson et al., 2010). Although an advantage of using an equal number of unlinked pairs to linked pairs includes simplicity in analysis, this is not generally representative of conducting BCL in practice. Burrell et al. (2012) argues that crime analysts will typically examine every crime with every other crime from a large police database when looking at crimes likely to belong to a crime series, potentially containing many more unlinked crimes than linked. The main advantage of using an equal number of linked to unlinked cases is that it reduces the number of case pairings and can easily be accomplished without the need of specialised software packages, often not available to the majority of crime analysts.

In their comparison of studies with variation in the number of unlinked cases to linked cases, Bennell, Mugford, Ellingwood, and Woodhams (2013) found no consistent differences in linking accuracy, relative to the ratio of linked to unlinked cases in the sample. This suggests that limiting the number of unlinked cases to the number of linked cases (an 'equal n' sample) is a valid research method in BCL.

Behavioural case linkage with Burglary

Although BCL research is increasing, the volume or amount of research using BCL for residential burglary is not great and limited to a few geographical locations, predominantly the United Kingdom (Bennell et al., 2013; Tonkin et al. 2011). Although it is acknowledged that using offender behaviour alone is unlikely to result in perfect discrimination between linked and unlinked crimes, Bennell and Canter (2002) tested the degree to which behavioural domains and features of an offence aided in correct linking decisions. Using a sample of 86 solved commercial burglaries committed by 43 serial burglary offenders (two offences for each offender) from a large metropolitan city in the United Kingdom, Bennell and Canter (2002) found that the distance between two offences was a consistently reliable indicator of whether the offences were linked or not. That is, the closer offences were in relation to each other the more likely they were committed by the same offender (linked).

The finding relating to the usefulness of inter-crime distance as an accurate linking feature supports the considerable body of research that offenders, including burglars, do not travel far to commit their offences (Brantingham & Brantingham, 1981; Goodwill

& Alison, 2006; Green et al., 1976; Rossmo & Velarde, 2008; Tonkin Santtilla & Bull, 2011).

“Criminals often work their own neighbourhoods, so a geographical separation of sets of burglaries will usually indicate the work of different people” Green et al. (1976, p. 388).

Offenders generally victimise geographical locations they are familiar with and the choice of an offender’s crime location typically relates in some way to the offender’s home base from which he operates (Goodwill & Alison, 2006). This also suggest that a serial offender’s crime locations will be in close proximity to each other. Merry (2000) reports that in a sample of 50 residential burglaries committed by different offenders in one town in England, 62% of offenders travelled less than one mile from their home base to commit the offence and 92% of offences were committed by offenders living within the borough where the offence occurred. An analysis of residential burglaries in Hawke’s Bay, New Zealand, committed by 64 offenders in a three month period in 2013 revealed that nearly 40% offended within 500 meters of their home, 50% within one kilometre and 70% within a two kilometre radius from their home base. Brantingham and Brantingham (1981) report that for inter-personal crimes the distance from the offence to the offenders home is shortest with distances increasing for property offences including burglary. They note that as the distance from an offenders home increases there is a corresponding decrease in offending.

Other behavioural domains examined by Bennell and Canter (2002) included the crime scene behavioural domains of target selection, method of entry, and property stolen.

The property stolen domain was found to be the least accurate of the predictors. Bennell and Canter (2002) suggest this is likely to be due to the context specific nature of these domains. An offender has complete control of which target they choose to burgle and when to burgle it. However, how easy it is to enter and what property is discovered inside and available to steal can vary greatly.

In their replication of the Bennell and Canter (2002) study, Bennell and Jones (2005) extended the research on BCL by including residential burglary in addition to commercial burglary. They examined serial offences across three differing sized police districts, again exploring those behavioural features of burglaries that tended to be associated with linked cases and differentiating them from unlinked cases. The three geographical areas were chosen to explore whether there were differences in linking accuracy relative to the size of the geographical location. The locations ranged in size from 112 square kilometres to 230 square kilometres and had population densities ranging from 1,467 persons per square kilometre to 4,053 persons per square kilometre. The time period from which the sample was drawn from was five calendar years, considerably larger than that of Bennell and Canter (2002).

While Bennell and Jones (2005) found support for the usefulness of crime scene behaviours in distinguishing between linked and unlinked cases, and models had a high degree of predictive accuracy with inter-crime distance again being most effective at distinguishing between linked and unlinked crimes, there was variation in linking accuracy across the three policing districts and between residential and commercial

burglary. This suggests that a specific or generic model for crime linking decisions may not be useful across different locations and crime types and that an optimal model needs to be developed for specific crime types and locations. Bennell and Jones (2005) note that the poor performance of crime scene behavioural features in the accuracy of linking decisions for residential and commercial burglary may be due to the often varied descriptions found in Police reports.

While inter-crime distance is based on very reliable geocoded location data, an officer's narrative description of a crime scene is subject to a great deal of variation and may explain the difference in linking decision accuracy reported. As Canter and Alison (2000) point out, the quality of information is crucial when relying on a statistically driven approach to crime scene analysis. Canter and Alison (2000) comment that police reports often contain vast amounts of information which varies from report to report, stemming from crime scene attenders that may rely largely on subjective and highly varied descriptions of the crime. For example, one crime scene attender might describe the offender's search of a house as 'thorough' whereas a different crime scene attender might describe the search as 'messy'.

In a later study, Markson et al. (2010) extended the research of Bennell and Canter (2002) and Bennell and Jones (2005) by comparing the usefulness of crime scene behaviours, using 80 linked offences and 80 un-linked offences of residential burglary from Northamptonshire, a semi-rural, non-metropolitan area of Britain. The linking features used by Markson et al. (2010) were crime scene behaviours, geographical proximity

(distance between offences measured in kilometres) and temporal proximity (distance in time between offences, measured in days). The aim of that study was to examine if prior findings in BCL would generalise to a different geographical location.

Although semi-rural, Northamptonshire has an area of 2,400 square miles and has a population of 650,000. The addition of temporal proximity as a linkage predictor was included, suggesting that those offences closer in time to each other would be more likely to be linked offences (Goodwill & Alison, 2006). The crime scene behaviours used in Markson et al. (2010) were the same as Bennell and Canter (2002) and Bennell and Jones (2005), with the addition of several property stolen items that were not in the original lists, but present in the offences examined. These additional items were credit cards, mobile phones, personal music players, and gifts.

As in the previous studies of Bennell and Canter (2002) and Bennell and Jones (2005), logistic regression and ROC analysis were conducted for all behavioural domains, individually and collectively, to determine the accuracy of predicting whether a crime pair were linked or not linked. Mean differences between linked and unlinked pairs were examined and both inter-crime distance and temporal proximity means were statistically significantly smaller for linked pairs than un-linked pairs ($p = < 0.0001$). Those crimes that were closer together in time and geographical distance were, on average, more likely to be committed by the same offender than those crimes committed by different offenders.

Neither target selection, entry behaviour nor property stolen domains reached a significant level of difference between linked and unlinked pairs, however all crime scene behaviours combined did ($p = <0.05$). Similar to Bennell and Canter (2002) and Bennell and Jones (2005), support was found for the usefulness of inter-crime distance in making accurate linking decisions. In this case the combination of inter-crime distance and temporal proximity correctly predicted linkage status in 75% of cases.

However, the sample was drawn from a much larger geographical area (2,400 square miles) than the previous studies which may have artificially inflated the predictive usefulness of inter-crime distance as an accurate linking feature. As reported in Burrell et al. (2012) where the linking features for robbery offences was examined in two phases, 1) a large 'force wide' area, and 2) a smaller 'borough' area, inter-crime distance was less effective in predicting linkage status in the smaller borough than the larger geographical area. Additionally crime scene behaviours increased in accuracy for predicting linkage status within the smaller borough. As it has been shown that many offenders commit their crimes close to home, the usefulness of inter-crime distance as a linking feature may be related to the size of the geographical area a sample is drawn from.

Cross-national differences

A criticism of prior BCL research made by Tonkin et al. (2011), was that it was focused on samples from the United Kingdom. To address this limitation Tonkin et al. (2011), used a sample of 234 solved residential burglaries committed by 117 serial offenders in

the Helsinki area (800 square kilometres) of Finland. It was predicted that, similar to the United Kingdom based findings, inter-crime distance and temporal proximity would prove to be the most accurate behavioural features in distinguishing linked from unlinked cases. However, they also expected that crime scene behaviours would show greater ability in the predictive accuracy of linking decisions in Finland than that found in the United Kingdom. This being due to differences in housing and population density, in that there is greater variation in housing in Finland than the United Kingdom, with a more spread-out population. Tonkin et al. (2011), used the same methodology of Bennell and Canter (2002) and Bennell and Jones (2005) in forming the linked and unlinked pairs and used logistic regression and ROC analysis to analyse the data.

Inter-crime distance again emerged as the most accurate of predictors followed by a combined model (all behavioural domains), then temporal proximity. Similar to the earlier studies, the geographical location was considerably large. Additionally the time period this sample was drawn from was over a period of 11 years, a much larger time frame than any of the earlier studies. However, Tonkin et al. (2011) noted that the individual MO domains performed better than that reported for the United Kingdom research, with the poorest performer being the domain of property stolen. A possible reason put forward by Tonkin et al. (2011) for the increase in performance of the MO behaviours was that Finnish police may record MO in more detail and more consistently than that recorded in the United Kingdom.

While there was consistency in the behavioural lists of Bennell and Canter (2002), Bennell and Jones (2005) and Markson et al. (2010), the crime scene behaviours used by Tonkin et al. (2011) to code the offences, while similar, included behaviours not used in the earlier studies. These included behaviours inside the property (e.g. search type and method), offender exit behaviours and whether there was any forensic evidence left behind by the offender/s. These additional behaviours were included as there was sufficient detail in their recording by crime scene attenders. It is possible that the addition of these behaviours not used in the earlier studies accounted for the increase in performance of crime scene behaviours in distinguishing between linked and unlinked cases in this sample. This suggests that increases in the usefulness of crime scene behaviours for making accurate case linking decisions can be made if consistent and detailed crime scene behaviours are recorded by police. The difference in findings in relation to the usefulness of crime scene behaviours for case linking purposes found in Finland compared to the United Kingdom, adds support for the need for further studies with different samples in different locations and times.

Behaviours used in behavioural case linkage research

Crime scene behaviours, when used in isolation, have generally been shown to be poor performers when it comes to linking offences (Bennell & Canter, 2002; Bennell & Jones, 2005; Goodwill & Alison, 2006; Markson et al., 2010). While there is not always general agreement amongst BCL researchers on what behaviours to include for case linking, some behavioural lists are more consistent than others. Three behavioural domains or themes that are generally used in research on BCL are target characteristics, entry

behaviours, and items stolen (Bennell & Jones, 2005). Internal behaviours are also included which incorporate the type of search; messy, tidy, or none, and other behaviours committed by the offender while inside including causing malicious damage, using facilities or defecating (Goodwill & Alison, 2006; Tonkin et al., 2011).

Bennell and Jones (2005) and Markson et al. (2010) suggest that the weaker performance of crime scene behaviours in ability to identify linked crimes may be due to situation factors. An offender may have a preferred method of entry however if an offender who usually uses force to enter a dwelling may find the premises insecure (such as an open window), and able to be entered without using force. Conversely, where access to a dwelling is constrained by security measures, an offender will be forced to enter using a method that has worked for them in the past. Although, there is a limited number of entry points and methods with many commonly used by a majority of offenders. There are only so many ways to break into a house and Bennell and Canter (2002) suggest that this limited range of available MO's makes distinguishing between different offenders by crime scene behaviour less successful.

According to Turvey (2002), an offender learns, develops and refines their techniques upon each successive offence. As such, an offender's MO may not be consistent over time. Counter to this is the notion that what has worked for an offender in the past is reliable so he/she uses the technique or behaviour again. Either way, an offender's MO is the feature of a crime that is most dependent on the situation rather than the individual and as a result is most likely to be the feature that changes (Merry, 2000). The

crime scene behaviour list in the Goodwill and Alison (2006) study included 40 individual behaviours, considerably less than Bennell and Canter (2002) and Bennell and Jones (2005), 75 behaviours; Markson et al. (2010), 79 behaviours and Tonkin et al. (2011), 77 behaviours. Goodwill and Alison (2006) may have found more support for the crime scene behavioural domains in reliably distinguishing between linked and unlinked cases had they used a more complete list of behaviours as with previous studies.

A further reason crime scene behaviours are a poor predictor of linked status is how behaviours are captured, interpreted and recorded in police databases, which can vary greatly. Victim accounts can differ in accuracy and be subject to bias in interpretation (Markson et al, 2010). In many jurisdictions not all burglaries are attended by police as some burglaries are reported over the phone without any examination of the crime scene. There is also variation in staff that attend burglaries with some attended by response officers and others attended by SOCOs. As a result some behaviours may be overlooked or not considered relevant by the investigating officer or analyst. These inconsistencies and lack of standard crime scene recording practices can impact the reliability of recorded crime scene behaviour.

Coding practices of researchers also differ with some researchers coding the data exactly as it has been recorded in the police database while others have coded from narrative accounts of the offence. Tonkin (2015) notes that variations also exist in the operationalisation of offender behaviour and this variation exist across police forces, jurisdictions and countries. For example, when coding the type of search, options

include 'tidy' and 'untidy' or 'messy' and 'limited' or 'thorough'. Deciding which to code requires a subjective judgement on behalf of the victim, call taker, or attending officer. As a result, offence similarities based on poorly operationalised behavioural items will have reduced reliability in contributing to linking decisions based on crime scene behaviours.

For crime scene behaviours to be a reliable measure on which to make linking decisions there needs to be a level of confidence that the behaviours coded as present did actually occur and that the person (police officer, analyst or researcher) has coded the behaviours correctly. Measures of behavioural coding reliability are seldom presented in prior research on case linkage (Snook, Luther & MacDonald, 2015). Some exceptions include Markson et al. (2010) where Cohen's Kappa (Cohen, 1960) was used to ensure reliability in coding and to report on the level of consistency. In that study, 10% of the burglary sample was dual coded and achieved an adequate level of inter-rater reliability ($k = .80$). In assessing coder reliability in a sample of personal robbery offences, Burrell, Bull, Bond, and Herrington (2015) used two independent coders to code 10% of the sample, achieving a very good level of reliability ($k = .95$, ranging from $.81 - 1.0$). Tonkin et al. (2011) reported a median case-by-case reliability of $k = .78$. Snook et al. (2015) are critical of BCL research that does not include measures of inter-coder reliability, arguing that in its absence there is no way of judging the reliability of the results, bringing into question the trustworthiness of conclusions drawn from those studies. Snook et al. (2015) suggest a minimum level of 80% agreement is generally an acceptable level of reliability and that future studies using BCL should have the level and range for each

variable reported. The fact that differences exist between two coders examining the same offence on whether the behaviour was present or not further illustrates the variation that exists in the interpretation of police recorded data, decreasing the effectiveness of crime scene behaviours in the ability to accurately link two offences.

Throughout BCL research, the property stolen domain is often reported as a poor performer of accurately discriminating between linked and unlinked crimes, sometimes no better than chance. In a behavioural linking study examining personal robberies, Burrell et al. (2015) found that the property stolen domain was not useful at all for measuring behavioural similarity. Arguably the property stolen in a street robbery offence is limited to what victims will have on their person and also likely to be similar across many victims, for example cash, wallets, watches, handbags, and credit cards. Likewise, property stolen from a vehicle is also limited to what might commonly be expected to be found inside. This includes smaller personal items such as cell phones, wallets, cash, and items relating to the car including radar detectors, stereos and car batteries. This may explain the poor performance of the property stolen domain in BCL research to accurately distinguish between cases.

Property stolen is not always only that which is available but often property that is specifically targeted. Some offenders ignore typically desirable property and only take items of a specific category. For example, burglars entering a residential dwelling may ignore electronic items taking only jewellery. In a series of commercial burglaries in Hawke's Bay during 2015, several licenced premises were broken into and the thieves

deliberately ignored cigarettes and alcohol, both readily available, only targeting cash from the tills.

Property lists can also quickly become dated as new technology results in more popular and prevalent consumer goods. Consequently some property items become less useful in identifying certain behavioural preferences by offenders. As Markson et al. (2010) found when examining offences in their sample, some items of property were present that were not on the original lists of Bennell and Canter (2002) and Bennell and Jones (2005). Therefore property lists used in BCL research and in practice need to be current, appropriate to the crime type, and representative of the stolen items reported in the offences being examined.

Inter-crime distance and temporal proximity

Inter-crime distance has consistently been shown to be the single most useful linkage feature in predicting linked status between linked and unlinked pairs of crimes (Burrell et al. 2015) across a range of crime types (Snook et al. 2015). Inter-crime distance refers to the straight line kilometre distance between offences using geo-coded (x, y) coordinates. The assumption being that the closer two offences are in distance the more likely they are to be linked: having been committed by the same offender/s (Tonkin & Woodhams, 2015). Unlike the crime scene domains of target selection, entry behaviours, and internal behaviours, both geographical distance and temporal proximity are objective measures with a greater degree of accuracy and reliability, with little room for bias in interpretation, as they are measures of distance (metres) and time (days)

respectively (Bennell & Jones, 2005). This is not the case for MO behaviours including what property is stolen, as these features of an offence are often unreliably recorded, inaccurate or incomplete. Whether these details are recorded at all depends upon many factors including the reporting by the victim and the recording practices by police, and it may be some time after the offence that a victim realises additional items of property have been stolen. This may explain why inter-crime distance has become such a reliable predictor of linked versus unlinked cases in BCL research, compared to other behavioural domains.

The majority of research showing prominent support for inter-crime distance as a reliable linking feature have drawn samples from geographically large policing areas with high population densities. Although in a study examining 32 serial burglary offenders from small towns in the South of England, Baker (2000) found support for the short distances travelled by serial burglars from the home. Baker also examined the distances travelled in terms of the order of offences committed by each offender's first five burglaries in their series. The distance from the offender's home to the first offence in the series was significantly shorter than the distance from the home to the remaining four offences. Baker also reported that the remaining offences were committed in different directions from the offender's home implying a developing awareness of an offender's space as they move throughout the offending location, generally centred on their home base.

Second to inter-crime distance, temporal proximity has emerged as the next most reliable predictor of linkage status in BCL research (Goodwill & Alison, 2006; Markson et al., 2010). Temporal proximity refers to the distance in time between two offences, with the assumption that the closer two offences are in time the more likely they are to have been committed by the same offender/s. The use of temporal proximity was not included as a linking feature in Bennell and Canter (2002) and Bennell and Jones (2005) but was used in the replication studies of Markson et al. (2010) and Tonkin et al. (2011). Goodwill and Alison (2006) suggest that the combination of inter-crime distance and temporal proximity should act as a first filter in linking crimes before the consideration of other crime scene behaviours.

Although temporal proximity has shown to be an accurate linking feature, there is wide variation across all studies in the timeframe the sample is taken from ranging from one year (Bennell & Canter, 2002) to 11 years (Tonkin et al., 2011). It is possible that the longer the timeframe the more inaccurate temporal proximity is likely to be in linking accuracy, especially if an offender's crimes are separated in time. There may be periods when an offender is incarcerated in the middle of the series used in the analysis. The choice of offences from an offender's crime series also varies in the literature, ranging from two offences (Bennell & Canter, 2002; Bennell & Jones, 2005; Woodhams & Toye, 2007) to five offences (Goodwill & Alison, 2006). The selection method of the offender's offences also varies including random selection, choosing the first n in a series, and choosing the most recent offences in a series.

Goodwill and Alison (2006) found that the ideal time period to maximise linking decisions is 28 days. This time period is much closer to the time period used by crime analysts in scanning for patterns in offending, with Bartol and Bartol (2013) suggesting that longer time periods between offences decreases the chances that the offences will be linked by analysts. Bartol and Bartol (2013) suggest that for crime scene profiling linking one offender to multiple offences to work in practice, the offences should cluster in time as well as space: committed within weeks or months rather than years. If crimes, including burglary, are separated by years they are less likely to be linked by crime analysts.

Limitations

BCL research is often criticised for being far removed from the case linking process in practice. Often cited as a limitation of the studies is the over-reliance on solved crimes as in reality a crime analyst or investigator will be dealing with unsolved offences or an initial index offence with which linking decisions need to be made (Burrell et al, 2012; Tonkin et al., 2011). As BCL research uses crimes with identified offenders, this group of offenders may behave in a more consistent way than offenders responsible for unsolved crimes therefore not representative of all burglary offenders. As Woodhams and Toye (2007) suggest, the similarity of solved cases used in the research might explain why these cases were solved in the first place, potentially biasing the results.

As the majority of research on BCL uses police data, the accuracy of MO behaviours contained in police records varies considerably and is often incomplete (Woodhams &

Toye, 2007). As Woodhams, Bull and Hollin (2007) point out, how the offence was committed is often the result of a victim's account: a second hand version of events and the offender's actions. The accuracy and completeness of the account may also be affected by the memory and the emotional state of the victim when the offence is reported. Additionally, police data used for BCL research has not been captured and recorded for the purpose of research, rather for the purpose of respective police forces, limiting the content, quality and control available to researchers. However, in spite of this limitation, considerably good levels of predictive accuracy for identifying linked offences have been made (Woodhams et al., 2007). Bennell and Jones (2005) argue that in spite of the limitations of police data, the use of police data adds ecological validity to any findings that result offering promise for the use of BCL in applied settings.

A further limitation of any statistical process for linking crimes is that it is difficult to be definitive when using behavioural features as filters and thresholds to make decisions on whether two crimes are linked or not. In a burglary crime pattern observed in Hawke's Bay during 2016, the offences were characterised by a specific MO where properties were entered, vehicle keys taken and the vehicle stolen. This was a new crime pattern involving several offences yet dispersed over a wide area within Hawke's Bay. The offenders were apprehended and had committed offences in a range of locations dispersed across Hawke's Bay. Had linking decisions been made on inter-crime distance and temporal proximity alone, as recommended by Goodwill and Alison (2006) this crime series would have been missed.

Arguably the greatest limitation of BCL research to date is its confinement to a few locations, predominantly the United Kingdom, with few studies replicating research to other areas (Bennell et al., 2013). Tonkin et al. (2011) found differences in the usefulness of MO behaviours in making linking decisions in a sample from Finland, compared to that of the United Kingdom research, and Bennell and Jones (2005) also found differences in the predictive ability of linking domains across varied locations within the United Kingdom. For BCL to have validity in jurisdictions outside the United Kingdom, the research needs to be extended to other locations and countries. As Tonkin et al. (2011) found, the type of housing, population density, urban geography and differences in sociodemographic characteristics can influence offender behaviour. Additionally, testing BCL in smaller locations where the usefulness of inter-crime distance does not become an artefact of the geographical size of the study location will also be informative. Burrell et al. (2012) suggests that BCL findings to date might not generalise to other countries and that replicating BCL research in countries with similar police forces to the United Kingdom (for example, New Zealand or Norway), would be valuable in determining the predictive accuracy of linking features reported.

New Zealand has a similar population density to Finland (17 persons per square kilometre) and a very different residential housing type to that of the United Kingdom: predominantly detached housing in New Zealand (76%), whereas the majority of housing in the United Kingdom is terraced or semi-attached (54%). It is likely that offender target selection options in respect of dwelling type are similar for Finland and New Zealand, suggesting similar levels of offending behavioural consistency. However

due to the more dispersed New Zealand population compared to the United Kingdom, there may be differences in inter-crime distances travelled by serial burglars in New Zealand. It is therefore important to see if results from both the United Kingdom studies and the Finnish study in the reliability of BCL using crime scene behaviours (MO), temporal proximity, and inter-crime distances will generalise to a New Zealand context.

Study aims and hypothesis

The current study aims to replicate the earlier BCL research on residential burglary from the United Kingdom (Bennell & Canter, 2002; Bennell & Jones, 2005; Markson et al., 2010) and Finland (Tonkin et al., 2011) by examining the validity of the BCL findings in a different geographical location, namely the city of Napier, New Zealand. Based on previous BCL research on residential burglary (Bennell & Canter, 2002; Bennell and Jones, 2005; Markson et al., 2010; Tonkin et al., 2011), it was hypothesised that the crime scene behaviours (MO) would show a moderate level of predictive ability of whether burglary pairs were committed by the same offender. It was also hypothesised that, similar to previous research, temporal proximity and inter-crime distance would show the highest levels of predictive accuracy providing support for the validity of BCL in a New Zealand context.

Method

This study followed the Bennell Methodology (refer Figure 1) using a sample of residential burglary offences from New Zealand. Behaviours used to code each offence were based on prior research and incorporated crime scene behaviours prevalent in the

current sample of offences. Each offence was coded for the presence or absence of behaviours. Following coding, pairs of offences were created which included linked pairs (two crimes committed by the same offender) and unlinked pairs (two crimes committed by different offenders). Similarity coefficients were calculated for each crime pair. Logistic regression analysis was used to determine which behaviours or combination of behaviours best predicted which pairs were linked and which were not linked. ROC analysis was then conducted to test the discrimination accuracy of each of the behavioural domains.

Sample data base

The present sample were solved residential burglary offences committed in the city of Napier, New Zealand, between January 2012 and December 2014. In accordance with the definition used by Bennell and Jones (2005) and Markson et al. (2010), a residential burglary was defined as a burglary to an inhabited, domestic dwelling as opposed to a commercial premise.

Eighty-two solved cases were extracted from the New Zealand Police National Intelligence Application (NIA) data base. These offences had been committed by 45 serial residential burglary offenders. A serial burglary offender was defined as an offender who had committed at least two residential burglaries in the city of Napier during the timeframe. Eight of the serial burglars in the sample had committed their offences with a co-offender, and were kept in the sample as they had only committed

offences with the same co-offender and had not committed any offences alone (Burrell et al., 2015).

The definition of 'solved' is not always consistent in the research with Markson et al. (2010) defining a solved offence as one where a guilty offender has been identified but not necessarily prosecuted for the offence. Whereas the samples in Bennell and Canter (2002), Bennell and Jones (2005), and Goodwill and Alison (2006) consisted of burglary offences committed by convicted offenders. Other studies simply report that the offence was committed by a known offender (Tonkin et al., 2011). For the current study, solved offences were those burglary crimes recorded in NIA that had been cleared with a person added to the offence in the role of 'Offender'. This could mean that a person was warned or prosecuted for the offence, not necessarily convicted. A serial burglar was defined as anyone associated to two or more burglary offences within the time period, recorded in NIA with the role of offender.

Serial burglars' offending in the current sample ranged from two offences to 16 offences with an average of three offences per crime series. As discussed in previous replication studies of the Bennell and Canter (2002) research, each serial offender was limited to two offences, namely the last two offences from the series, which was necessary to prevent more prolific serial offenders in the sample from unduly influencing the findings. This could be a possibility if those more prolific offenders were unusually consistent in their offending behaviours (Burrell et al., 2015). The mode in the current sample was also two offences per crime series, representing 58% of the sample. The majority of

offenders in the sample were male (n=40 or 89%), and aged between 12 and 49 with an average age of 22 years at the time of offending. Females were generally younger than males with an average age of 20. Nearly two thirds of the sample (n=28 or 62%) were recorded as Maori compared to 31% (n=14) recorded as European. The remaining three offenders were recorded as Pacific Island (n=2) and European/Maori (n=1).

The 45 offenders in the current sample had amassed a total of 519 convictions for burglary over their life time ranging from two to 128 with an average of 12 convictions each. The number of convictions per offender in the current sample was heavily skewed by one offender with 128 convictions. The median number of convictions were six offences per offender. The males in the sample had slightly more convictions than the females (median males = 6, median females = 5).

Materials and Procedure

Characteristics of each offence in the sample, retrieved from the NIA database, included an offence narrative (what had occurred and how), details of the offence timing (the start date and time, and end date and time), and an offence location recorded as the geocoded (x, y) coordinates. Burglaries are most often reported after the event when a victim returns to discover that their house has been broken into. As a result the exact time of the burglary is commonly not known (Bernasco, 2014). Methods exist for determining the most likely time a burglary occurred including probability based estimates, namely Aoristic analysis (Ratcliff, 2000). However the method of using the mid-point between the start and end date and times, as used in the previous research

in residential burglary case linking, (e.g. Goodwill & Alison, 2006; Tonkin, et al., 2011) was used in the current study.

Each offence record contained details required to code each offence in respect of the presence or absence of behaviours exhibited by the offender. As discussed in Bennell and Canter (2002) the details of a burglar's MO are not consistently prescribed in the literature so accordingly those features used in the Bennell and Canter (2002) study and those later modified by Bennell and Jones (2005), Markson et al. (2010) and Tonkin et al. (2011) formed the basis for the current crime scene behaviours. A full list of crime scene behaviours used in the current study is contained in Appendix A.

Selection of linked and unlinked crime pairs

As in previous research, linked pairs contained the two most recent offences committed by the same offender and unlinked pairs contained two offences committed by different offenders. The number of linked pairs and unlinked pairs depends on the total number of offences in the sample and the choice of using an equal number of unlinked pairs to linked pairs, or by pairing every offence with every other offence, representing every possible linked and unlinked pairing of offences in the sample. In this study an equal number of unlinked pairs to linked pairs was used, resulting in a sample containing 41 linked pairs (offences committed by the same offender, with one pair for each offender) and 41 unlinked pairs (two offences committed by different offenders). The 41 unlinked pairs were created and selected from a random ordering of all the possible offence

pairings, using the =RAND() function in Microsoft Excel, and checked to ensure each pair contained offences committed by different offenders (Burrell et al., 2012).

Data coding

Each offence report contained details of how the offence was committed (MO), either in a recorded MO category or detailed in the narrative of the offence record. The crime scene behaviours were based on previous behavioural lists used in BCL research on residential burglary (Bennell & Canter, 2002; Bennell & Jones, 2005; Markson et al., 2010; Tonkin et al., 2011) with adaptations made to include those behaviours most prevalent in the current sample. Each offence was dichotomously coded for the presence or absence of crime scene behaviours. If the behaviour was present then that behaviour was coded with a '1'. If absent the behaviour was coded with a '0'. As in the research of Markson et al. (2010), 10% of the current sample were dual coded by an independent coder to assess the reliability of the coding resulting in a median inter-case reliability of 0.84, ranging from 0.62 to 0.89, an acceptable level of agreement (Snook et al., 2015).

Measuring similarity

For each crime pair the similarity measure used for comparing crime scene behaviours was Jaccard's coefficient (*J*). Although there are several measures of similarity previously used in BCL research Jaccard's coefficient is most commonly used across all crime types (Bennell et al. 2015) and was the similarity measure used in previous BCL research on residential burglary. An advantage of Jaccard's coefficient is that it only takes into account joint occurrences of behaviours across crime pairs, ignoring cases of joint non-occurrences of behaviours. This is useful when using police data as although a

behaviour might have been present in the commission of the offence it may not have been reported or recorded (Burrell et al., 2012). Consequently the presence of a particular behaviour across crimes is evidence of consistency whereas the absence of behaviour is not necessarily evidence of inconsistency.

For each pair of offences, A and B, J is:
$$J = \frac{a}{a+b+c}$$

Where a equals the number of behaviours common to both offences, while b and c equal the number of behaviours unique to both A and B respectively. The resulting coefficient will be a measure of similarity between '0' and '1'. A coefficient of '0' indicates no similarity and a coefficient of '1' indicates perfect similarity. The higher the similarity coefficients of paired cases the more likely the cases are linked. Microsoft Excel spreadsheets were created for each pair in the sample, containing the Jaccard's formula, enabling the similarity coefficients for each crime pair to be calculated based on the coded presence or absence of crime scene behaviours.

In addition, the inter-crime distance (the geographical distance in metres between the two offence locations in each pair of offences), and the temporal distance (the distance in time, measured in days, between the two offences in each pair) were calculated. Inter-crime distance was measured using the Euclidean distance between the two geo-coded (x, y) offence locations (Pythagoras theorem). Euclidean distance was the measure used in previous research (e.g. Bennell & Canter, 2002; Bennell & Jones, 2005;

Markson et al., 2010) providing an approximate measure of the distance travelled by an offender as the actual routes were unknown. Microsoft Excel was used to calculate the distance between the offences in each pair.

The exact time of a burglary offence is difficult to measure accurately as unless the burglary is discovered in progress, the time of the offence is most commonly reported as occurring any time between a start date/time and an end date/time. As a result temporal proximity (distance in time) between two offences measured in days was made using the mid-point between the reported start date and time and the reported end date and time (similar to the studies of Goodwill & Alison, 2006; Tonkin et al., 2012). Cases closer in distance and temporal proximity are more likely to be linked (committed by the same offender/s). Microsoft Excel was used to calculate the temporal proximity between the two offences in each crime pair. The formulas and Excel functions used to calculate inter-crime distance and temporal proximity are detailed in Appendix B.

Data analysis and model development

Logistic regression analysis develops statistical models used to predict whether two crimes are linked or not and has become the common data analysis method used in BCL research (Bennell, et al., 2013). As discussed in Bennell and Canter (2002) and Bennell and Jones (2005), potential bias resulting from developing and testing a regression model on the same sample can be avoided if the sample is split into a development or experimental sample and a test sample. Regression analysis is conducted on the experimental sample and the resulting model can then be validated on the test sample .

In the current study the total sample of 41 crime pairs was split in half to create the experimental sample (21 crime pairs) to build predictive models, and a test sample (20 crime pairs).

A separate direct logistic regression analysis was conducted using SPSS (version 23) on the experimental sample for the three domains of offender behaviour: crime scene behaviours (MO), inter-crime distance, and temporal proximity. Probability predictions obtained from the logistic regression analysis were compared to the actual linked status of pairs of crimes to determine how successful the model was in accurately distinguishing between linked and unlinked pairs of offences (Tonkin, 2012).

Regression coefficients from the experimental sample, constant (a) and logit (b), were then used to calculate the estimated probabilities of each pair in the test sample. ROC analyses were conducted to determine the degree of predictive accuracy the various regression models had in accurately classifying burglary pairs in the test sample as either linked or not linked (Bennell & Jones, 2005). Data entered in to the ROC analysis included the estimated probabilities of every pair in the test sample and data representing whether the pair were linked or not linked.

Results

The full sample contained 82 crime pairs; 41 linked and 41 unlinked. The distributions of the three independent predictor variables of inter-crime distance, temporal proximity, and crime scene behaviour (Jaccard's scores) for each crime pair were first examined to assess normality. All three variables had distributions with departures from normal, evidenced by histograms with a considerable positive skew for inter-crime distance and temporal proximity and a slightly positive skew for crime scene behaviour.

The distributions of the three predictor variables were then assessed for normality using the Kolmogorov-Smirnov test. As shown in Table 1, both temporal proximity ($p < .001$) and inter-crime distance ($p < .001$) were significantly different from normal. The results for the Shapiro-Wilk test showed significant departures of normality for all three predictor variables ($p < 0.05$).

Table 1. Kolmogorov-Smirnov and Shapiro-Wilk tests of normality

Variable	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Crime scene behaviour (<i>J</i>)	0.07	82	.200*	0.968	82	.036
Temporal Proximity (days)	0.174	82	.000	0.869	82	.000
Inter-Crime Distance (metres)	0.211	82	.000	0.736	82	.000

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Consequently, median instead of mean scores were used to compare the samples. Table 2 displays the range and median scores for inter-crime distance (meters), temporal proximity (days), and crime scene behaviours (Jaccard's similarity coefficient). The median scores for inter-crime distance and temporal proximity were lower for the linked pairs than the unlinked pairs indicating that crimes committed by the same offender were, on average, closer together in geographical distance and time compared to the crimes committed by different offenders.

Table 2. Range and median scores for linked and unlinked behavioural domains

Behavioural domain (IV)	Crime Pairs			
	Linked (<i>n</i> = 41)		Unlinked (<i>n</i> = 41)	
	Range	Median	Range	Median
Inter-crime Distance (m)	23 - 9510	697	35 - 11323	1886
Temporal Proximity (days)	0 - 816	21	35 - 898	362
Crime Scene Behaviours (<i>J</i>)	.00 - .64	0.27	.00 - .36	0.16

The higher median Jaccard score for crime scene behaviours indicates that those crimes committed by the same offender in this sample were, on average, more behaviourally similar than those crimes committed by different offenders. The initial comparison of median scores suggest that all three behavioural domains will be useful in distinguishing crimes committed by the same offender than those committed by different offenders, offering initial support for the assumption of behavioural similarity of offenders in the commission of residential burglary in Napier.

Tests of difference using the Mann-Whitney U test for non-parametric samples were then conducted. Results shown in Table 3 indicate that the differences between linked and unlinked crime pairs was statistically significant for all three predictor variables. Effect sizes were all large: $r=.50$ for crime scene behaviours, $r=.57$ for inter-crime distance, and $r=.79$ for temporal proximity, a very large effect size (Cohen, 1988).

Table 3. Mann-Whitney U test outcomes

Behavioural domain	Mann-Whitney U (z)	Significance	Effect Size (r) [†]
Inter-crime Distance	1239.5 (3.703)	$p<0.05$	0.57
Temporal Proximity	285 (-5.152)	$p<0.001$	0.79
Crime Scene Behaviours	488 (-3.269)	$p<0.001$	0.5

[†]Cohen (1988) indicates that $r=.10$ is a small effect size, $r=.30$ is a medium effect size and $.50$ is a large effect size.

The Mann-Whitney U distributions of the linked versus unlinked crime pairs for each of the three behavioural domains were examined, shown in Figure 2. The distributions for Inter-crime distance and temporal proximity show a higher frequency of crimes committed with shorter distances and time periods respectively than unlinked crime pairs. The distribution for crime scene behaviours indicates a distribution with higher Jaccard scores for linked crime pairs than those for unlinked crime pairs.

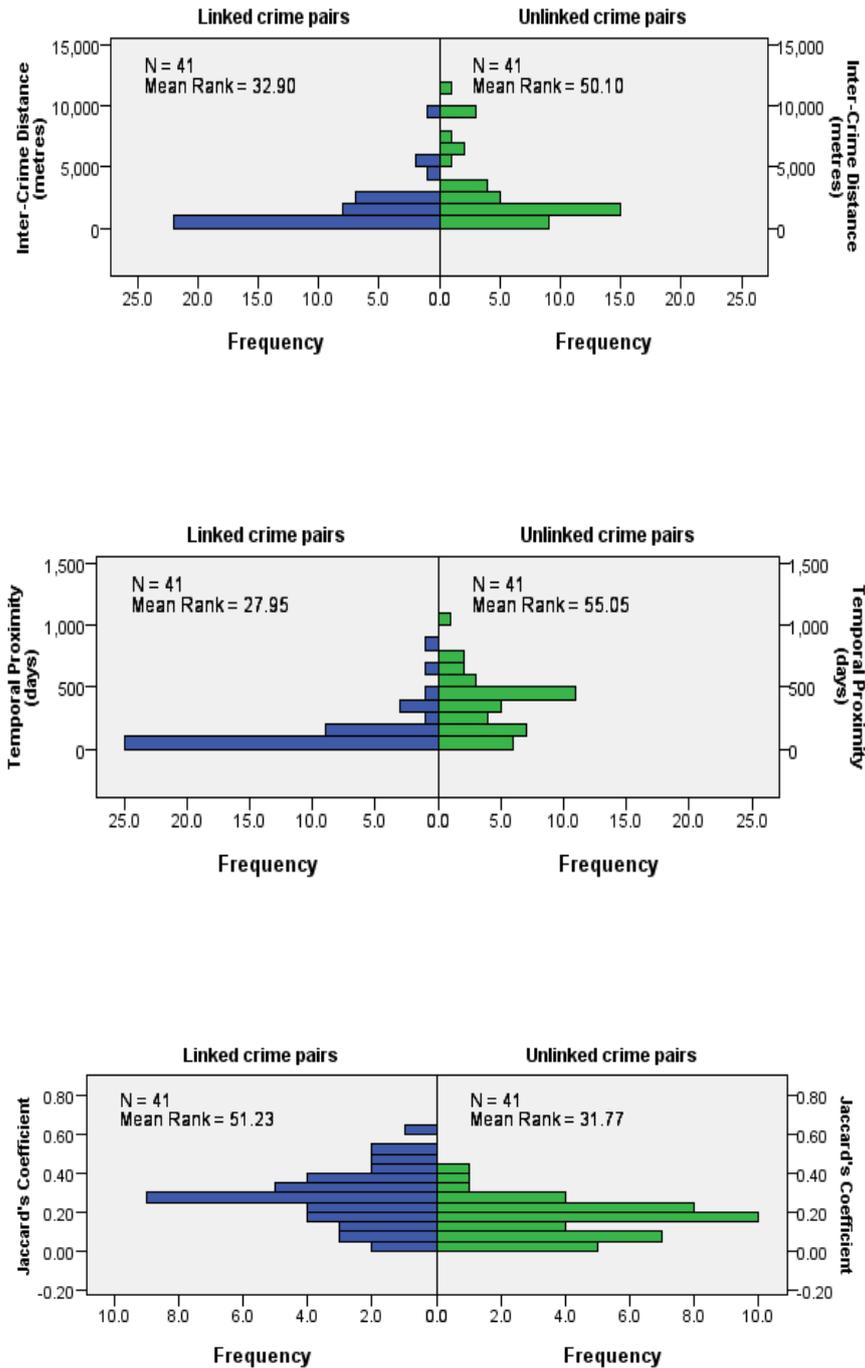


Figure 2 Linked and unlinked crime pair distributions for the three variables of interest; inter-crime distance, temporal proximity and crime scene behaviours (Jaccard's coefficient).

Logistic regression and ROC analysis

In line with previous research (Bennell & Canter, 2002; Bennell & Jones, 2005; Markson et al., 2010; Tonkin et al., 2008; Woodhams & Toye 2007), separate logistic regression

analysis were run with the experimental sample, with each of the three behavioural domains. A forward stepwise logistic regression analysis was then conducted to determine which combination of variables would result in an optimal model, returning the highest level of predictive accuracy. A summary of the logistic regression outputs is shown in Table 4.

Table 4 Logistic Regression analysis summary of model performance

Statistic	Inter-crime Distance (ICD)	Temporal Proximity (TP)	Crime Scene Behaviours (MO)	Optimal Model (MO and TP)
α constant (SE)	1.201 (.587)	1.327 (.547)	-2.569 (.942)	-1.156 (1.098)
β logit (SE)	-.001 (.000)	-.007 (.002)	12.514(4.351)	MO 11.637 (4.847) TP -.006 (.003)
Wald (df)	4.84 (1)*	7.597 (1)**	8.310 (1)	MO 5.764 (1)* TP 5.327 (1)*
Model X^2	10.084**	12.952***	13.069***	21.349***
Nagelkerke R^2	.285	.354	.357	.531
Random	50.0	50.0	50.0	50.0
Model	61.9	76.2	81.0	85.7

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All four models fit the data well as indicated by highly significant model chi-square tests. Each of the three individual behaviour models showed predictive ability improvement over chance ranging from 12% for inter-crime distance to 31% for crime-scene behaviour. The optimal model containing crime scene behaviour and temporal

proximity resulted in a 36% improvement in predictive accuracy over chance. The Nagelkerke R-square values indicate the amount of variation in linked status explained by each model. These ranged from 28.5% for inter-crime distance to 53% variation explained by the optimal model.

Receiver operator characteristic (ROC) analysis was then conducted on the test sample using the logistic regression models developed with the experimental sample. The use of ROC analysis overcomes a potential difficulty when using samples that are not statistically independent, an important assumption in the use of logistic regression, which can influence predictive accuracy (Bennell & Canter, 2002; Markson et al., 2010). Predictive probabilities (ranging from 0 -1), were calculated and used to produce ROC curves for each of the four models (Bennell & Canter, 2002).

Regression equations for calculating probabilities

Model 1: ICD

- a) Calculate Log odds = $1.201 + -.001 \times X_1$
- b) Calculate odds (linked) = $e^{1.201 + -.001 \times X_1}$
- c) Calculate probabilities (linked) = $\text{odds} / 1 + \text{odds}$

Model 2: TP

- a) Calculate Log odds = $1.320 + -.007 \times X_1$
- b) Calculate odds (linked) = $e^{1.320 + -.007 \times X_1}$
- c) Calculate probabilities (linked) = $\text{odds} / 1 + \text{odds}$

Model 3: MO

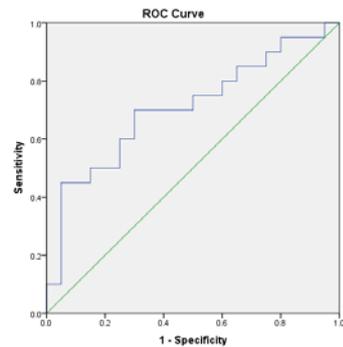
- a) Calculate Log odds = $-2.569 + 12.514 \times X_1$
- b) Calculate odds (linked) = $e^{2.569 + .12.514 \times X_1}$
- c) Calculate probabilities (linked) = $\text{odds} / 1 + \text{odds}$

Model 4: Optimal (MO + TP)

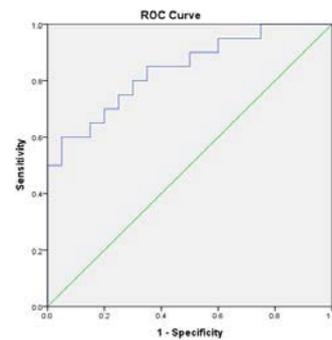
- a) Calculate Log odds = $-1.156 + 11.637 \times X_1 + -.006 \times X_2$
- b) Calculate odds (linked) = $e^{-1.156 + 11.637 \times X_1 + -.006 \times X_2}$
- c) Calculate probabilities (linked) = $\text{odds} / 1 + \text{odds}$

The sensitivity (y axis) in the ROC curves relate to the probability of a 'hit' or a correct prediction that the offences in the crime pair are linked. The specificity (x axis) in the ROC curves relate to the probability of a 'false alarm', or a prediction that the offences in a crime pair are linked when in fact they are unlinked. The resulting test statistic produced by ROC analysis is the *area under the curve (A)*. A can range from '0.50' (the diagonal line from the lower left corner of the graph to the upper right corner of the graph) indicating no predictive accuracy, to '1.0', indicating perfect predictive accuracy (Swets, 1988). The larger the area under the curve the more predictively accurate is the model. The value of 'A' from a ROC analysis also enables standardised comparisons to be made across predictors measured on different levels, and allows predictive accuracy measures to be compared across studies using the same predictor variables.

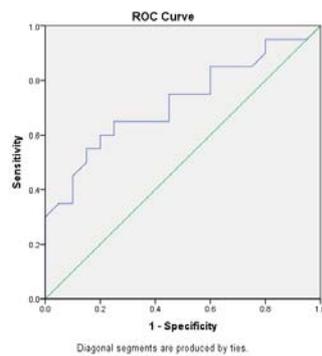
As shown in Figure 3, of the three individual predictor variables, the ROC curve for temporal proximity indicates the highest level of predictive accuracy ($A = 0.84$) followed by crime scene behaviour ($A = 0.72$) and inter-crime distance ($A = 0.71$).



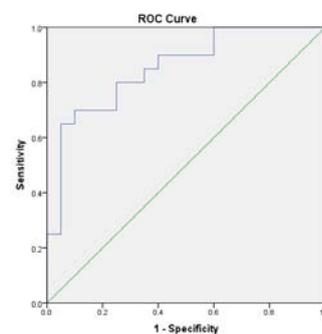
Inter-crime Distance ($A = 0.71$)



Temporal Proximity ($A = 0.84$)



Crime Scene Behaviours ($A = 0.72$)



Optimal Model ($A = 0.85$)

Figure 3. Receiver operating characteristic (ROC) curves for the three individual predictor variables; inter-crime distance, temporal proximity and crime scene behaviours, and an optimal model.

This result differs from the logistic regression analysis conducted on the experimental sample, where crime scene behaviours was indicated as the variable with the most predictive accuracy. However, the results of both the logistic regression analysis from the experimental sample and the ROC analysis from the test sample indicate that the

combination of crime scene behaviours and temporal proximity has the greatest predictive accuracy ($A = .85$), an optimal model. Full results of the ROC analysis are detailed in Table 5.

Table 5 ROC AUC values for four models

Model	AUC	SE	Significance	95% CI
Inter-Crime Distance	0.71	0.084	$P = 0.025$.544-.871
Temporal Proximity	0.84	0.062	$P = 0.000$.719-.961
Crime Scene Behaviour	0.72	0.082	$P = 0.017$.559-.881
Optimal	0.85	0.06	$P = 0.000$.735-.970

Note: AUC, area under the curve; SE, Standard error; CI, Confidence interval. An AUC value of 0.50 is non-informative, a value of 0.50-0.70 reflects low predictive accuracy, 0.70-.90 reflects moderate predictive accuracy, and 0.90-1.00 high predictive accuracy (Swets, 1988).

All models had statistically significant AUCs with moderate predictive accuracy. As shown in Table 5, the best performing model was the optimal model consisting of a combination of temporal proximity and crime scene behaviour ($A = .85$, 95% CI = .735, .97). Of note are the lower confidence interval levels for inter-crime distance and crime scene behaviours being no better than chance. Temporal proximity, with an AUC of 0.84, performed almost as good as the optimal model and for the sake of parsimony may be sufficient as a predictor on its own. These findings offer support for the hypothesis of offender behavioural consistency and distinctiveness in crime scene behaviour. The hypothesis that temporal proximity is a useful predictor of crime pair linked status was also supported. Although inter-crime distance was a useful predictor of linked status, achieving a moderate level of predictive accuracy, the consistent finding that inter-crime distance is the most accurate predictor variable for identifying linked

cases reported in previous studies (Bennell & Canter, 2002; Bennell & Jones, 2005; Goodwill and Alison, 2006; Markson et al., 2010, Tonkin et al., 2011) was not supported with this sample.

Discussion

Based on prior research in the United Kingdom and Finland, evidence suggested that certain behaviours of criminals in the commission of the offence of residential burglary could reliably distinguish between offences committed by the same offender from those committed by different offenders. The current study sought to extend these findings to a New Zealand context, using a sample of solved residential burglaries committed in the city of Napier. The three behavioural domains of inter-crime distance, temporal proximity, and crime scene behaviours were all found to have moderate predictive ability in determining which cases were linked and which were not. There were, however, differences found in the strength of the reported predictive abilities of certain behavioural domains compared to prior studies. An optimal model consisting of temporal proximity and crime scene behaviours was found to have the greatest predictive ability in distinguishing between linked and unlinked burglaries. These findings are consistent with prior BCL research, supporting the hypothesis that BCL is a valid process for linking residential burglaries in a New Zealand context.

Inter-crime distance

Inter-crime distance has consistently been found to be the domain with the greatest degree of predictive ability in BCL research. Bennell and Jones (2005), Markson et al.

(2010) and Tonkin et al. (2011) reported inter-crime distance AUCs ranging from 0.84 to 0.90., and although found to have moderate predictive ability, the current finding relating to inter-crime distance was an AUC of 0.71. This result for inter-crime distance is the weakest compared to all prior BCL studies and across all crime types. A possible explanation for the poor performance of inter-crime distance here may be the smaller geographical area from which this study's sample was drawn. The geographical area of 140 square kilometres was one of the smallest in any of the prior studies on residential burglary. The study of Bennell and Jones (2005) compared three different sized locations with one police district being 112 square kilometres, however that district had a population of 470,000 and a population density of 1,467 people per square kilometre. The population size within the current sample area was considerably smaller at 61,500 and much more dispersed with a population density of 570 people per square kilometre. Population densities in previous residential burglary research (Bennell & Jones, 2005; Markson et al., 2010; Tonkin et al., 2011) ranged from 1,358 per square kilometre to 4,053 per square kilometre. Consequently, population density may impact on the distance an offender needs to travel to commit an offence, affecting the usefulness of inter-crime distance as a reliable case linking feature.

There are also differences in housing type between New Zealand and the United Kingdom. The typical residential dwelling in many New Zealand cities are single level, separate houses (80%) (Statistics New Zealand, 2014) siting on a comparatively large section or 'plot' ranging in average size from 1,012 square meters in 1970 to 450 square meters in 2010 (Montgomery, 2010). In comparison, terraced and semi-detached

housing made up over half (54%) of all homes in England in 2011 (Department for Communities & Local Government, 2013), presenting many more potential burglary targets within a similar sized geographical area. New Zealanders also have greater access to private vehicles with 92% of households having at least one motor vehicle compared to 73% of households living in built up areas in England and Wales (Office for National Statistics, 2013). As a result, burglary offenders in New Zealand are able to be more mobile and travel comparatively greater distances to commit offences.

Burrell et al. (2012) found that the predictive accuracy of inter-crime distance changed if geographical constraints were imposed when selecting unlinked crime pairs. Burrell argued that this more closely resembles how a crime analyst works at a local level. The current study was limited to the city of Napier and many such similar sized locations in New Zealand are the subject of real time crime analysis.

As discussed in Bennell and Jones (2005), a common practice of crime analysts is the examination of burglaries within much smaller, concentrated areas namely 'hot spots', suggesting that the use of inter-crime distance to discriminate between different offenders would be very difficult if used with these small locations. In this situation there may be more than one prolific offender operating and the inter-crime distances for the offenders in the same small location are likely to be similar. Alternatively, offenders may be mobile and committing offences across a wide geographical area. In both these instances crime scene behaviours and temporal proximity are likely to be more useful as crime linking predictors.

For example, relying on an inter-crime distance as a linking feature may not be as useful at the suburban level within the city of Napier, but be very useful when examining the wider policing area of Hawke's Bay, which includes the similarly sized cities of Napier and Hastings. Just where the threshold lies where inter-crime distance becomes most useful is uncertain and further research is warranted. This could then guide analysts in the appropriateness of employing each of the linking factors dependent upon the size of their scanning area, being selective in applying different weights to each of the linking features appropriately. The findings of the reduced usefulness of inter-crime distance as a predictive linkage variable in this study has important implications for analysts working at similar geographic levels. For BCL to be effective in a practical setting, further evidence for its use needs to come from studies examining various sized locations.

Temporal proximity

Of the three behavioural domains examined, temporal proximity recorded the highest AUC value at 0.84, comparable to that of Markson et al. (2010) (0.86) and Tonkin et al. (2012) (0.82). The strength of temporal proximity as a predictive linking variable offers support for the use of temporal proximity as a useful linking feature in practice. However, unlike inter-crime distance and crime scene behaviour, there is little research examining the theoretical assumptions underlying the importance of temporal proximity in relation to linking crimes. In spite of this, temporal proximity continues to feature strongly in the research as a useful behavioural filter in determining which offences are linked and which are not. However, as in previous studies, the time period from which this study's sample was drawn from was relatively long (three years) and not reflective of the practical application of BCL by crime analysts. Additionally, if offender's MO develops

over time and in the course of repeat offending then using a long time frame to draw a sample of offences from may affect the behavioural consistency of offenders as there is greater opportunity for their crime scene behaviours to change. Consequently, limiting the sample time frame may result in an increase in the predictive accuracy of crime scene behaviours as a predictive linking feature. The 'normal' or usual period of time an analyst will search with the aim of identifying crime patterns is typically much shorter than that used in the research: anything from 24 hours to 31 days. Goodwill and Alison (2006) suggest that 28 days is an optimum period of time within which to identify crimes committed by the same offender. Future research on crime linkage should consider this more ecologically valid time frame when sampling cases for crime linkage as it better reflects the process in a practical setting. Further exploring the theoretical assumptions relating to a serial offender's frequency of residential burglary offending is also warranted.

Crime scene behaviours

Previous studies have separated offender crime scene behaviours into domains, often finding little support for the predictive ability of each of the domains in isolation. The current study used a combined behavioural domain incorporating all of the 80 crime scene behaviours so cannot report on the usefulness or otherwise of the separate domains of target selection, point and method of entry, internal behaviours, and property stolen, often reported in previous research. However it seems sensible to combine these for several reasons. Comparing higher level groupings of behaviours from the total behavioural lists would result in an unequal distribution of items amongst the

domains ranging from 11 target selection items to 37 property stolen items in this study. Markson et al. (2010) found no statistically significant support for the predictive ability of separate behavioural domains but a combined domain consisting of all behavioural items was found to be a statistically significant predictor of linked status. There is also evidence reporting inter-correlations among behavioural domains suggesting that an individual's behaviour in one domain, method of entry for example, may be related to the behaviours from another domain, perhaps internal behaviours including the type of search an offender may undertake once inside. Further research could shed light on how some behaviours from one domain are correlated with behaviours from another domain.

The combined crime scene behaviours in the current study had an AUC of 0.72, the same value reported in the Finland study (Tonkin, 2011), however greater than 0.65 which was the average AUC for the combined crime scene behaviours reported in the United Kingdom based research (Tonkin, 2015). As Tonkin (2011) suggests, the increased predictive ability for crime scene behaviours reported for the Finnish burglaries could be due to greater detail being recorded by attending police staff. However, both the Finnish study and the current study used the addition of internal behaviours (e.g. search type and extent) which were not incorporated in the United Kingdom research. It could be that the addition of internal behaviours adds more behavioural detail increasing the ability to distinguish between offenders. This suggests that there should be sufficient crime scene behaviours recorded to adequately distinguish between offenders and yet still provide support for the behavioural consistency of an individual offender. The behavioural variables in the list need to be detailed enough to separate out the

behavioural preferences of different offenders but not so detailed that the behaviour is lost amongst the detail.

Optimal model

As in the previous research, stepwise logistic regression was used to find a combination of domains resulting in the greatest AUC value, in this case a model consisting of crime scene behaviours and temporal proximity with an AUC of 0.85. This compares with the United Kingdom studies of Bennell and Jones (2005) and Markson et al. (2010) with reported optimal model AUC's of 0.90 and 0.95 respectively. Although a weaker result than the United Kingdom research findings the result is comparable with the Finnish finding of 0.86 (Tonkin et al., 2011). However, the optimal models reported in earlier studies all included inter-crime distance in combination with one or other of the behavioural domains. These were; inter-crime distance and entry behaviours (Bennell & Canter, 2002; Bennell & Jones, 2005), inter-crime distance and items stolen (Bennell & Jones, 2005), inter-crime distance and temporal proximity (Markson et al., 2010; Tonkin et al., 2011) and inter-crime distance, temporal proximity and target selection (Tonkin et al., 2011). These optimal models may have over-inflated AUCs due to the influence of inter-crime distance as a linking feature simply as a result of the sample being taken from a large geographical area.

Limitations and future directions

As with prior studies on BCL, several limitations are noted for the current study. These limitations include; 1) using 'solved' offences, 2) a comparatively small sample size, 3) limiting a serial offender's crimes to two per offender, 4) lack of standardised reporting,

recording and coding of crime scene behaviours inherent in the use of police data, and
5) the lack of generalisability of the findings to other locations within New Zealand.

These limitations are further discussed in detail.

Solved offences

The use of solved offences in BCL research is regularly cited as a limitation in that while supporting BCL in theory, in practice BCL linking needs to be applied to unsolved crimes to be of benefit. Consequently, future BCL research should include unsolved crimes, coding offences and making linking decision in real time. Alternatively, rather than using BCL to make a decision of whether two or more crimes are linked, in practice cases could be prioritised according to the degree of similarity detected through the BCL process and the prioritised list could be used to guide investigators in which cases to include within a potential crime series. Further research on the predictive accuracy of prioritised lists of potentially linked offences would be beneficial.

Sample size

The sample of 82 residential burglaries (41 linked pairs and 41 unlinked pairs) in the current study was smaller than those in prior studies, although comparable to Bennell and Canter (2002) (86 commercial burglaries). In a BCL study comparing two similarity coefficients (including Jaccard's coefficient) across a range of sample sizes involving a re-sampling procedure from samples of 10, 50, & 100 paired cases, variation in predictive accuracy reduced considerably for both similarity coefficients when sample sizes

approached 100 paired cases (Bennell, et al., 2010). Consequently the comparatively smaller sample size in the current study may have impacted on the predictive accuracy of the behavioural domains reported. As a result it is recommended that future BCL studies aim to have a minimum of 100 paired cases.

Number of offences per serial offender

Previous research has limited the number of offences in a serial offender's crime series to a certain number of offences per offender, for example two offences each. The justification for this is to limit the possibility of the behaviours of more prolific burglars in the sample to influence the results, in that the more prolific offenders may be more behaviourally consistent than less prolific burglars. However, limiting the behaviours to two offences each means that the full picture of an offender's behaviour is not assessed and there may be more behavioural consistency shown for certain behaviours over others. As many crime scene behaviours are context bound, limiting the number of offences per offender crime series also reduces the opportunity to see consistency in behaviour across offences and offenders. If prior research supports the offender consistency hypothesis then this could be further tested with more prolific offenders. Research could be conducted with offenders responsible for five or more offences in a crime series, as an example, and comparisons made to the behavioural consistency of less prolific offenders, enabling greater opportunity for the distinctiveness / consistency patterns and differences to emerge.

Lack of standardised recording of crime scene behaviour

In spite of variation in recording and coding practices, the crime scene behaviour domain in this study managed a respectable level of accuracy in predicting linked status of offences. However there is room for improvement. As discussed by Snook et al. (2015) it is in the interests of Police and researchers that crime scene data is reliably captured and coded for both research and investigative purposes. Nearly a quarter (23%) of the burglaries in the current study were not attended by a scene examiner, either having been reported through a crime reporting line or personally at the counter of a police station. The level of detail recorded for the offences where no scene examination was undertaken was not as great as those attended by a trained SOCO. Crime scene behaviours of offences reported via the crime reporting line were captured at data entry by call takers, where MO items from a list of nearly 400 individual MO items available for residential burglary in NIA were selected, in addition to recording location and offence date and time data. While some offences had MO items recorded on the occurrence records, 20 offences did not, with MO detail only recorded in narrative form, if at all. The offences where NIA MO items were recorded ranged from 1 item (3 offences) to 21 items (2 offences) with the majority (19 offences) having three MO items recorded. With so many individual MO behaviours in NIA to choose from and such wide variation in recording practices by call takers, there is little likelihood of obtaining a list of behaviours that will be useful for capturing consistencies in offender behaviours if data coded at data entry only is used for research and coding purposes. There is also questionable reliability in linking decisions based on crime scene behaviours when such variation in recording and coding practices exist.

The crime scene behaviours captured by the SOCOs was generally more thorough and easily interpreted for coding purposes. However, the 56 burglaries attended by SOCOs were attended by six individual SOCO's and five crime scenes were attended by two SOCOs. As a result, variation in how the crime scenes were examined and recorded cannot be ruled out. Snook et al. (2015) argue that for Police to increase the reliability of crime scene data there should be a routine process of inter-rater reliability, for example having two officers examine the scene and code the crime scene data ensuring accuracy of the crime scene behaviours reported. With current constraints on Police numbers this is an unrealistic expectation. Crime scene behaviours reported by attending SOCOs could be captured using a standardised behavioural list provided by analysts, increasing the reliability of crime scene data for both researchers and investigators. Additionally, crime analysts could work with crime scene attenders to better operationalise the more subjective behaviours providing easily interpretable definitions with which to categorise behaviour. Snook et al. (2015) recommend the creation of a crime scene coding manual with clear operational definitions of behaviours to further increase reliability of coded data. This would avoid offence narratives containing different words describing a similar behaviour and increase the reliability of crime scene data for case linking purposes.

Generalisability to other New Zealand locations

The current study has found support for the use of BCL with residential burglary in the city of Napier, New Zealand. There is evidential support to link offences in practice by associating case files for example, so that when assigned to an investigator the files can

be investigated together, offering an opportunity to increase offender apprehensions and clearance rates. Consequently, crime analysts in New Zealand Police can have some assurance that prioritising burglary investigation files most likely to be committed by the same offender, though the use of BCL, is a valid process and can add to the investigative tools currently used by police officers and crime analysts.

However, as Tonkin (2015) highlights, any results from BCL research are limited to the methodology, the behaviours used as linking predictors, sample size, and geographical location. The lack of generalisability to other locations in New Zealand of differing size and demographic makeup presents as an opportunity to extend BCL research in New Zealand to include larger metropolitan cities, perhaps including Auckland, Wellington and Christchurch, all with larger populations, differing population densities, and socio-economic demographics.

Conclusion

The findings reported support BCL as an additional investigative tool capable of identifying multiple offences committed by serial offenders in a New Zealand context, and replicate the prior studies using BCL with residential burglary (Bennell & Canter, 2002; Bennell & Jones, 2005; Markson et al., 2010; Tonkin et al., 2011). The reduced predictive ability of inter-crime distance found, compared to prior research, suggests caution should be taken in relying on inter-crime distance alone as a linking feature when linking cases within a small geographical location. The use of crime scene

behaviours and temporal proximity together achieved the greatest predictive accuracy in respect of identifying linked cases. Increasing the accuracy of reporting, recording and coding of crime scene behaviours through tighter operationalisation and standardisation of behavioural items is likely to further increase the usefulness of the crime scene behaviour domain in accurately identifying cases committed by the same offender/s.

References

- Bandyopadhyay, S. (2012). *Acquisitive crime: imprisonment, detection and social factors*. Retrieved from Civitas: Institute for the Study of Civil Society website: <http://www.civitas.org.uk/content/files/crimeanalysis2012.pdf>.
- Baker, M. (2000). The criminal range of small-town burglars. In D. Canter & L. Alison (Eds.), *Profiling Property Crimes*. Aldershot: Dartmouth Publishing.
- Baker, G. & Gray, A. (2005a). *Victims* (Research on the effectiveness of Police practice in reducing residential burglary: Report 8). Wellington: Ministry of Justice.
- Baker, G. & Gray, A. (2005b). *Burglary offenders* (Research on the effectiveness of Police practice in reducing residential burglary: Report 9). Wellington: Ministry of Justice.
- Bartol, C. R., & Bartol, A. M. (2013). *Criminal and behavioral profiling: Theory, research and practice*. Thousand Oaks, CA: Sage.
- Beaton, A., Cook, M., Kavanagh, M., & Herrington, C. (2000). The psychological impact of burglary. *Psychology, Crime & Law*, 6, 33-43.
- Becroft, A. (2009, May). *What causes youth crime and what can we do about it*. Paper presented at the NZ Bluelight Ventures Inc.-Conference and AGM, Queenstown, New Zealand.
- Bennell, C., & Canter, D. V. (2002). Linking commercial burglaries by modus operandi: Tests using regression and ROC analysis. *Science and Justice*, 42 (3), 153-164.
- Bennell, C., & Jones, N. J. (2005). A method for linking serial burglaries by Modus Operandi. *Journal of Investigative Psychology and Offender Profiling*, 2, 23-41.

- Bennell, C., Bloomfield, S., Snook, B., Taylor, P., & Barnes, C. (2010). Linkage analysis in cases of serial burglary: Comparing the performance of university students, police professionals, and a logistic regression model. *Psychology, Crime & Law*, 16 (6), 507-524.
- Bennell, C., Gauthier, D., Gauthier, D., Melnyk, T., & Musolino, E. (2010). The impact of data degradation and sample size on the performance of two similarity coefficients used in behavioural linking analysis. *Forensic Science International*, 85-92.
- Bennell, C., Jones, N. J., & Melnyk, T. (2009). Addressing problems with traditional crime linking methods using receiver operator characteristic analysis. *Legal and Criminological Psychology*, 14, 293-310.
- Bennell, C., Mugford, R., Ellingwood, H., & Woodhams, J. (2013). Linking crimes using behavioural clues: Current levels of linking accuracy and strategies for moving forward. *Journal of Investigative Psychology and Offender Profiling*, 11, 29-56.
- Bennett, T. & Wright, R (1984). *Burglars on burglary: prevention and the offender*. Aldershot, Hampshire: Gower Publishing Company.
- Bernasco, W. (2014). Residential burglary. In G. Bruinsma & D. Weisburd (Eds.), *Encyclopaedia of criminology and criminal justice* (1st ed.). New York: Springer.
- Blevins, K. R., Khuns, J. B, & Lee, S. (2012). *Understanding decisions to burglarize from the offender's perspective*. University of North Carolina at Charlotte Department of Criminal Justice and criminology. Retrieved

from <http://airef.org/wp-content/uploads/2014/06/BurglarSurveyStudyFinalReport.pdf>.

Brantingham, P. L., & Brantingham, P. J. (1981). Notes on the geometry of crime. In P. L. Brantingham and P. J. Brantingham (Eds.), *Environmental criminology*. London: Sage Publications.

Bouhana, N., Johnson, S.D., & Porter, M. (2014). Consistency and specificity in burglars who commit prolific residential burglary: Testing the core assumptions underpinning behavioural case linkage. *Legal and Criminological Psychology*, 21(1), 77-94.

Burrell, A., Bull, R., & Bond, J. (2012). Linking personal robbery offences using offender behaviour. *Journal of Investigative Psychology and Offender Behaviour*, 9(3), 201-222.

Burrell, A., Bull, R., Bond, J., & Herrington, G. (2015). Testing the impact of group offending on behavioural similarity in serial robbery. *Psychology, Crime & Law*, 21(6), 555-569.

Burrows, J., & Tarling, R. (2004). Measuring the impact of forensic science in detecting burglary and autocrime offences. *Science & Justice*, 44(4), 217-222.

Canter, D., & Alison, L. (2000). Profiling property crimes. In D. Canter & L. Alison (Eds.), *Profiling Property Crimes*. Aldershot: Dartmouth Publishing.

Chetwin, A. (2005). *Overview: research on the effectiveness of police practice in reducing residential burglary* (Research on the effectiveness of Police practice in reducing residential burglary: Report 10). Wellington: Ministry of Justice.

- Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20*, 37-46.
- Cohen, J. (1988). *Statistical power analysis for the behavioural sciences (2nd ed.)*. Hillsdale, NJ: Lawrence Erlbaum Associates. ISBN 0-8058-0283-5.
- Collins, J. (2016). *Official crime stats released today* [Press release]. Retrieved from <https://www.beehive.govt.nz/release/official-crime-stats-released-today>.
- Corboy, M., Gilbert, E., Purdie, R., & McKenna, K. (2005). New Zealand Police communications centres service centre independent review final report. Retrieved from <http://www.police.govt.nz/sites/default/files/publications/comm-centres-review.pdf>.
- Couch, B. (2011). *Does targeting prolific offenders reduce crime rates?* University of South Florida. Retrieved December 15, 2015, from <http://legacy.usfsm.edu/academics/cas/capstone/2010-2011/criminology/couch-targeting%20prolific%20offenders.pdf?from=404>.
- Crimes Act, New Zealand Statutes s241 (1961).
- Davidson, R. N. (1980). Patterns of residential burglary in Christchurch. *New Zealand Geographer, 36*(2), 73-78.
- Davies, K., Tonkin, M., Bull, R., & Bond, J. W. (2012). The course of case linkage never did run smooth: A new investigation to tackle behavioural changes in serial car theft. *Journal of Investigative Psychology and Offender Profiling, 9*(3), 274-295.

Department for Communities & Local Government (2013). *English housing survey: Homes 2011*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211324/EHS_HOMES_REPORT_2011.pdf.

Ellingwood, H., Mugford, R., Bennell, C., Melnyk, T., & Fritzon, K. (2013). Examining the role of similarity coefficients and the value of behavioural themes in attempts to link serial arson offences. *Journal of Investigative Psychology and Offender Profiling, 10*, 1-27.

Everson, S. (2003). Repeat victimisation and prolific offending: Chance or choice. *International Journal of Police Science & Management, 5*(3), 180-194.

Fritzon, k. (2001). An examination of the relationship between distance travelled and motivational aspects of fire setting behaviour. *Journal of Environmental Psychology, 21*, 45-60.

Gavin, H. (2014). *Criminological and forensic psychology*. London: Sage.

Goodwill, A., & Alison, L. (2006). The development of a filter model for prioritizing suspects in burglary offences. *Psychology, Crime and Law, 12*(4), 395-416.

Green, E.J., Booth, C.E., & Biederman, M.D. (1976). Cluster analysis of burglary M/Os. *Journal of Police Science and Administration, 4*, 32-38.

Hockey, D. (2016). Burglary crime scene rationality of a select group of non-apprehend burglars. *Sage Journals*. Doi: 10.1177/2158244016640589.

- Hendery, S. (2016, December 9). *Stuff*. Retrieved from <http://www.stuff.co.nz/national/crime/87398318/christmas-present-burglary-in-napier-has-happy-ending-as-police-swoop-early>.
- Harvey, S. (2005). *Literature review: Police practice in reducing residential burglary* (Research on the effectiveness of Police practice in reducing residential burglary: Report 3). Wellington: Ministry of Justice.
- Home Office (2013). *Home Office statistical bulletin: Crimes detected in England and Wales 2012 – 2013*. Retrieved from <https://www.gov.uk/government/collections/crimes-detected-in-england-and-wales>.
- Keppel, R.D. (2002). Serial offenders: linking cases by modus operandi and signature. In S. H. James & J. J. Nordby (Eds.), *Forensic science: an introduction to scientific and investigative techniques*. Boca Raton, United States: CRC Pres.
- Lock, A. (2016). *The New Zealand Herald*. Burglaries and theft on the rise in Hawke's Bay. Retrieved from http://www.nzherald.co.nz/hawkes-bay-today/news/article.cfm?c_id=1503462&objectid=11739937.
- Maguire, M. (1980). The impact of burglary upon victims. *British Journal of criminology*, 20(3), 261-275.
- Markson, L., Woodhams, J., & Bond, J. (2010). Linking serial residential burglary: Comparing the utility of Modus Operandi behaviours, geographical proximity, and temporal proximity. *Journal of Investigative Psychology and Offender Profiling*, 7, 91-107.

- Melnyk, T., Bennell, C., Gauthier, D., & Gauthier, D. (2011). Another look at cross-crime similarity coefficients for use in behavioural linkage analysis: An attempt to replicate Woodhams, Grant and Price (2007). *Psychology, Crime and Law*, 17(4), 359-380.
- Merry, S. (2000). Crime analysis: principles for analysing everyday serial crime. In D. Canter & L. Alison (Eds.), *Profiling Property Crimes*. Aldershot: Dartmouth Publishing.
- Merry, S. & Harsent, L. (2000). Intruders, Pilferers, Raiders and Intruders: The Interpersonal Dimension of Burglary, in D. Canter & L. Alison (Eds.), *Profiling Property Crimes*. Aldershot: Dartmouth Publishing.
- Ministry of Justice, (2014). New Zealand Crime and Safety Survey. Retrieved December 16, 2015, from <http://www.justice.govt.nz/publications/global-publications/n/new-zealand-crime-and-safety-survey-2014/publications/global-publications/n/new-zealand-crime-and-safety-survey-2014/documents/nzcass-main-findings-report>.
- Moffitt, T. E. (1993). Adolescence-limited and life-course-persistent antisocial behavior. *Psychological Review*, 100, 674-701.
- Montgomery, R. (2015, April). *Spread your risk: reconsidering the "quarter acre" dream from an evolutionary perspective*. Paper presented at the New Zealand Planning Institute conference 2015. Retrieved from http://www.planning.org.nz/Attachment?Action=Download&Attachment_id=3181.

- Napier, M. R. & Baker, K. P. (2003). Criminal personality profiling. In S. H. James & J. J. Nordby (Eds.), *Forensic science: An introduction to scientific and investigative techniques*. Boca Raton, United States: CRC Pres.
- Nee, C. & Meenaghan, A. (2006). Expert decision making in burglars. *British Journal of Criminology*, *46*, 935-949.
- Nee, C., White, M., Woolford, K., Pascu, T., Baker, L., & Wainwright, L. (2015). New methods for examining expertise in burglar's decision making in natural and simulated environments: Preliminary findings. *Psychology, Crime, & Law*, *21*(5), 507-513.
- New Zealand Police National Headquarters, (2014, October). Eastern District Crime Statistics 2014. Retrieved December 12, 2015, from <http://www.police.govt.nz/sites/default/files/publications/crime-stats-fiscal-eastern-20140630.pdf>.
- New Zealand Police (2015). New Zealand Crime Statistics 2014: A summary of recorded and resolved offence statistics. Retrieved <http://www.police.govt.nz/sites/default/files/publications/crime-stats-national-20141231.pdf>.
- New Zealand Police (2016). New Zealand Police Four Year Plan (2016/17 - 2019/20). Retrieved from <http://www.police.govt.nz/sites/default/files/publications/strategic-plan-2016-2020-four-year-plan.pdf>.

Office of the Auditor-General. (2006). *New Zealand Police: Dealing with dwelling burglary-follow-up audit*. (Controller and Auditor-General, performance audit report ISBN 0-478-18148-5). Retrieved from <http://www.oag.govt.nz/2006/burglary/docs/burglary.pdf>.

Office for National Statistics (2013). *2011 Census: Characteristics of built-up areas*. Retrieved from <https://www.ons.gov.uk/peoplepopulationandcommunity/housing/articles/characteristicsofbuiltupareas/2013-06-28>.

Online Library Liberty Fund (n.d.). *Sir Edward Coke: selected writings of Sir Edward Coke, vol. 1 [1600]*. Retrieved from http://oll.libertyfund.org/titles/coke-selected-writings-of-sir-edward-coke-vol-i--5#Coke_0462-01_528.

Paulsen, D. J., Bair, S., & Helms, D. (2010). *Tactical crime analysis: Research and investigation*. New York: CRC Press Taylor & Francis Group.

Ratcliffe, J. H. (2000). Aoristic analysis: the spatial interpretation of unspecific temporal events. *International Journal of Geographical Information Science*, 14(7), 669-679.

Ratcliffe, J. H. (2008). *Intelligence-led policing*. Devon: Willan Publishing.

Santtila, P., Fritzon, K., & Tamelander, A. L. (2004). Linking arson incidents on the basis of crime scene behaviour. *Journal of Police and Criminal Psychology*, 19(1), 1-16.

Santtila, P., Korpela, S., & Hakkanen, H. (2004). Expertise and decision making in the linking of car crime series. *Psychology, Crime and Law*, 10, 97-112.

- Shadwell, T., Thomas, R., & Fryers, A., (2016, August 31). *Stuff*. Retrieved from <http://www.stuff.co.nz/national/crime/83751836/Official-crime-stats-reveal-burglaries-and-crime-rising>.
- Snook, B., Luther, K., & MacDonald, S. (2015). Linking crimes with spatial behaviour: a need to tackle some remaining methodological concerns. In J. Woodhams & C. Bennell (Eds.), *Crime linkage: Theory, research, and practice*. London: CRC Press.
- Statistics New Zealand (2006). Crime in New Zealand: 1996 - 2005. Retrieved from <file:///H:/Downloads/Chrome/crime-in-nz-96-05.pdf>.
- Statistics New Zealand (2014). *2013 Census: Quick stats about housing*. Retrieved from <http://www.stats.govt.nz/census/2013-census/profile-and-summary-reports/quickstats-about-housing.aspx>.
- Statistics New Zealand (2016). *Crime statistics: September 2016 - media release*. Retrieved from http://www.stats.govt.nz/browse_for_stats/people_and_communities/crime_and_justice/crime-stats-sep16-MR.aspx.
- Swets, J., A. (1988). Measuring the accuracy of diagnostic systems. *Science*, 240, 1285-1293.
- Thornley, A. M. (2004). Crime in space and time: A spatial and temporal analysis of burglary in Christchurch. (Master's thesis, University of Canterbury, Christchurch, New Zealand). Retrieved from <http://www.http://ir.canterbury.ac.nz/>.

- Tonkin, M. (2015). Testing the theories underpinning crime linkage. In J. Woodhams & C, Bennell (Eds.), *Crime linkage: Theory, research, and practice*. London: CRC Press.
- Tonkin, M. J. (2012). *Behavioural case linkage: Generalisability, ecological validity, and methodology* (Doctoral dissertation, University of Leicester, Leicester, United Kingdom). Retrieved from ira.le.ac.uk/bitstream/2381/27620/1/2012tonkinmphd.pdf.
- Tonkin, M., Grant, T., & Bond, J. W. (2008). To link or not to link: A test of the case linkage principles using serial car theft data. *Journal of Investigative Psychology and Offender Profiling*, 5, 59-77.
- Tonkin, M. J., Santtila, P., & Bull, R. (2011). The linking of burglary crimes using offender behaviour: Testing research cross-nationally and exploring methodology. *Legal and Criminological Psychology*, 17(2), 276-293.
- Tonkin, M., & Woodhams, J. (2015). The feasibility of using crime scene behaviour to detect versatile offenders: An empirical test of behavioural consistency, distinctiveness, and discrimination accuracy. *Legal and Criminological Psychology*. doi/10.1111/lcrp.12085/abstract.
- Turvey, B. E. (2002). *Criminal profiling: An introduction to behavioural evidence analysis*. San Diego: Academic Press.
- United Nations Office of Drugs and Crime (2014). Burglary breaking and entering at the national level, number of police-recorded offences. Retrieved from

[www.https://data.unodc.org/?lf=1&lng=en#state:0](https://data.unodc.org/?lf=1&lng=en#state:0). Retrieved on 17 August 2016.

Weatherburn, D., Hua, J., & Moffatt, S. (2006). How much crime does prison stop? The incapacitation effect of prison on burglary. *Contemporary Issues in Crime and Justice, 93*. New South Wales Bureau of crime Statistics and Research. Retrieved from <http://www.bocsar.nsw.gov.au/Documents/CJB/cjb93.pdf>.

Woodhams, J., Bull, R., & Hollin, C.R. (2007) Case linkage: Identifying crimes committed by the same offender. In R.N. Kocsis (Ed.), *Criminal profiling: International theory, research, and practice*. Totowa, NJ: Humana Press Inc.

Woodhams, J., Hollin, C. R., & Bull, R. (2007). The psychology of linking crimes: A review of the evidence. *Legal and Criminological Psychology, 12*(2), 233-249.

Woodhams, J., & Toye, K. (2007). An empirical test of the assumptions of case linkage and offender profiling with serial commercial robberies. *Psychology, Public Policy, and Law, 13*, 59-85.

Appendix A: Crime scene behaviours

Target Selection

Timings	1	Daylight
	2	Darkness
Scene	3	House / dwelling / Flat
	4	Shed / Garage / sleep-out / Caravan / Outbuilding
	5	Driveway / carport / section - yard
	6	Vehicle on property
Occupancy	7	Occupiers present
	8	Occupiers temporarily away (<24hrs)
	9	Offender known to Occupier
Security	10	Security Light
	11	CCTV

Entry Behaviour

Point of Entry	12	Window
	13	Door
Location of Entry	14	Front
	15	Side
	16	Back / Rear
Method of entry	17	Manual Force, Bending
	18	Insecure / unlocked / open
	19	Tool marks / jemmied
	20	Access by smashing / breaking glass
	21	Access by removing glass
	22	Brick / Rock / Stone used to break
	23	Reached in and unlocked/unlatched
	24	Tool used brought to the scene
	25	Tool used from the scene
	26	Climbed on object to assist entry
	27	Climbed to higher level / floor
	28	Similar Key / Stolen Key
29	Access using confidence/ trick/ excuse	

Internal Behaviour

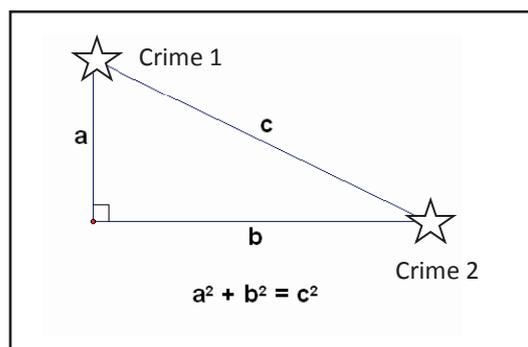
Search Type	30	Tidy
	31	Untidy / Messy
	32	Gratuitous mess
Extent of search	33	Nothing
	34	Limited (one room)
	35	Extensive (multiple rooms)
	36	Drawers and Cupboards opened
	37	Contents tipped out
Other offender behaviour	38	Consumed food / drink
	39	Caused Damage (Spread food / paint/ graffiti / smashed walls & doors)

	40	Moved items but not taken
	41	Fingerprints lifted / DNA / Shoe impressions (Forensics)
	42	Glove Marks
	43	Other evidence left behind by offender
Property Stolen		
Nothing	44	Nothing
Electronics Appliances	45	T.V.
	46	DVD Player
	47	Laptop / Tablet / Computer / accessories / Printer / external hard drive
	48	iPod / personal music player / headphones
	49	Stereo / Speakers / Amplifier
	50	Cell phone / charger
	51	Camera / Video Camera
Electronics Games, DVDs, CDs	52	Xbox / Play stations / Games / Accessories
	53	Records / CD's / DVDs
Food	54	Food
	55	Alcohol
	56	Soft drink
Tools / Garden	57	Lawn Mower
Tools / Power / Builder	58	Power tools
Cheques / Cards / Cash	59	Handbag / Wallet
	60	Credit Cards / Documents / Cheques
	61	Cash / gift vouchers
	62	Driver's Licence / Passport / ID card
Personal equipment	63	Clothing / shoes
	64	Jewellery
	65	Perfume / makeup / cosmetics / Toiletries
	66	Drugs / prescription medication
	67	Watches
	68	Sunglasses
	69	Hair straighteners / Hairdressing supplies
	70	Bedding
Vehicles / Transport	71	Keys
	72	Bikes / scooters / Mountain bikes
	73	Cars
	74	Motor bikes / motor scooters/ Quad bikes / Mobility scooter
Other	75	Dive gear / Fishing gear
	76	Ornament / unique / rare
	77	Musical Instrument
	78	Sports gear
	79	Kitchen appliances / Crockery / Cutlery
	80	Bag / carrier

Appendix B: Formula for calculating inter-crime distance and temporal proximity

Inter-crime distance was calculated for each crime pair using Pythagoras' theorem incorporating the geocoded co-ordinates (x, y) for each offence in a pair. Data for each offence extracted from NIA included the x, y geocoded coordinates in the form of eastings and northings, given in metres from a reference meridian. In accordance with Pythagoras' theorem, the distance between two points forming the hypotenuse of a right angle triangle is equal to the square root of the summed squares of the two other sides of the triangle.

Figure Appendix.B1: Calculating the distance between two crimes using Pythagoras' theorem



Hence calculating the squared distance of eastings and northings enables the length of the distance between the two locations (hypotenuse) to be calculated as follows:

$$Distance = \sqrt{(eastng1 - eastng2)^2 + (northings1 - northings2)^2}$$

An example of how the distance between two offences can be calculated in Microsoft Excel, including the Excel function for Pythagoras' theorem, is shown in figure Appendix .B2.

Figure Appendix.B2: Using Microsoft Excel to calculate distances using Pythagoras' theorem

D3 : <input type="checkbox"/> <input checked="" type="checkbox"/> <i>fx</i> =SQRT(((B2-B3)^2+(C2-C3)^2))							
	A	B	C	D	E	F	G
1	Case No.	Easting	Northing	Distance			
2	1	1931165	5603996				
3	2	1931452	5605331	1366			
4							

Distance between case 1 and case 2 (D3) =SQRT((B2-B3)^2 + (C1-C2)^2)

In the example above, the distance between Case 1 and Case 2 is 1366 metres.

Temporal Proximity was calculated using the difference in days from the mid -point between the start date and time and end date and time of each offence in the pair. An example of how the difference in mid-points can be calculated using Microsoft Excel is shown in figure Appendix.B3.

Figure Appendix.B3: Using Microsoft Excel to calculate distances inter-case temporal proximity

D2 : <input type="checkbox"/> <input checked="" type="checkbox"/> <i>fx</i> =(B2+C2)/2					
	A	B	C	D	E
1	Case No.	Offence Start Date/Time	Offence End Date/Time	Offence Mid-Point	Temporal Distance
2	1	8/08/2013 11:10	8/08/2013 11:28	8/08/2013 11:19	
3	2	29/07/2013 7:30	29/07/2013 17:30	29/07/2013 12:30	9.95
4					

The mid-point is calculated using a function that takes the average of the start date/time and end date/time. The temporal distance between two cases is calculated by subtracting the mid-point of one case from the mid-point of another case. In this example giving a temporal distance of 9.95 days between case 1 and case 2.