

**CRIME LINKAGE AND ITS APPLICATION TO SERIAL, STRANGER, SEXUAL
ASSAULTS**

by

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ABSTRACT

This thesis investigates the application of crime linkage to sexual assaults with an adult sample where the offender is a stranger to the victim. Chapter 1 gives an overview of crime linkage and sexual offending. Additionally, it examines the theories that crime linkage is based on, with focus on situations that may impact on the effectiveness and usefulness of crime linkage. Chapter 2 compares serial and one-off sexual offenders; finding that there is almost little difference between the behaviours during an offence. Chapter 3 tests the two basic assumptions of crime linkage; behavioural consistency and distinctiveness. Using a larger sample than most current research, and then extending the dataset to include one-off offenders, excellent levels of predictive accuracy were achieved, thus providing support for the assumptions underpinning crime linkage. Chapter 4 test if the stage during the sexual offences has an impact on the predictive accuracy of the behaviours. However, the complete sample of behaviours still performed best. Chapter 5 investigates the performance of five different similarity coefficients with crime linkage analysis. None of the coefficients significantly outperformed the current one. Chapter 6 concludes the thesis, summarises the findings, and discusses the implications on both academic and practical applications of crime linkage.

To my parents and my brother for always believing in me.

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STATEMENT OF AUTHORSHIP

Chapters 2 and 3 contain material that has been published¹ for publication to two journals. Consequently, these two chapters have their own introductions. While every effort has been made to avoid repetition, there may still be an overlap in some of the background material included in these two articles.

The authorship on Chapters 2 and 3 indicates collaborative work. As clarification, I am the primary author after having obtained and analysed the data in the chapters. My supervisor, Jessica Woodhams, and temporary supervisor, Catherine Hamilton-Giachritsis, are the other named authors, as they provided comments and feedback on the drafts.

¹ Chapter 2 - Slater, C., Woodhams, J., & Hamilton-Giachritsis, C. (2014). Can serial rapists be distinguished from one-off rapists?. *Behavioral Sciences and the Law*, 32(2), 220-239. doi: 10.1002/bsl.2096

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CHAPTER 1: INTRODUCTION

Currently it is almost impossible to turn on a television and not see a crime fiction programme being broadcast, and many of these include the sometimes controversial element of psychological profiling. Representations of psychological profiling have become prominent in popular media such as *The Silence of the Lambs* (Herndon, 2007). However, many researchers in the field point out that the media misrepresents profiling, something that could negatively impact investigations (Canter & Youngs, 2003; Muller, 2000). Most often, the media makes use of offender profiling as defined by Goodwill and Alison (2007), as the prediction of offender characteristics based on crime scene analysis. This information is used to narrow the suspect pool and develop new lines of inquiry in serial crimes (Dowden, Bennell, & Bloomfield, 2007; Woodworth & Porter, 2000). In the television shows, these tactics seem intuitive; they are a combination of the profiler's intelligence, experience and 'a little bit of luck.' But behind the media's glamorous portrayal of profiling, there is real science and academic studies being conducted, and from these studies a newer area of research has emerged: "crime linkage."

It is at times difficult to separate crime linkage from profiling. The two areas coexist under the umbrella term of 'investigative psychology' and modern day profilers, called Behavioural Investigative Advisors in the UK, engage in both profiling and crime linkage (Alison, Goodwill, Almond, van den Heuvel, & Winter, 2010). Offender profiling was defined by Canter (2000) as, "the derivation of inferences about a criminal from aspects of the crime(s) he or she has committed" (p. 23). Whereas crime linkage focuses on determining if two or more crimes are linked, or committed by the same offender (Grubin et al., 2001). Crime linkage is a psychological practice whereby police records are analysed with the aim of identifying

similarities in crime scene behaviour between crimes that would suggest two or more crimes were committed by the same offender (Woodhams & Grant, 2006). It is closely related to how serial crimes are already linked to offenders using evidence such as DNA, fingerprints or witness statements. Crime linkage goes by a variety of names such as the behavioural linking task (e.g., Bennell & Canter, 2002), comparative case analysis (CCA; e.g., Davies, 1992), linkage analysis (e.g., Hazelwood & Warren, 2004), behavioural linking (e.g., Bennell & Jones, 2005), crime linking (e.g., Sjöstedt, Långström, Sturidsson, & Grann, 2004), behavioural consistency (e.g., Salfati & Bateman, 2005), case linkage (e.g., Woodhams & Grant, 2006) and crime linkage (Woodhams, 2012). From the plethora of names being used, in this thesis the term “crime linkage” will be used as it refers to the application to criminal offences but is broad enough to allow for different types of analysis.

Crime Linkage can be used with many different types of serial crimes. Thus far, studies have been conducted focusing on sexual assault/rapes (e.g., Grubin, Kelly, & Brunson, 2001), arson (e.g., Hakkanen, Puolakka, & Santtila, 2004), burglaries (e.g., Bennell & Jones, 2005), homicides (e.g., Santtila, Hakkanen, Canter, & Elfgren, 2003), robberies (e.g., Lin & Brown, 2006), and car theft (e.g., Tonkin, Grant, & Bond, 2008). The scope of this thesis will however focus only on crime linkage as applied to violent interpersonal crime, specifically stranger sexual offences. Sexual offences are one of the crime types to which behavioural linkage can successfully be applied (as opposed to geographical or temporal linking) (Tonkin, Woodhams, Bull, & Bond, 2012).

The practical use of crime linkage includes not only advising in criminal investigations but also assists in the legal proceedings that can follow. Crime linkage evidence is already used to direct police investigations and has been used in legal proceedings in the UK, the US,

Australia and South Africa (Bosco, Zappala, & Santtila, 2010; Charron & Woodhams, 2010; Hazelwood & Warren, 2004; Labuschagne, 2006). Crime linkage can be used to assist investigators in connecting crimes to an unknown offender through combining evidence from the separate crime scenes to give the investigators a more comprehensive spread of evidence. The information from crime linkage can also be used for suspect prioritisation. If similarities are found with a crime committed by a known offender this can expedite his/her arrest. This same information can then be used in court to assist prosecutors in suggesting to the jury or judge that the defendant is the offender (Bosco et al., 2010; Woodhams & Toye, 2007). The crime linkage research findings can also be used to support expert testimony (Bosco et al., 2010; Charron & Woodhams, 2010; Woodhams & Toye, 2007).

However, in the future, as research in the field of crime linkage develops, its potential to assist ongoing investigations may grow. Ideas put forward in more recent research include creating a computer or statistical program capable of linking crimes for investigators (Schroeder, Xu, Chen, & Chau, 2007; Yokota, Fujita, Watanabe, Yoshimoto, & Wachi, 2007) or developing structured decision-making tools to assist crime analysts (Woodhams & Bennell, 2011). It is a fast growing field of research and with each study there is a better understanding of how crime linkage works, and the potential for more benefits grows.

The Emergence of Crime Linkage

Crime linkage as a practice has been around a long time and predates the research conducted on it. What has come to be known as linking originally appeared in research as far back as the 1970s (Green, Booth, & Biderman, 1976), but it was not until the late 1990s and early 2000s that there was a real rise in the research in the area. The term “linking” began to

appear in profiling research to denote the idea of exploring the similarities of the crimes, rather than what the crimes predicted about the offender, at the end of the 1990s. At that time, however it was still researched with profiling as they share common assumptions (Canter, 2000). One of these early examples was Salfati and Haratsis (2001), who found that there were certain similarities shared by solved homicides, which differed significantly from the unsolved cases.

While there was a paper by Grubin, Kelly and Ayias in 1997 that focused solely on the behavioural linking of crimes, it was the Grubin, Kelly and Brunson, 2001 article with the Home Office that arguably began the modern era of crime linkage. In this, they proposed that in the absence of more concrete forensic or physical evidence, analysing the offenders' behaviours might be a way to link serial crimes. Using a sample of serial sexual offenders, they divided the actions of the offenders into four separate domains: controlling the victim, the sexual behaviour, escape behaviour, and personal style of the offender. Cluster analysis was used to create types within each of these four domains. Grubin et al. found that 83% of all offenders were consistent in at least one domain throughout their series, and that 26% were consistent across all four domains. There was also more consistency shown in the control domain whereas the least stable domain was the style domain. This was a very promising start for crime linkage analysis, but Grubin et al. cautioned that their study was merely to contribute to the formation of a tool for conducting linking, not confirmation of linking. Just as DNA 'fingerprinting' evidence faced scrutiny when first introduced to the legal systems (Lynch, 2003), crime linkage will be subjected to close scrutiny and it will need to be supported by research and statistics.

Despite important differences, crime linkage continued to be discussed and researched alongside profiling in subsequent years (e.g., Alison, Bennell, Mokros, & Ormerod, 2002; Mokros & Alison, 2002). However, at the same time, some publications focused entirely on

crime linkage continued to appear (e.g., Bennell & Canter, 2002) and with case studies of crime linkage (e.g., Hazelwood & Warren, 2004). It was in both Alison et al. (2002) and Bennell and Canter (2002) that the assumptions underpinning crime linkage were given explicit attention. These are the assumptions of a) behavioural consistency (Canter, 1995) and b) distinctiveness or differentiation (Bennell & Canter, 2002; Woodhams, Hollin, & Bull, 2007).

The Assumption of Behavioural Consistency is the belief that offenders are consistent in the actions and inactions they perform during a crime (Woodhams & Toye, 2007).

The Assumption of Behavioural Distinctiveness is the belief that the commission of the crimes will be distinguishable between different offenders (Woodhams & Toye, 2007). Alison et al. (2002) phrased the latter in terms of inter-individual behavioural variation being greater than intra-individual variation, meaning that the offender's crimes would be more different in behavioural variation from other offenders' crimes than to other crimes they committed themselves.

These same two principles also underpin offender profiling. Alison et al.'s (2002) article highlighted the dearth of research on these basic assumptions. The critique of offender profiling by Alison et al. (2002), along with the emerging studies on crime linkage (Bennell & Canter, 2002; Grubin et al., 2001), seemed to prompt the divergence of crime linkage from offender profiling and the subsequent interest in crime linkage as a research topic in its own right.

Behavioural Consistency and Distinctiveness in Personality Psychology

There is much research that discusses the consistency and distinctiveness in non-criminal behaviours (Pervin, 2002). At the same time, literature focused on the consistency and distinctiveness of criminal behaviours has been accumulating since the 1970s (Green, Booth, &

Biderman, 1976). Within the personality psychology literature there has not always been a clear link between the belief that individuals' behaviours would be stable and the research findings (Shoda & Smith, 2004). As Woodhams and Bennell (2014) discuss in their book, the methods used to study consistency in personality psychology meant measuring the behaviours that represent the traits. These traits would be measured by means such as questionnaires of behavioural observations, and it was expected that the results of these would be the same if conducted at different times. The Personality psychologists were disappointed when this was not the case, however others postulated that it meant that the situation had influenced the results (Mischel, 1973, 2009 as cited in Woodhams & Bennell, 2014).

CAPS Model

One of the most useful models explaining behaviour from Personality Psychology comes from Mischel and Shoda (1995), called the Cognitive-Affective Personality System (CAPS). This model proposes that when an individual is faced with a situation there is a psychologically salient feature that causes internal reactions within the person.

“This model proposes that the situations we all encounter in our daily life contain features that are psychologically salient to the individual and that these features trigger internal reactions (cognitive and affective) within the person. What reactions are triggered in a given person's CAPS depends on their learning history, their expectations, and how they interpret the situational cues. The personality system is proposed to consist of mental representations, or cognitive-affective units, that are activated by situational features and through whose activation behaviour it is produced.” (Mischel & Shoda, 1995 as summarised by Woodhams & Bennell, 2014).

The response of the individual is based on their personal experience and understandings. The model accounts for differences between people in that not everyone reacts the same way to the same situation and therefore are distinct from one another.

The CAPS model uses the basis of “*if...then*” statements. The *if* represents the situational trigger, whereas the *then* statement is the subsequent behaviour. With the *then* statements, people’s responses will vary depending on that person’s biological and lived experiences. As these responses are based upon a person’s life experiences it is possible that even within an individual the *then* responses will change as they gain different experiences and learning in their lives, and therefore it is open to evolution.

With application to crime linkage, the CAPS model would predict that an offender would react in a specific way to certain situations within an offence. However, the CAPS model would also allow for the offender to evolve their behaviour as they commit more offences or learn from other more criminally sophisticated individuals.

Research on the Assumptions of Crime Linkage

As mentioned before, there are two main assumptions about the serial offender’s behaviour that form the base of crime linkage. There is a large body of research that exists discussing the consistency and distinctiveness in non-criminal behaviours (Caspi & Herbener, 1990; Mischel, Mendoza-Denton, & Shoda, 2002; Pervin, 2002). At the same time, literature focused on the consistency and distinctiveness of criminal behaviours has been accumulating since the 1990s (Grubin, Kelly, & Ayias, 1997).

The research on crime linkage so far has primarily focused on studying these two assumptions. The research has covered a wide range of crimes which will be discussed in more

detail later in this chapter. There have also been a wide array of statistical methods used to test the assumptions, including discriminant function analysis (DFA) and multidimensional scaling (MDS; e.g., Santtila, Junkkila, & Sandnabba, 2005) and iterative classification tree analysis (e.g., Tonkin, Woodhams, Bull, Bond, & Santtila, 2012), but one of the most common methods is the use of ROC analysis (e.g., Bennell, Jones, & Melnyk, 2009; Woodhams & Labushgna, 2012b; Woodhams & Toye, 2007). This last method has been rather effective when applied to studying sexual offences.

Crime Linkage by Crime Type

Linking High Volume Crimes

High volume crimes have also been studied with crime linkage. These include robberies (Woodhams & Toye, 2007), burglaries (Bennell & Jones, 2005), arsons (Häkkinen, Puolakka, & Santtila, 2004), and car theft (Tonkin, Grant, & Bond, 2008), crime which can happen in higher numbers, and often do not have crime scene behaviours to investigate.

There are two techniques that are used to determine links in these volume crimes that have proved less useful when applied to sexual assault: temporal and geographic linking. These are how close in time or geographical space two crimes occurred. There have been several studies that have looked at both temporal and geographic distances (Davies, Tonkin, Bull, & Bond, 2012; Goodwill & Alison, 2006; Markson, Woodhams, & Bond, 2010), but others have solely focused their studies on the geographic distances (Bennell & Jones, 2005; Kent, Leitner, & Curtis, 2006; Tonkin, Grant & Bond, 2008).

A study by Santtila, Laukkanen, Zappala and Bosco (2008) looked into the distances travelled and behaviours with not just robberies but also rape and homicide. It was found that, in

robberies against businesses, the offenders travelled (a median) 5.76km, whereas, for rape, it was 1.84 km, and less than 0.98 km for homicides. They also found that there were certain crime features that impacted the distances travelled in the rape cases (e.g. a weapon other than a blunt weapon was used, such as a gun, belt or scissors) and homicide cases (e.g. where the body was found outside). There were no data for the offence behaviours of the robberies, so it is unknown if there was another variable impacting the distance in those cases. This study is unique in that it looked at three very different crime types, but also that it only included one offence from each offender, rather than a series, making it difficult to apply to other studies.

While Santtila et al. (2008) looked at distances travelled with robberies, it is more common for robberies to be studied with behavioural data (Lin & Brown, 2006; Woodhams & Toye, 2007). Unlike other high volume crimes, robberies have an interaction with the victims, and are therefore an interpersonal type of crime. In their 2007 study, Woodhams and Toye found that there was some support for the basic assumptions of crime linkage, especially when the control domain was studied. This is similar to the findings of Grubin et al. (2001) where the control domain showed the most consistency when applied to sexual offences.

Linking Homicides

Another type of interpersonal crime that has been studied with the application of crime linkage is homicide. However, unlike sexual assault and the high volume crimes, the application of crime linkage with homicide has been less successful, and the assumption of consistency cannot be confirmed (Bateman & Salfati, 2007). Of the different types of crime that have been looked at with crime linkage, homicide has been one of the least effective.

In a study very similar to the Santtila et al. (2008) study, Santtila, Laukkanen, and Zappala (2007) looked at the distances travelled in homicides and rapes by the offenders. Homicides were found to have a median travel distance of 0.85 km, and crime features correlated with distance at $r_s = 0.77$, $p < 0.001$. Crime features included elements such as destroying or hiding evidence, which was correlated with shorter median distances.

However, homicide has been more often studied in a similar way to sexual assault, in that it has also been studied based on behaviours from the crimes scene (Bateman & Salfati, 2007; Salfati & Bateman, 2005; Santtila, Hakkanen, Canter, and Elfgren, 2003; Santtila, Pakkanen, Zappala, Bosco, Valkama, & Mokros, 2008; Sorochinski & Salfati, 2010). It was found, when looking at homicide behaviours (i.e. planning, wounding, or interacting with the victim), that the offenders were most consistent in their interaction with their victims (Sorochinski & Salfati, 2010). However, other studies based on the behaviours have found that the offenders are not very consistent (Salfati & Bateman, 2005), even when certain behaviours are grouped together (Bateman & Salfati, 2007).

Some ideas have been proposed as to why homicide has not performed as well as other crimes. One of the main theories is that homicides are too personal and that each one presents such a unique set of circumstances that the offender's behaviours are not consistent as their cognitive strategies change to accomplish their goal (Sorochinski & Salfati, 2010). There is also trouble gathering a larger enough sample to sufficiently test crime linkage with homicides as there are not as many serial murderers as there are other types of serial criminals.

Cases of Linkage in the Courts. Whilst still relatively a new field in academia, crime linkage has already made its way into the courtrooms of several different countries (Labuschagne, 2014). There is a more in depth discussion of crime linkage in the courts in

Chapter 3. Many of these cases have focused on crime linkage as it applies to serial homicide. Below are two examples of the evidence that was used and the varying levels of success that was achieved with the evidence.

State v. Russell (1994). This case was discussed by Pakkanen, Santtila, and Bosco (2014) in their chapter about crime linkage as expert evidence. They report that in 1994, George. W. Russell was convicted for the murders of Mary Ann Pohlreich, Carol Beethe, and Andrea Levine. During the trial the State's expert witness, Robert Keppel, discussed that all the victims had been posed whilst nude, all were female, and all were killed within a short time period of their contact with the offender. Keppel further noted that each crime included the insertion of a foreign object in a sexual manner in the victims and that the bodies were not only displayed but left so that their discovery was ensured. During the course of the cross-examination of Keppel a line of questions allowed him to state his opinion that all of the murders were committed by the same offender.

Supporting Keppel's testimony, the State's other expert, John Douglas, also testified to the matching signature behaviours in the three cases. Douglas based this opinion of the signature behaviour on the posing of the victims and that the murders had happened within a short time window (67 days) in a small geographical area. Both Douglas and Keppel used databases (the Washington State Attorney General's Homicide Investigation Tracking System (HITS) and the Federal Bureau of Investigation's Violent Criminal Apprehension Program (ViCAP)) to support their opinions on the rarity of the behaviour of posing the victims.

State of New Jersey v. Fortin (2000, 2007). One of the cases that has been discussed several times in conjunction with crime linkage is *The State of New Jersey v. Steven Fortin* (Charron & Woodhams, 2010; Labuschagne, 2014; Pakkanen, Santtila, & Bosco, 2014), which

first went to trial in 2000 and then after appeals retried in 2007. Fortin was arrested after the attempted murder of Officer Gardner in Maine. Similarities from that crime to the murder of a woman (Melissa Padilla) in New Jersey were enough for Fortin to be extradited to New Jersey. During the trial Robert Hazelwood, a former FBI profiler, presented evidence of behavioural similarities between the cases. These similarities included “bite marks on the left breast and chin, severe facial assault, manual strangulation from the front, and anal penetration” (Labuschagne, 2014, p. 208). Hazelwood’s testimony was considered expert testimony, and he was allowed to discuss the similarity between the two crimes, but not whether the defendant was responsible for attacks. Fortin was convicted and sentenced to death by lethal injection.

In 2004, the conviction against Fortin was reversed on appeals. It was argued that Hazelwood’s testimony did not have the support of a ‘reliable database.’ When the case was retried in 2007, the judge did not allow any behavioural evidence aside from the bite-marks. The other behavioural similarities were deemed too common behaviours of a violent sexual assault to be paid special consideration. The bite-mark evidence could not be presented by an expert but was allowed, and the jury was asked to decide on their own if it constituted enough for a signature. Fortin was again convicted for the murder of Padilla.

Crime Linkage with Sexual Offending

Crime, and the threat of crime, is a very real fear for many people (Reisig & Parks, 2000). The fear increases for females, specifically a fear of sexual assault committed by a stranger (Hickman & Muehlenhard, 1997; Wilcox, Jordan, & Pritchard, 2006). Sexual assaults and rape cases are notoriously underreported (Allen, 2007), and, of those reported, only a fraction make it to court and then to a conviction (Kelly, Lovett, & Regan, 2005; Temkin &

Krahé, 2008). Nearly 20% of all women have experienced a sexual assault at some time during their lifetime (Elliott, Mok, & Briere, 2004; Tjaden & Thoennes, 2000).

To clarify for this thesis the definitions for sexual assault and rape will come from the Sexual Offences Act (2003). Under this legislation sexual assaults are defined as intentionally touching another person in a sexual way without that person's consent. Similarly, rape is defined as the offender "intentionally penetrates the vagina, anus or mouth of another person with his penis" without the consent of the person being penetrated (p. 1). Both of these offences include a clause about the offender not believing that the victim has consented to the action.

A joint report released by the Ministry of Justice, the Home Office, and the Office for National Statistics (2013) reported some of the most current figures on sexual assault in England and Wales. Based upon data collected from the "Crime Survey for England and Wales" (CSEW) for years spanning 2009 until 2012. The CSEW, and its predecessor the British Crime Survey, are considered by the Home Office to provide "a better reflection of the extent of household and personal crime than police recorded statistics because the survey includes crimes that are not reported to or recorded by the police" (Home Office: Research Development statistics: Crime, para. 3). An average of 2.5% of women reported that they had been the victim of either a sexual assault or an attempted sexual assault in the previous 12 months. This equates to approximately 404,000 adult females per year in England and Wales. This figure encompasses all types of sexual assaults. When rape or sexual assault by penetration is focused on, the number drops to 85,000 victims per year. Of these women, almost 90% knew their offender. When asked if they had reported the most recent incident to police, only 15% of the victims had done so. The 2,900 defendants prosecuted for rape in 2011, on average, had 2.3 rape offences included in their case.

These numbers are similar to ones previously reported (e.g., Temkin, 2002), and shed light on the problem that rape and sexual assaults present for the police and society.

A large number of the studies on crime linkage have focused on sexual offences. A particular focus has been paid to those that are typically difficult to solve, such as the serial stranger offences. The use of linking in these cases could be advantageous to the investigators. Only a brief overview of this specific area will be covered here, as there will be more details provided in Chapter 3 as it replicates and expands on several of these studies.

Indeed as highlighted, one of the first papers on crime linkage (Grubin, Kelly, & Brunsdon, 2001) focused on the behavioural linking of sexual offences. Using cluster analysis on their sample (81 serial offenders from a UK database), after coding the data into four domains, they found evidence that offenders were consistent in their behaviours across crimes; 83 per cent were consistent in at least one of the four domains, while 26% were consistent across all four domains. Specifically, they found that the control and escape domains performed the best, whereas, style and sex had less single domain consistency. It was thought that this was related to the amount of factors that the behaviours were dependant on, and control and escape had less influence created by the victim.

In the many papers that have since followed Grubin et al. (2001), researchers have sought to refine the techniques used in that paper by studying the basic assumptions underlying crime linkage. Most of these studies have found evidence that sexual offenders' consistency across crimes is higher than what would be expected by chance (Mokros & Alison, 2002; Sjöstedt, Långström, Sturidsson & Grann 2004; Woodhams, Grant, & Price, 2007; Yokota, Fujita, Watanabe, Yoshimoto, & Wachi, 2007). However, as discussed by Mokros and Alison (2002), the assumption of consistency alone is too simple an explanation for crime linkage. By itself the

assumption could not provide a stable or defensible base for crime linkage. If serial sexual offenders were only consistent the only thing researchers would be able to determine was if a crime was committed by a serial offender, not which serial offender. Thus, the assumption of distinctiveness was needed as well.

Many researchers have looked at both the basic assumptions simultaneously in samples of serial sexual offences. Using larger databases, other studies have sought to not only look at the consistency of crime series but also the ability to differentiate between series, and many of them have been able to do this at levels above chance (range of AUCs from .74 to .89) (Bennell, Gauthier, Gauthier, Melnyk, & Musolino, 2010; Bennell, Jones, & Melnyk, 2009; Santtila, Junkkila, & Sandabba, 2005; Winter et al., 2012). These studies have mostly come to rely on the use of a ROC analysis to determine the predictive accuracy using crime pairs.

Looking at a different set of behaviours, specifically the rapists' speech, Woodhams and Grant (2006) found higher inter-rater reliability and the ability to classify a greater number of phrases. They used a sample of 188 rapists' words from the victims' accounts of the rape, and analysed them using a system based on linguistic theories of pragmatics. The system was able to give a category to the majority of the rapists' utterances (91%), however, this did mean that there were many categories. There is still potential to expand this area of research and utilize it in a similar way to crime linkage.

A new aspect of studying sexual assaults was addressed in the study of the basic assumptions by Woodhams and Labuschagne (2012a) as they attempted to test the assumptions on unsolved rapes. Their research found evidence to support the underlying assumptions even when applied to crimes that had been linked by DNA but not solved. This is one of the first

studies that has been able to include unsolved cases in their database, and further supports the growing evidence of the two assumptions of crime linkage.

A recent study by Woodhams and Komazynska (2014) is the only study where all the offenders included in the sample are known to have a mental disorder. When they conducted crime linkage research on a sample of mentally disordered offenders they found that they were able to accurately distinguish linked and unlinked crime pairs at very high levels of accuracy. However, they do caution that it is unknown if this is due to the small sample size ($N=20$ offenders), or if there was a distinguishing element to the crime series that caused the offenders to be caught. Then they further investigated the consistency and variability of the offences with a qualitative study with four of the offenders. Woodhams and Komazynska found that the offenders had trouble recognizing when they had performed consistently across their crimes. It was noted that even this population, which is expected to be the most consistent, did have changes of behaviour across their crimes. Additionally, it was found that the offenders used their experiences of non-sexual offending to guide their sexual offending. This is important as it suggests the potential to use sexual offences in studies examining across crime types crime linkage, where different types of crimes committed by the same offender could be linked.

Sexual Fantasy's Influence

There has been the suggestion made by some researchers that the offender's sexual fantasy can be a driving influence on why the offender commits their offences in a similar way (Gee & Belofastov, 2006). Sexual fantasy has been defined as:

“...almost any mental imagery that is sexually arousing or erotic to the individual. The essential element of a deliberate sexual fantasy is the ability to control in imagination exactly what takes place. Even reminiscences of past

events can be altered so that only particularly exciting aspects are recalled or enhanced.” (Leitenberg & Henning, 1995, p. 470)

One important part of this definition is the mention of the person’s control over the fantasy. In their 2011 paper, Bartels and Gannon point out that there currently is not a set definition for “deviant sexual fantasy.” However, Gee, Devilly and Ward (2004) suggested a new term, offence-focused fantasy, “fantasies that contain sexually deviant material that, if acted out, would legally constitute a sexual offence” (p. 323). This is useful as it assists in differentiating between fantasies that may guide a sex offender from those in non-offender populations that might otherwise be classed as “deviant sexual fantasies” (Gee & Belofastov, 2006).

Some researchers have argued that offence-focused sexual fantasies can act as a form of mental trial run for the deviant sexual behaviour (MacCulloch, Snowden, Wood, & Mills, 1983; Pithers et al., 1988; Ward & Hudson, 2000). This mental rehearsal could have an impact on the actual commission of an offence and may account for the preference of certain Modus Operandi (MO) behaviours (Gee & Belofastov, 2006; Hazelwood & Michuad, 2001).

In their study, Bourke, Ward and Rose (2102) found that offenders used fantasy, masturbation, and other mental simulation (such as mentally walking through their planned offence) to practice for their offence. With these mental practices the offender was able to refine the MO behaviours and experiment before actually committing their offence. They stated that the offenders participate in something that Corballis (2011) called “mental time travel” where the fantasy allows the offender to reflect on the past, present and future, in order to devise a better plan to achieve their goal of completing the offence.

When these ideas of offence-focused sexual fantasies are applied in the context of crime linkage, it supports the theory of behavioural consistency. The offenders will try to replicate the fantasy that they have rehearsed in their minds and therefore their behaviours will be consistent.

Yet, as Gee and Belofastov point out in their 2007 chapter, it may be extraneous variables that can disrupt the offence and therefore cause the offender to react and alter their mental rehearsed plan. These can be factors such as the victim resisting or someone interrupting the offences, which would then make the offender react and change their mental plan. Or it could even happen before as Bourke et al. (2012) pointed out, that the offender's mental rehearsal may reflect on previous crimes, and therefore refine their plan, and alter some behaviours, but the underlying fantasy would still be similar. On the other hand, some offenders have MO's that deteriorate over the course of their crimes (their crime behaviours become less planned and less useful in their continued evasion of the law), rather than refine. Geberth (1981) has pointed out that when this happens it could be due to deteriorating mental state, substance abuse, or overconfidence in the offender's ability to remain free from capture. These changes in the offenders' plans can account for some variation in the behaviours displayed and the subsequent similarity scores when the offences are compared.

Benefits of Crime Linkage

The majority of crime is committed by a minority of offenders (Laub, 2004; Piquero, Farrington, & Blumstein, 2007) and, although the percentages of crimes committed by this minority of offenders varies by country, this still remains true (Farrington & West, 1993). In the last decade, money for policing has reduced (Police Funding, 2012) and, police have been facing more and more limited resources, leading them to turn to intelligence-led policing to target the criminals who perpetrate the larger number of crimes (Innes, Fielding, & Cope, 2005). With the time and money costs of processing physical evidence, the police need to utilise other methods of investigating the crimes (Santtila, Junkkila, & Sandabba, 2005).

With investigators facing these problems, the ability to introduce more crime linkage would be helpful. There would be several advantages to identifying crimes that have been committed by a serial offender; such as more efficiency in the dispersal of police resources (Grubin et al., 2001). This would be especially useful in sexual offences, which are known to be difficult to prosecute (Ellison, 2005).

If crime linkage is used to influence police investigations and legal proceedings, an inaccurate prediction of the linking evidence by a practitioner could have dire consequences (Grubin et al., 2001). Specifically as seen in the problems caused by behavioural profiling in the Rachel Nickell's murder case and the miscarriages of justice that happened (Grubin, 1995). Thus, there is a need for extensive research on crime linkage that is not only thorough but can withstand scrutiny (Lindqvist & Skipworth, 2000). However, there are still some gaps in the research on crime linkage and areas that could be improved upon before crime linkage can be completely implemented. These include more realistic samples that better mimic police and investigator databases, what the best way of conducting linking is (the statistical method used), if linking works with unsolved crimes, and what some of the base rates are for linking.

Aims of the Thesis

The overall aim of the thesis is to examine crime linkage in the specific application to a sexual assault sample where the offences were committed by adult males who were strangers to their victims. Several gaps in the literature and current limitations were addressed to further our understanding of crime linkage.

The main advancements that this thesis aimed to make were:

- Conducting a test of the crime linkage assumptions with a larger sample of sexual offences than most crime linkage studies.
- Testing the assumptions in a more ecologically valid manner by including one-off offenders as well as serial offenders in the sample.
- Considering the offence of rape as a set of stages (rather than a whole) and thus considering how consistency and distinctiveness might vary across these stages as a result of situational interference and offenders' ability to exert their influence.
- Assessing the differential performance of a range of similarity coefficients with the same sample to determine if crime linkage might be improved by adopting a different coefficient to Jaccard's coefficient.

Structure of the Thesis

The thesis is divided into 6 chapters. Chapters 1 and 2 provide the introduction and background information needed for the rest of the thesis. In chapter 1 the concept of crime linkage is introduced, the history discussed, and the need for crime linkage is investigated. Additionally, the theories underpinning crime linkage are discussed and highlight why crime linkage may work in certain situations and may not work in other circumstances. In chapter 2, serial and 'one-off' rapists are compared in terms of the behaviours they exhibit during the offence. If major differences exist between serial and one-off offenders in terms of behaviours shown, there may be no need for crime linkage, as a single behaviour, or several behaviours, could be used instead of all the behaviours exhibited.

Chapter 3 spans the gap between what is known and starting to test new ideas in crime linkage. One of the current problems in the crime linkage literature is the difference between the

samples used in academic research compared to the information investigators work with. This chapter starts to address the differences in the data sets and attempts to close the gap between the two. This study tests the assumptions of consistency and distinctiveness, but with a larger sample size than previous studies and with the inclusion of apparent one-off offenders. While Grubin et al. (2001) used a sample of both serial and apparent one-off offenders, since the introduction of ROC analysis, there has been only one study including the apparent one-off offenders with sexual offences (Winter et al., 2013). The rest of the crime linkage research has consisted solely of serial offences, where the unlinked crime pairs were compiled from mixing the offences of the serial offenders (Bennell, Gauthier, Gauthier, Melnyk, & Musolino, 2010; Bennell, Jones, & Melnyk, 2009; Woodhams, Grant, & Price, 2007; Woodhams, Hollin, & Bull, 2008). The sample size of 50 serial offenders and 50 apparent one-off offenders (offenders who are only known to have committed a single sexual offence, rather than a series of offences) is a much larger sample than most previous research which has ranged from 16 to 42 offender series ($N=42$ series (126 offences), Bennell et al., 2009; $N=16$ series (43 offences), Santtila et al., 2005; $N=30$ series (90 offences), Winter et al., 2013; $N=22$ series (119 offences), Woodhams & Labuschagne, 2012). The inclusion of apparent one-off offenders and the larger number of offenders than previous studies will better reflect the pool of offences that investigators would be working with and overcome the current limitations in the academic research and address the needs of the practitioners.

The third part of the thesis, chapters 4 and 5, expand current approaches to assessing the principles of crime linkage and attempts to determine ways in which the process might be improved in practice. A closer examination of the methodologies used in crime linkage is needed to support the more evidence-based research in crime linkage. Not all variables identified in the

current literature have worked equally well in analysis, with some far outperforming others (Bennell & Jones, 2005; Goodwill & Alison, 2006; Markson, Woodhams, & Bond, 2010; Woodhams & Toye, 2007). Grubin et al. (2001) found that certain behaviours could be grouped together by function to create domains, and that the “control domain” worked best for linking. Chapter 4 will code behaviours based on when they occur during the commission of a sexual offence, using theory introduced by Grubin et al. (2001). By grouping offences into the “approach,” “maintenance,” and “closure stages,” the usefulness of certain sets of behaviours can be evaluated.

Chapter 5 then investigates a different aspect in the statistical analysis of crime linkage. Bennell et al. (2010) tested the impact of data degradation and sample sizes on two commonly used coefficients in crime linkage. However, there are several other similarity coefficients that may also be suitable to use with crime linkage. Using the data from the test of the two assumptions of crime linkage from Chapter 4, this chapter compares five similarity coefficients to see which one performs the best. Specific focus is given to comparing four other similarity coefficients to the Jaccard’s coefficient, which is the coefficient most commonly used in the research on crime linkage.

The final chapter concludes the thesis. The main results of the previous chapters are summarised, and overarching themes that span the thesis chapters are discussed. Future directions and current limitations of crime linkage research are considered and the practical implications are stated.

CHAPTER 2:

CAN SERIAL RAPISTS BE DISTINGUISHED FROM ONE-OFF RAPISTS?

The aim of this chapter was to investigate if there were any differences in the behaviours demonstrated by serial as opposed to one-off rapists. As explained in Chapter 1, a key aim of the thesis was to include one-off rapists in the sample used to test the principles of crime linkage. It was, therefore, important to establish if the behaviours of serial rapists differed to those of one-off rapists. This study aimed to improve upon previous research by including a larger sample size.

The following chapter has been adapted from a paper that was accepted for publication in Behavioral Sciences and the Law, online first in October 2013, doi: 10.1002/bsl.2096. This journal is based in the USA and therefore American spelling was used throughout the paper, but has been changed to UK English for this thesis. Permission was obtained for its inclusion in the thesis.

Chapter 2: Can Serial Rapists be distinguished from One-Off Rapists?

In a recent Government report entitled *Forging the links: Rape investigation and prosecution*, Her Majesty's Inspectorate of Constabulary (HMIC) and Her Majesty's Inspectorate of the Crown Prosecution Service (HMICPS) (2012) reported on their investigation of current police procedures and results in England and Wales. One of the main recommendations of their investigations was to improve the collection of intelligence, specifically with regard to serial rapists. The report noted confusion within police forces regarding what constituted a serial rapist and adopted the definition commonly used in academic research (Beauregard, Rossmo, & Proulx, 2007; Grubin, Kelly, & Brunson, 2001; LeBeau, 1987; Park, Schlesinger, Pinizzotto, & Davis, 2008; Santtila, Junkkila, & Sandnabba, 2005) and also used in the current chapter: Serial rapists are those who commit more than two offences against different victims. A key recommendation of this publication was that police forces in England and Wales should treat every stranger rape that is reported to them as part of a potential series. This is a potentially costly recommendation to implement, in terms of both time and resources (Rainbow, 2014).

In responding to such a recommendation in a cost-effective way, it would be beneficial for police forces to be able to differentiate at the early stages of an investigation whether they are indeed dealing with a serial rapist or a "one off" rapist. One way of achieving this has been suggested by previous authors (Grubin et al., 2001) and involves attempting to use crime scene behaviour (as reported by the victim) to predict whether a rapist is likely to be a serial rapist or a one-off rapist. In such a scenario, when a rape is reported to police, a crime analyst could analyse the behaviour of the offender (as reported by the victim) to identify any key features, established

by empirical research, that would suggest the offence was part of a series. Where such indicators are found, they could then be communicated to the investigative team. This may result, for example, in the analyst being tasked to try and identify other crimes that form part of the same series based on behavioural similarity (a practice termed crime linkage).

As the main focus of this thesis is on the crime linkage and the application of crime linkage to serial sexual offences it is important to investigate any differences between serial offenders and apparent one-off offenders. With the inclusion of 50 of these one-off offenders in the dataset used in chapter 3, this chapter will investigate the differences between the two types of offenders. It will be useful to have an indication on the sort of impact the inclusion of the one-off offenders could have on the application of crime linkage to a mixed dataset.

Differentiating one-off from serial offenders

To be able to accurately differentiate the crimes of serial versus one-off offenders, and therefore avoid providing the police with erroneous recommendations, there must be differences in behaviour that are consistently observed between these two groups. In the scenario described above, a crime analyst presented with a given crime would not know whether it was the work of a one-off offender, or, if the work of a serial offender, at what stage in a series the crime was committed. In an ideal world, the behaviour of one-off offenders would differ from all the crimes committed by a serial offender. This would require consistency in the crime scene behaviour of serial offenders, as well as all serial offenders differing from one-off offenders in the same way. Research of crime linkage, which is concerned with the relative consistency and distinctiveness of the behaviour of serial offenders, indicates that this ideal scenario does not exist. In fact, it has been shown that while some serial offenders do show a high degree of consistency in

behaviour, not all do (e.g., see Woodhams & Labuschagne, 2012). In addition, this research shows that different serial offenders behave in different ways (Sorochinski & Salfati, 2010). Therefore, the ideal scenario whereby only serial offenders (and not one-off offenders) show behaviour X and that behaviour X is consistently observed within crime series, thereby enabling perfect prediction of whether a crime is the work of a serial or one-off offender, will not be realised. This does not, however, mean that the search for behaviours that might be more suggestive of a serial offender is doomed. It is possible that the variability in behaviour seen within series in the crime linkage literature reflects evolution of crime scene behaviour and there may be some behaviours that are more likely to be produced by serial offenders at the end of their series. Indeed there has been some evidence of this (Grubin et al., 2001). Such behaviours could still be utilised to suggest the presence (or not) of a serial offender but there will likely be a degree of error associated with such predictions.

Several studies have tried to identify means of differentiating between serial and one-off offenders. These studies have tended to focus on homicide offenders or rapists. For example, Kraemer, Lord and Heilbrun (2004) studied a sample of homicide offenders gathered from Federal Bureau of Investigation records. Their sample consisted of 195 single (one-off) offenders (who accounted for 133 victims), and compared them to the first offence of 147 serial offenders (who accounted for 133 victims) (the number of offenders is greater than the number of victims due to several offenders having worked together). Using a chi squared analysis they looked at victim and offender characteristics, intent, relationship between victim and offender, approach, locations, body disposal, and different evidence types. Their three most significant findings were that serial offenders were more often strangers to their victims, more likely to strangle their victims, and more likely to leave the victim's body in a remote location. Using a Discriminant

Function Analysis based on the crime scene variables they were able to correctly classify the offences as either a single or serial homicide for 72.2% to 76% of the cases (depending on the number of variables included), and when focusing on female victims only the percentage increased to 78.6%.

Salfati and Bateman (2005) also investigated single and serial homicides. They compared a sample of 23 serial murderers from the USA to a sample of 247 single murderers from the UK from a previous study (Salfati, 2003). They examined 61 crime scene behaviours and 33 offender characteristics. They found that serial murderers were more likely to display behaviours that reflected a higher degree of planning and control, compared to the single murderers whose crimes were more impulsive and emotional. The serial offenders' behaviours appeared to be more frequently motivated by delaying detection, controlling the victim, theft of property and engaging in sexual acts with the victim. The most common behaviours displayed by the single offenders were related directly with the killing. Salfati and Bateman suggested single (one-off) murderers are focused on the actual murder whereas serial murderers are influenced more by other motives.

With regards to differentiating serial from one-off *rapists*, only three studies have investigated ways of doing this. In 1987, LeBeau investigated the offending patterns of serial rapists compared to "open" cases of rape (rapes where the identity of the suspect remained unknown) and one-off rapists. The sample was comprised of all 612 incidences of rape perpetrated by a lone offender in San Diego, California, from 1971-1975; separated into 194 open cases, 80 single, and 151 serial offences. Using chi square analyses, the relationship between the rapist and the victim, the approach, and the number of scenes involved in the offence were compared across groups. Similar to Kraemer et al.'s findings for serial murderers,

LeBeau found that the serial rapists were significantly more likely to be strangers to their victims. The serial offenders were also more likely to use a blitz style approach and not move their victims very far. LeBeau speculated that several behaviours commonly displayed by the serial rapists were related to avoiding or delaying their apprehension. The serial rapists, therefore, were similar in this respect to the cases that remained unsolved (the open cases) allowing the serial offender to commit multiple offences before being apprehended.

It was not until 2001 that Grubin and colleagues conducted the next study to investigate differences between serial and singleton (one-off) offences of serious sexual assaults. From a UK database of sexual assaults they sampled the crimes of 129 one-off offenders and 81 serial offenders who had committed 339 attacks. They arranged 30 crime scene behaviours present in their sample into four different domains and used cluster analysis to develop distinct types within each domain. The four domains were termed control (behaviours focused on gaining control of the victim), sex (behaviours that are part of the sexual component of the attack), escape (behaviours associated with leaving the crime scene or avoiding detection), and style (behaviours that are not necessary for the attack that reflect the offender's personality or style). Having grouped the crime scene behaviours in this way, Grubin et al. initially conducted a cluster analysis to determine whether "singleton" offences would cluster differently to serial offenders' "first", "second", etc. offences. From this analysis, a cluster was identified that contained 61% of the singleton cases and first offences in the series, however it also contained 42% of the subsequent crimes in the series meaning any differences between this cluster and others would be of limited practical value.

A more recent study on serial and one-off rapists was conducted by Park et al. (2008). The behaviours of 22 serial rapists from the USA were compared to 22 one-off rapists using chi-

square analyses. For the serial rapists, two offences from each series were randomly selected for comparison to the one-off rapists' offences. Twenty-eight different behavioural variables were studied which were divided into three themes: violence, interpersonal involvement, and criminal sophistication. The violence theme contained 11 variables that represented the nature of the offender's violence towards the victim (e.g., blitz-style attack, weapon use, vaginal penetration). The one-off rapists were more likely to display these types of behaviours; specifically threatening the victim and engaging in manual hitting and kicking, as well as vaginal and/or oral penetration. The interpersonal involvement theme comprised seven variables which described the type of interaction between the victim and offender (e.g., using a confidence approach, making sexual comments, extending time with the victim). One-off offenders were more likely to force the victim to pretend to participate willingly in the sexual assault and more often made sexual comments (e.g., "Do you like it?") than the serial offenders. The criminal sophistication theme consisted of 10 variables that focused on assisting the offender in the commission of the offence (e.g., having forensic awareness, planning, gagging the victim). Here the serial offenders were more likely to display forensic awareness, deter the victim's resistance, gag the victim, use a surprise attack, ask the victim questions, and complete the act of rape.

The most recent study comparing serial and one-off offenders was conducted by Corovic, Christianson, and Bergman (2012). Using a dataset of 31 single-victim rapists (one-off) and 35 serial rapists, they found that serial rapists were more criminally sophisticated in their first two rapes than one-off rapists. However, there were no significant differences between the two types of rapists in terms of physical violence and sexual behaviours displayed at the crime scene. Corovic et al. applied their findings to criminal profiling and were able to use a combination of three behaviours (kissed victim, controlled victim, and offender drank alcohol before the

offence) to predict offender type with an accuracy of 80.4%. However, it is difficult to apply their findings to other studies as their data collection used more information that would have been available to the investigators, including offenders' pre-crime behaviours.

Rationale

As can be seen above, the existing literature on whether there are differences in crime scene behaviour between serial and one-off offenders is very limited, meaning there is little guidance at present that the police could utilise in trying to determine early in an investigation if they are dealing with a serial or a one-off offender. With regards to the recommendations from the *Forging the links* report, there are only three existing studies of serial versus one-off rapists that could give any indication as to what crime scene behaviour might suggest a rape was committed by a serial offender, rather than a one-off rapist. In addition, all three studies with rapists cited above suffer from the same methodological flaw, that they have analysed samples of rapists who have a mixture of relationship types with their victims, i.e., their samples contain offenders who were acquainted with their victims as well as those who were strangers to their victims. The relationship between offenders and victims will likely impact the behaviours displayed during the offence, such as the approach style utilised or the means used to control the victim. For example, associations between victim age and victim-offender relationship have been reported in studies of rape with older victims more likely assaulted by strangers (Muram, Hostetler, Jones, & Speck, 1995), as well as differences between stranger and acquaintance rapes in terms of approach location, violent acts, weapon use, sexual acts, use of intoxicants and post-rape offender behaviour (Bownes, O'Gorman, & Sayers, 1991; Koss, Dinero, Seibel, & Cox, 1988). Previous findings of differences in the offence behaviour displayed by serial versus one-

off rapists could therefore be a product of differences in the proportions of victim-offender relationships in the two subsamples. It was determined to more closely replicate previous studies and to try and eliminate some of the interactions from other factors to only use rapes and attempted rapes in this study. This is a subset of the offences that are included in chapters 3, 4, and 5, and this focus explains the differing number of offenders and total offences that were used in this chapters compared to the others.

In addition, previous studies comparing the behaviour of one-off and serial offenders have failed to include cross-validation of their findings of differences between the two. Further, it has been common practice to compare the offences of one-off offenders to a randomly-selected crime from each series of the serial offenders. The difficulty with this approach is that, as alluded to above, the behaviour of serial offenders is not always consistent from crime-to-crime. The current study aimed to develop the literature in this area by overcoming this fundamental limitation and not only comparing the behaviour of one-off rapists to that displayed in a randomly selected rapes committed by each serial rapists, but by also making comparisons to the behaviour displayed in the first (known) rape in each series and the last (known) rape in each series. This allowed for assessment of whether apparent differences in behaviour between the two groups of rapist would generalise across these three subsets of offences and therefore whether they were robust.

METHOD

Sample

A non-random national sample of rapes was obtained from the Serious Crime Analysis Section (SCAS), of the Serious Organised Crime Agency, UK. SCAS is an analytical unit with

national responsibility to carry out analytical work on behalf of all police forces. SCAS collates and analyses information on serious crimes that fulfil its criteria, predominately stranger murders, and serious sexual assaults and/or rapes. SCAS hold a database called the Violent Crime Linkage Analysis System (ViCLAS) which contains information about the location of sexual crimes that meet their criteria and the behaviours displayed during each offence by the offender. They hold the most comprehensive dataset of stranger rapes in the UK.

A sample of rapes and attempted rapes committed by serial and one-off adult male, sexual offenders was requested from SCAS. The rapes all met the definition of rape as stated in the Sexual Offences Act of 2003. This defines rape as where “A person commits an offence if he intentionally penetrates the vagina, anus or mouth of another person with his penis” and that person does not consent (Sexual Offences Act, 2003, p. 1). A sample of 38 serial and 50 one-off rapists and their offence behaviours were provided for analysis. The cases only included those with a lone, female victim and a lone, stranger, male offender. All crimes included in the sample were from cases that were closed with the offender having been convicted of the offence.

Serial Rapists

The sample of serial rapists represented 38 males with a mean age at the time of the offence of 31.4 years (range 18-57 years). Seventy-four per cent of the offenders ($n=28$) were of White European ethnicity, 8% ($n=3$) were Dark European, 13% ($n=5$) were African or Caribbean, and 5% ($n=2$) identified as Other.

The serial offenders committed a combined 147 known sexual offences, of which 120 were rapes or attempted rapes. Only the latter 120 offences were utilised within the analysis comparing serial versus one-off rapists to ensure consistency in the offence types under

comparison. The offenders' series ranged from two to 10 offences, and the mean series length was four offences (the mode was three offences per offender).

One-Off Rapists

The one-off rapists had a mean age at the time of the offence of 30.9 years (range 18-55 years). All offenders were male. Seventy per cent of the offenders ($n=35$) were of White European ethnicity, 2% ($n=1$) were Dark European, 12% ($n=6$) were African or Caribbean, 10% ($n=5$) were Asian, 4% ($n=2$) were Arabic, and 2% ($n=1$) were identified as Other. Of the 50 offences they had committed, 10 were attempted rapes, while 40 were completed rapes.

Serial Rapists' Victims

All 38 of the victims, from the studied sample, were female, and their mean age at the time of the offence was 30.0 years (range 18-76 years). Seventy-six per cent ($n=29$) of the victims were of White European ethnicity, 3% ($n=1$) were Dark European, 3% ($n=1$) were Arabic, and for 18% ($n=7$) their ethnicity was not recorded on the police database.

One-Off Rapists' Victims

All the victims were female, with a mean age at the time of the offence of 28.2 years (range 18-59 years). Eighty-four per cent ($n=42$) of the victims were of White European ethnicity, 2% ($n=1$) were African or Caribbean, 4% ($n=2$) identified as Other, and for 10% ($n=5$) their ethnicity was not recorded.

Procedure

Based on the victim's account of the crime, SCAS codes each offence that comes to their attention in a standard manner onto their ViCLAS database. The data regarding the offenders' behaviours during the offence were provided to the authors as a spreadsheet of numerical codes representing this standardised coding. In total, 217 different behaviours were included in this spreadsheet ranging from the type of location at which the offence was committed, to forms of violence used against the victim to forensic precautions and sexual acts. All the variables had been coded dichotomously, where 1 represented the presence of an action or behaviour during the offence, while 0 represented an absence or unknown data for a given behaviour.

Inter-rater reliability assessments of this coding were not possible as the data were already coded when it was provided to the authors. However, all data inputted onto the SCAS database is completed by a team of highly trained individuals, and is done in-house in a controlled environment. Prior to employment, applicants are tested for their attention to detail and ability to identify relevant information. Upon recruitment, staff undergo a rigorous and lengthy training programme, which requires them to evidence a clear understanding of behavioural vagaries, as well as detailed knowledge of the system. From recruitment to working unsupported takes several months, in order to ensure accuracy and knowledge. Initial training is not undertaken on a live database, and staff will not begin working on the live database until they have evidenced their capability to complete inputs accurately. A 'Quality Control Guide' is utilised by everyone inputting data on the database, which ensures consistency in decision making in relation to difficult issues. Where an unusual aspect is encountered, for which no precedent has been set, a dedicated, experienced team meets to review the situation and make a decision. This decision is then recorded for future reference to ensure future consistency. In addition to having undertaken the above, each

inputted case goes through a detailed quality assurance process prior to any analysis taking place. This involves a review of the inputted information in comparison to case details, by an analyst from within the team and anomalies or errors are fed back to the inputter and amended on the database.

No information that could be used to identify the offender, victim, or location was present within the spreadsheet given to the authors thereby protecting the identity of all parties. In accordance with previous research on the behaviour of serial rapists (Santtila et al., 2005), behaviours that did not occur in at least five per cent of the total offences were not included in the analysis. These behaviours were determined to be too uncommon to be of pragmatic use to the police, additionally this five per cent threshold has been used by other researchers as a cut off for behaviours that are too rare to be useful (e.g., Grubin et al., 2001; LeBeau, 1987; Park et al., 2008; Salfati & Bateman, 2005). This resulted in a total of 80 offence behaviours for comparison across serial and one-off rapists.

As noted above, the number of offences committed by each serial rapist varied from two to 10. In order to prevent the more prolific of the serial offenders from unnecessarily biasing the results, only one crime from each offender was included in any analysis. It is standard practice in research on serial criminals to control for potential bias in this way (Bennell & Canter, 2002; Park et al., 2008). Several different methods have been used to select such cases from a larger pool including using the last known offences committed (e.g., Woodhams & Toye, 2007), or randomly selecting one offence from each series (e.g., Park et al., 2008). While the random selection method has been used in studies comparing one-off versus serial rapists in the past (Park et al., 2008), three sampling methods were used to create three serial subsets for comparison with the one-off rapes; a) randomly sampling one offence per series, b) selecting the

first offence from each series, and c) selecting the last offence from each series. In each analysis there were 38 serial rapes/attempted rapes and 50 one-off rapes/attempted rapes. Of the 38 serial offences randomly chosen, six were attempted rapes, while the other 32 were completed rapes, and for the 50 one-off offences, 10 were attempted rapes, while the other 40 were completed rapes. In the first serial offences vs. one-off offences sample, five of the serial offences were attempted rapes while the other 33 were completed rapes, and in the last serial offence vs. one-off offences sample, six of the serial offences were attempted rapes with the other 32 being completed rapes.

RESULTS

Comparisons were made between the frequencies of behaviours exhibited by serial vs. one-off offenders for the 80 offence behaviours. For ease of presentation, these behaviours have been grouped into four behavioural domains (control, sex, escape, and style behaviours) commonly used to describe sexual offending behaviour (e.g., Grubin et al., 2001; Woodhams, Grant, & Price, 2007).

For each behaviour, the relative frequency of occurrence in the offences of serial vs. one-off offenders was assessed using chi-square analyses. Significant associations are highlighted in bold in Tables 1-4 and effect sizes (ϕ) are reported for all comparisons. A Phi coefficient between .2 and .3 is considered a small effect size, .3 and .5 is a medium effect size, and a value greater than .5 is considered a large effect size (Field, 2009). Each table also displays the frequencies of behaviours for all three subsets of the serial rapes alongside the frequencies for the one-off rapes. In addition, for each subset the frequency of each behaviour in the serial and one-off rapes combined is reported.

When multiple chi-square analyses are run it is generally advisable to calculate a correction to adjust for possible statistical errors. While a Bonferroni correction can be used to reduce Type 1 errors (Pallant, 2007), it is argued to be too conservative, resulting in Type 2 errors (Hochberg & Benjamini, 1990). The Benjamini-Hochberg has been shown to have greater statistical power than the Bonferroni (Williams, Jones, & Tukey, 1999) and is less conservative, therefore the Benjamini-Hochberg correction (1995) was used to correct for Type 1 errors. To calculate the Benjamini-Hochberg correction, the P-values are first sorted and ranked. The smallest value gets rank 1, the second rank 2, and the largest gets rank N. Then, each P-value is multiplied by N and divided by its assigned rank to give the adjusted P-values. In order to restrict the false discovery rate to a p-value such as 0.05, all the variables with adjusted P-values less than 0.05 are selected. The findings pre- and post-correction are reported below.

Table 1: *Incidence of Behaviours in the Control Domain*

Behaviour	Non-Serial % of Offences (N=50)	Random			First			Last		
		Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)	Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)	Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)
Indoors	42.00	21.05	-0.22*	32.95	21.05	-0.22*	32.95	23.68	-0.19	34.09
Outdoors	76.00	86.84	0.14	80.68	89.47	0.17	81.82	86.84	0.14	80.68
Industrial Area	4.00	7.89	0.083	5.68	10.53	0.13	6.82	7.89	0.083	5.68
Retail Area	42.00	63.16	0.21*	51.14	65.79	0.24*	52.27	57.89	0.16	48.86
Residential Area	84.00	71.05	-0.16	78.41	65.79	-0.21*	76.14	81.58	-0.032	82.95
Rural Area	8.00	13.16	0.084	10.23	7.89	-0.002	7.95	10.53	0.044	9.09
Living Quarters	40.00	23.68	-0.17	32.95	26.32	-0.14	34.09	23.68	-0.17	32.95
In a Vehicle	14.00	15.79	0.025	14.77	15.79	0.025	14.77	18.42	0.060	15.91
Entertainment Area	20.00	7.89	-0.17	14.77	7.89	-0.17	14.77	2.63	-0.26*	12.50
Public Area	10.00	15.79	0.087	12.50	13.16	0.049	11.36	13.16	0.049	11.36
Parking Area	6.00	23.68	0.26*	13.64	15.79	0.16	10.23	21.05	0.23*	12.50
Alleyway	8.00	5.26	-0.054	6.82	10.53	0.044	9.09	7.89	-0.002	7.95
Wooded Area	2.00	13.16	0.22*	6.82	7.89	0.14	4.55	7.89	0.14	4.55
Access Path	14.00	18.42	0.060	15.91	15.79	0.025	14.77	15.79	0.025	14.77
Street	46.00	68.42	0.22*	55.68	76.32	0.31*	59.09	57.89	0.12	51.14
Main Road	24.00	18.42	-0.067	21.59	21.05	-0.035	22.73	18.42	-0.067	21.59
Park	10.00	15.79	0.087	12.50	10.53	0.009	10.23	10.53	0.009	10.23
Asked Victim for Help	8.00	2.63	-0.11	5.68	5.26	-0.054	6.82	5.26	-0.054	6.82
Solicited Victim	2.00	31.58	0.41**	14.77	31.58	0.41**	14.77	34.21	0.44**	15.91
Offered Ride to Victim	10.00	.00	-0.21*	5.68	.00	-0.21*	5.68	2.63	-0.14	6.82
Engaged Victim in Conversation	24.00	7.89	-0.21*	17.05	5.26	-0.25*	15.91	7.89	-0.21*	17.05
Threatened Victim upon Approach	8.00	2.63	-0.11	5.68	2.63	-0.11	5.68	2.63	-0.11	5.68
Snuck Up on Victim	28.00	44.74	0.17	35.23	42.11	0.15	34.09	36.84	0.094	31.82
Victim was Sleeping when Approached	12.00	7.89	-0.067	10.23	7.89	-0.067	10.23	7.89	-0.067	10.23
Gagged Victim	2.00	10.53	0.18	5.68	10.53	0.18	5.68	15.79	0.25*	7.95
Covered Victim's Mouth	24.00	34.21	0.11	28.41	28.95	0.056	26.14	34.21	0.11	28.41
Bound the Victim	.00	10.53	0.25*	4.55	10.53	0.25*	4.55	13.16	.28*	5.68
Verbally Threatened Victim	54.00	55.26	0.013	54.55	52.63	-0.014	53.41	52.63	-0.014	53.41
Attempted to Reassure Victim	24.00	31.58	0.084	27.27	26.32	0.026	25.00	39.47	0.17	30.68
Upon Resistance used Some Violence	16.00	28.95	0.16	21.59	21.05	0.065	18.18	31.58	0.18	22.73
Without Resistance used Some Violence	28.00	28.95	0.010	28.41	23.68	-0.049	26.14	31.58	0.039	29.55

Threatened to Use Weapon, but Never Seen	10.00	13.16	0.049	11.36	10.53	0.009	10.23	10.53	0.009	10.23
Displayed Weapon but did not Use	20.00	10.53	-0.13	15.91	13.16	-0.090	17.05	21.05	0.013	20.45
Weapon was Used	6.00	7.89	0.037	6.82	7.89	0.037	6.82	10.53	0.083	7.95
Weapon was Brought By Rapist	20.00	21.05	0.013	20.45	26.32	0.075	22.73	28.95	0.10	23.86
Weapon was a Stabbing Instrument	30.00	28.95	-0.011	29.55	23.68	-0.070	27.27	36.84	0.072	32.95

Note. * $p < .05$. ** $p < .001$, some percentages do not add up to 100% due to missing information or a variable having been removed from the table, additionally

some crimes had more than one location during the offences which causes some percentages to equal more than 100%

Table 2: Incidence of Behaviours in the Sex Domain

Behaviour	Non-Serial % of Offences (N=50)	Random			First			Last		
		Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)	Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)	Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)
Rapist Kissed Victim's Face	46.00	28.95	-0.17	38.64	18.42	-0.29*	34.09	18.42	-0.29*	34.09
Rapist Kissed Victim's Chest	14.00	7.89	-0.095	11.36	10.53	-0.052	12.50	7.89	-0.095	11.36
Rapist Kissed Victim on Other Area	8.00	5.26	-0.054	6.82	.00	-0.19	4.55	2.63	-0.11	5.68
Rapist Fondled Victim	30.00	52.63	0.23*	39.77	44.74	0.15	36.4	42.11	0.13	35.23
Rapist Masturbated	10.00	13.16	0.049	11.36	10.53	0.009	10.23	15.79	0.087	12.50
Rapist Performed Oral Sex on Victim	8.00	10.53	0.044	9.09	2.63	-0.11	5.68	7.89	-0.002	7.95
Rapist Used Hand to Penetrate Vagina	18.00	28.95	0.13	22.73	28.95	0.13	22.73	26.32	0.10	21.59
Rapist Used Penis to Penetrate Vagina	70.00	60.53	-0.099	65.91	63.16	-0.072	67.05	39.47	-0.31*	56.82
Rapist Penetrate Vagina from Behind	20.00	23.68	0.044	21.59	23.68	0.044	21.59	13.16	-0.09	17.0
Rapist Used Hand to Penetrate Anus	2.00	7.89	0.14	4.55	5.26	0.089	3.41	2.63	0.021	2.27
Rapist Used Penis to Penetrate Anus	18.00	28.95	0.13	22.73	23.68	0.070	20.45	15.79	-0.029	17.05
Victim Kissed Rapist's Face	8.00	5.26	-0.054	6.82	2.63	-0.11	5.68	.00	-0.19	4.55
Victim Masturbated Rapist	2.00	18.42	0.28*	9.09	13.16	0.22*	6.82	13.16	0.22*	6.82
Victim Performed Fellatio	28.00	34.21	0.067	30.68	44.73	0.17	35.23	28.95	0.01	28.41
Rapist was Naked	10.00	7.89	-0.036	9.09	5.26	-0.087	7.95	5.26	-0.087	7.95
Victim was Naked	16.00	23.68	0.096	19.32	18.42	0.032	17.05	13.16	-0.040	14.77
Victim was Partially Disrobed	40.00	36.84	-0.032	38.64	34.21	-0.059	37.50	34.21	-0.059	37.50
Victim's Clothing was Moved to Expose	32.00	21.05	-0.12	27.27	36.84	0.051	34.09	15.79	-0.19	25.00
Rapist Disrobed Victim	72.00	63.16	-0.094	68.18	71.05	-0.010	71.59	44.74	-0.28*	60.23
Victim Disrobed Herself	20.00	31.58	0.13	25.00	28.95	0.10	23.86	21.05	0.013	20.45
Rapist Disrobed Himself	76.00	76.32	0.004	76.14	73.68	-0.026	75.00	60.53	-0.17	69.32
Clothing was Removed without Damage	6.00	18.42	0.19	11.36	21.05	0.23*	12.50	10.53	0.083	7.95
Clothing Removed was Torn Off	16.00	15.79	-0.003	15.91	15.79	-0.003	15.91	18.42	0.032	17.05
Rapist Discussed Sex Acts	30.00	55.26	0.25*	40.91	55.26	0.25*	40.91	42.11	0.13	35.23

Note. * $p < .05$. ** $p < .01$

Table 3: *Incidence of Behaviours in the Escape Domain*

Behaviour	Non-Serial % of Offences (N=50)	Random			First			Last		
		Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)	Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)	Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)
Wore Gloves	2.00	10.53	0.18	5.68	15.79	0.25*	7.95	10.53	0.18	5.68
Covered Victim's Eyes	6.00	10.53	0.083	7.95	10.53	0.083	7.95	13.16	0.12	9.09
Told Victim 'Not to Look'	12.00	26.32	0.18	18.18	18.42	0.090	14.77	23.68	0.15	17.05
Used a Condom	6.00	5.26	-0.015	5.68	7.89	0.037	6.82	2.63	-0.080	4.55
Used a False Name	10.00	7.89	-0.036	9.09	7.89	-0.036	9.09	5.26	-0.087	7.95
Warned Victim Not to Report Offence	18.00	26.32	0.10	21.59	21.05	0.038	19.32	21.05	0.038	19.32
Instructions to Ensure His Safe Escape	18.00	15.79	-0.029	17.05	23.68	0.070	20.45	10.53	-0.10	14.77
Makes Reference to Justice System	6.00	18.42	0.19	11.36	18.42	0.19	11.36	7.89	0.037	6.82

Note. * $p < .05$

Table 4: *Incidence of Behaviours in the Style Domain*

Behaviour	Non-Serial % of Offences (N=50)	Random			First			Last		
		Serial % of Offences (N=38)	Phi	All Offenders % of Offences (N=88)	Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)	Serial % of Offences (N=38)	Phi	All Rapists % of Offences (N=88)
Discusses Victim's Sex Practices	6.00	7.89	0.037	6.82	.00	-0.16	3.41	10.53	0.083	7.95
Orders Victim to Participate	8.00	10.53	0.044	9.09	7.89	-0.002	7.95	7.89	-0.002	7.95
Uses Abusive Language	14.00	23.68	0.12	18.18	21.05	0.093	17.05	15.79	0.025	14.77
Expresses Curiosity About Victim	18.00	21.05	0.038	19.32	15.79	-0.029	17.05	23.68	0.070	20.45
Rapists Discloses Information about Self	38.00	44.74	0.068	40.91	39.47	0.015	38.64	31.58	-0.067	35.23
Tries to Ingratiating Himself with Victim	12.00	13.16	0.017	12.50	10.53	-0.023	11.36	18.42	0.090	14.77
Compliments the Victim	10.00	13.16	0.049	11.36	10.533	0.009	10.23	7.89	-0.036	9.09
Apologises to Victim	8.00	15.79	0.12	11.36	13.16	0.084	10.23	13.16	0.084	10.23
Attempts to Prolong Relationship	6.00	7.89	0.037	6.82	7.89	0.037	6.82	2.63	-0.080	4.55
Displays Personal Knowledge of Victim	4.00	7.89	0.083	5.68	5.26	0.030	4.55	5.26	0.030	4.55
Says Victim Feels Enjoyment in Offence	14.00	15.79	0.025	14.77	15.79	0.025	14.77	7.89	-0.095	11.36
Justifies Actions	14.00	13.16	-0.012	13.64	13.16	-0.012	13.64	7.89	-0.095	11.36

Control Domain

The Control domain contained any behaviour that is deemed “necessary to create and maintain an environment in which the crime can take place” (Grubin et al., 2001, p. 14). This includes actions such as where the offence occurred (e.g., Alleyway), how the offender approached the victim (e.g., Asked Victim for Help), and how the offender kept the victim incapacitated (e.g., Gagged Victim).

A number of significant associations were found as well as several small and a medium effect sizes (see Table 1). Three associations were significant across all three subsets: serial rapists were significantly more likely to use solicitation as a method to procure a victim (31.58% - 34.21%) than one-off rapists (2.00%) across all three subsets. This finding remained after Benjamini-Hochberg correction and had an associated medium sized effect. In contrast, across all three subsets, the serial rapists were significantly less likely (5.26% - 7.89%) to obtain a victim by engaging them in conversation than the one-off rapists (24.00%) representing a small effect size. The third consistent, significant association was between the victim being bound and the rapists being a serial offender, again representing a small effect size. Serial rapists were significantly more likely to bind their victims (10.53% - 13.16%) than one-off rapists (0.00%). The latter two findings did not remain following a Benjamini-Hochberg correction.

In addition to these more consistent findings, there were other significant associations within one or two subsets. The serial rapists were significantly more likely than one-off rapists to commit the offence in a retail area (63.16 or 65.79% vs. 42.00%), a parking area (21.05 or 23.68% vs. 6.00%), a street (68.42% or 76.32% vs. 46.00%) or a wooded area (13.16% vs. 2.00%); however, the effect sizes for these associations were small. In terms of other control behaviours used within the offence itself, serial rapists were significantly more

likely to gag their victims in the last offence subset than one-off rapists (15.79% vs. 2.00%) but, again, only representing a small effect size. None of these findings were significant following Benjamini-Hochberg correction.

Sex Domain

The Sexual behaviour domain contains the sexual acts that were part of the offence, including physical acts and verbalisations about sexual acts (Woodhams, Grant et al., 2007). For example, located within this domain are behaviours such as forms of penetration (e.g. Offender Used Penis to Penetrate Vagina), levels of undress (e.g., Victim was Naked), who undressed whom (e.g., Offender Disrobed Victim), and sexual comments made by the offender (e.g., Offender Discussed Sex Acts).

As can be seen from Table 2, the only behaviour consistent across all three offence subsets was the finding that serial rapists more often forced their victims to masturbate them than the one-off rapists (13.16 - 18.42% vs. 2.00%), however, this represented a small effect size. This finding did not remain after statistical correction.

There were, again, some significant associations that were present in either one or two subsets: serial offenders were more likely to fondle their victims (52.63% vs. 30.00%) and discuss the sex acts that they wanted the victim to perform (55.26% in both the random and first subset vs. 30.00%). Also, they were more likely to remove the victim's clothing without damage in the first offence subset (21.05% vs. 6.00%). The one-off rapists were more likely than the serial rapists to vaginally penetrate their victims with their penises in the last offence subset (70.00% vs. 39.47%), representing a medium effect size. Finally, they were also more likely than the serial rapists to disrobe the victim themselves in the last offence subset

(72.00% vs. 44.74%) (a small effect size). However, none of these significant associations remained following statistical correction.

Escape Domain

The Escape domain contains behaviours where the main function was to aid in the offender's escape from the scene and avoiding detection (Woodhams, Grant et al., 2007). These include certain precautions (e.g., Wore Gloves) and verbal themes used by the offenders (e.g., Warned Victim Not to Report Offence). As can be seen from Table 3, there was only one significant association found; within the first offence subset, the serial rapists were more likely to wear gloves than the one-off offenders (15.79% vs. 2.00%) representing a small effect size. This was no longer significant following Benjamini-Hochberg correction.

Style Domain

The Style domain contains behaviours that had no role in aiding the commission of the offence, but were instead something that the offender chose to do (Grubin et al., 2001). All of the behaviours in this domain were verbal themes (e.g., Apologises to Victim). As can be seen from Table 4, there were no statistically significant associations in this domain, nor were there any notable effect sizes.

DISCUSSION

This study aimed to address several of the limitations of existing research contrasting the crime scene behaviour of serial and one-off rapists by focusing solely on rapists who were strangers to their victims. Previous studies (LeBeau, 1987; Park et al., 2008) had found differences in the offence behaviours of serial versus one-off rapists; however it was unclear

if these were due to inherent differences between serial or one-off rapists or a result of the mixture of victim-offender relationships in the samples. In this study, by holding the type of victim-offender relationship constant, these two competing explanations could be disentangled. A further improvement on past study designs was the extension of the sampling frame from just randomly sampling one offence per series for comparison, to also comparing one-off offences with both the first and last (known) offence from each series. This enabled the robustness of significant associations to be assessed in terms of determining whether they were present across the three subsets.

As with earlier studies, the majority of the behaviours included in the analysis did not differ significantly in terms of frequency of occurrence between the serial and the one-off rapists (Park et al., 2008). This poses a significant challenge to using crime scene behaviour for the purpose of differentiating serial from one-off offences. As explained above, police forces in England and Wales are expected to treat each stranger rape reported to them as a potential serial offence. Information about crime scene behaviour is available to the police early in an investigation and so would be an effective means of supporting such investigative strategies if one-off and serial rapes could be discriminated accurately. The findings reported here indicate that there are few crime scene behaviours that could be used for this purpose.

Indeed, after conducting a Benjamini-Hochberg (1995) correction, the only statistically significant association remaining was the more frequent use of solicitation as a form of con-approach by serial rapists (con-approach is the use of confidence trickery in some way to mislead the victim). As well as remaining significant following statistical correction, this finding was also replicated across all three subsets of serial offences. By implication, the victims of serial rapists were therefore significantly more likely to be sex workers. There is evidence from other research that serial sex offenders target sex workers, and that the offences

against them are more violent (Silbert & Pines, 1982, 1984). Similarly, research on serial homicide has reported a tendency for serial murderers to target prostitutes (Fox & Levin, 1998). The serial rapists' apparent preference for targeting sex workers has another advantage for their continued offending: research shows that sex workers are reluctant to report rape and sexual assaults to the Police (Silbert, 1981, as cited in Barnard, 1993; Sullivan, 2007), therefore the offender can continue his offending without attracting police attention and hence is able to become a serial rapist.

Closely tied to the use of the con of soliciting were the locations that were chosen by the serial offenders for the offence, namely parking areas or on the street. One of the most striking advantages for the offender of targeting a sex worker as a victim is that he/she is likely to go alone with the offender to a more remote location. There are also certain locations that sex workers choose, specifically to facilitate their businesses, which are then sought by the offender (Douglas, Ressler, Burgess, & Hartman, 1986). Most of the scene locations were places where there would not have been many people around at the time of the offence. Several studies have shown that sexual offenders weigh up the costs and benefits of where and when they commit their offences, and that there is a rationale behind their actions (Beauregard & Leclerc, 2007; Beauregard, Rossmo, & Proulx, 2007).

The one-off offenders, in contrast to the serial offenders, were more likely to try and con their victim by engaging her in a conversation. There was also a trend for one-off rapists to more often offer the victim a ride. This was a very different style of approach to the serial rapists, and would tend to be associated with a different type of location than those frequented by sex workers and their clients. As such, the one-off offenders were subsequently more likely to commit their offence indoors. Given that the one-off offender would have had to talk face-to-face with the victim to either engage in a conversation or offer a ride, the victim has

more time during which to observe the offender's appearance and also possibly note other identifying information, such as their type of vehicle or registration plate. It is possible that such an approach, while successful in facilitating a completed or attempted rape, also aids in the apprehension of the offender, which might curtail the offending of an individual before a series can emerge.

Another behaviour within the control domain that might aid in the continued offending of serial rapists was their more frequent use of binding the victim. Binding the victim inhibits his/her ability to seek help from potential witnesses through physical means and could potentially buy the offender more time in which to escape safely from the scene before the victim could raise the alarm. Previous studies have suggested that serial offenders are more "criminally sophisticated" and that this is what aids them in avoiding detection (Park et al., 2008). Besides binding the victim, no other statistical differences in the control behaviours of serial or one-off offenders were found, although similar trends to Park et al.'s study were noted. For example, the elevated frequency of gagging the victims by serial offenders could also not only facilitate the commission of the offence itself by preventing disturbance by a third party, but also prolong the period of time in which the offender can make a safe departure.

The other main area of difference between serial and one-off rapists that was seen in this study was regarding the actions involved in the sexual component of the crime. The serial rapists engaged in more sexual acts than the one-off rapists; specifically fondling the victim, forcing the victim to masturbate the offender, and discussing sex acts with the victim during the crime. These are very different findings than those reported by Park et al. (2008) where similar behaviours to these were more often associated with the one-off rapists. Park et al. suggested that these verbal themes, especially communications with the victim about the

offender's fantasy and sex acts, helped investigators apprehend the offender. However, this study found that the serial offenders were more likely to talk about sex acts during the offence.

In their study of stranger rapists, Canter, Bennell, Alison and Reddy (2003) found four styles of behaviour within stranger rapes; control, theft, involvement and hostility, which have been previously reported in other studies of sexual offences (see Canter et al., 2003 for a review). These styles are proposed to affect the way a rapist will relate to his victim, for example, rapists adopting an involvement style treat their victim as a reactive individual (as a person), whereas more controlling rapists are proposed to treat their victim as an object. Canter et al. suggest that the style adopted will result in different themes of verbal communication between rapist and victim. This seems to be reflected in the sample for this study, with the serial rapists appearing to adopt a more involved style of verbal communication, although it should be noted that some of their other behaviours, such as forcing the victim to masturbate them and binding the victim, would represent a more hostile or controlling style, respectively.

Limitations

There were some limitations to the study that would necessitate caution before applying these findings to all stranger rapists. It cannot be guaranteed that the one-off rapists included in this study have only committed the one offence, since it is not possible to be certain that the offences included in a study are the only ones the offender has committed. As such, some one-off rapists in this study may instead be serial rapists. In addition, in the absence of definitive DNA evidence, we cannot be completely certain of the "serial" status given to some offenders, due to the possibility of miscarriages of justice. These are limitations

common to studies of this nature (Mokros & Alison, 2002; Santtila et al., 2005) which must rely on conviction to categorise the offenders in this way. Such errors in classification could mask potential differences in behaviour between one-off and serial rapists.

Similar to other studies in the area, we were unable to run a statistical cross-validation of the findings. Due to the size of the sample and the number of variables being considered, it was impossible to run a leave-one out logistic regression without violating the case: variable assumption (Peduzzi, Concato, Kemper, Holford, & Feinstein, 1996). However, this study improved on previous study designs by comparing the findings across three different subsamples (i.e., constituting one-off offences vs. first serial offence, one-off offences vs. last serial offence, and one-off offences vs. a randomly selected offence from each series) to determine if each finding was consistent.

The data that were utilised in this study were based only on offences for which there was a conviction; therefore, the sample cannot be considered representative of all stranger rapes. This is because it is well established that rapes which are prosecuted and result in a conviction more closely reflect rape myths in our societies (Frazier & Haney, 1996; Harris & Grace, 1999) and may contain different offence behaviours to those committed by offenders that have not been apprehended (Bennell & Canter 2002; Woodhams, Hollin et al., 2007). We cannot, therefore, be sure that our findings will transfer to crimes that remain unsolved, the type of crime to which investigators would apply the findings in practice. However, as noted above, the methodology required to compare apparent one-off with serial rapists necessitates it being “known” which offenders have committed just one offence or several; therefore it would be very difficult to overcome this limitation.

It should also be noted that the comparisons in this study were only between individual variables rather than by the domains. The domains were included only as a way to

view the data in more understandable clusters based on previous studies (e.g., Grubin et al., 2001; Woodhams, Grant, & Price, 2007). In future studies it would be helpful to analyse the differences between serial offenders and one-off offenders based on domains, as well as possibly different configurations of domains. However, this did not fit the scope of the current chapter and therefore was not investigated at this time.

Conclusion

It has long been a policing priority to target prolific offenders; however, in the current fiscal climate it is even more advantageous to be able to target limited police resources in this way. In 2012, in England and Wales, police forces were advised to initially consider every stranger rape part of a potential series (HMIC & HMICPS, 2012). This is potentially a costly and time-consuming exercise which could be aided if it were possible to distinguish serial from one-off stranger rapists on the basis of crime scene behaviour, reports of which are often available in the initial stages of a police investigation. This study aimed to contribute to a very small set of existing studies which have tried to empirically establish means of differentiating serial from one-off rapists using crime scene behaviour by addressing limitations in past study design.

The findings of this present study suggest that there may be a limited number of differences in the offence behaviour displayed by a one-off stranger rapist and a serial stranger rapist, particularly in terms of the type of victim targeted, the locations chosen for the offence, methods of control and the sexual acts that they force upon the victim. The only key distinction between the two types of offenders was the choice of sex workers as potential targets by serial offenders, which supports previous studies. However, what was most striking was the similarity in crime scene behaviour between these two types of rapist, meaning that it

would be difficult in practice to accurately differentiate serial from one-off rapes, at least on the basis of the crime scene behaviours investigated here.

It could be inferred from the findings that beyond the initial victim selection there are not any real behavioural differences. This leads to the idea that the differentiation between serial and one-off is actually an arbitrary one. The likelihood that one-off offenders are just serial rapists that have got caught earlier than other rapists would support their inclusion in crime linkage studies, as there may be more of their offences to include at a later analysis.

CHAPTER 3:
TESTING THE ASSUMPTIONS OF CRIME LINKAGE WITH STRANGER SEX
OFFENCES: A MORE ECOLOGICALLY-VALID STUDY?

The aim of this chapter was to test the two basic assumptions that underpin crime linkage (behavioural consistency and distinctiveness) which were described in Chapter 1. With the application of a previously tested statistical analysis (originally proposed by Bennell, 2002), a larger sample than most previous studies was used. Building upon this traditional assessment of the crime linkage principles, the sample was further improved to include one-off offenders in order to more closely represent the reality of the crime linkage task which involves searching for serial crimes within databases that also contain the crimes of one-off offenders. Consequently, this study also provided the opportunity to observe the effect that one-off offenders can have on the ability to link crimes accurately.

The following chapter has been adapted from a paper that was published in the *Journal of Police and Criminal Psychology*, 2015, doi: 10.1007/s11896-014-9160-3. This journal is based in the USA and therefore American spelling was used in the paper, but has been adapted to UK English to better match the rest of the thesis.

Chapter 3: Testing the assumptions of crime linkage with stranger sex offences: A more ecologically-valid study?

Crime linkage is a police operational practice whereby police records are analysed with the aim of identifying similarities in behaviour between two or more crimes that would suggest they were committed by the same offender (Woodhams & Grant, 2006). It is an area of research that has grown significantly in the past 10 years and has included investigations of sexual assaults and rape (e.g., Grubin, et al., 2001), homicides (e.g., Santtila et al., 2008), arson (e.g., Ellingwood et al., 2013), burglaries (e.g., Bennell & Jones, 2005), robberies (e.g., Lin & Brown, 2006), and car theft (e.g., Tonkin, et al., 2008). Notably, research has focused on the application of crime linkage with ‘hard to solve’ crimes such as those committed by a stranger who had no previous connection to the victim (e.g., Santtila, et al., 2005).

An impetus for research in this field has been the use of crime linkage analysis to advise police investigations, as well as its use in legal proceedings in some countries (Bosco, et al., 2010; Charron & Woodhams, 2010; Hazelwood & Warren, 2004; Labuschagne, 2006), necessitating a comprehensive test of its two underlying principles. First, this paper outlines the ways in which crime linkage is utilized in practice and what this means for testing the two underlying assumptions (behavioural consistency and distinctiveness, which are described in Chapter 1). It then briefly describes the existing studies of these assumptions with stranger sexual offences, explaining their limitations and how these affect the conclusions that can be drawn. The remainder of the paper presents a study designed to overcome a number of key limitations, which more closely reflects the type of data with which crime linkage would be conducted in reality. It therefore represents a more ecologically valid test of the underlying principles of crime linkage.

Crime Linkage in Practice

Although crime linkage is a relatively new area of research in legal and criminological psychology, with most research having been conducted in the last decade, it has been practiced for far longer than this. For example, the Violent Criminal Apprehension Program (ViCAP) of the Federal Bureau of Investigation (FBI) used to support crime linkage was devised in 1985 (Royal Canadian Mounted Police [RCMP], n.d.). It is also widely practiced across several countries including the United Kingdom, the United States, Australia, South Africa, Belgium, the Czech Republic, France, Germany, Ireland, the Netherlands, New Zealand, and Switzerland (Bosco et al., 2010; Hazelwood & Warren, 2004; Labuschagne, 2006; RCMP, n.d.).

The widespread use of crime linkage can be explained by the advantages it holds for police forces if conducted accurately. For example, the processing of physical evidence can take weeks or months in some countries and while waiting for such evidence, crime linkage can be used to identify potential linked cases that can be investigated while awaiting results regarding physical evidence (Labuschagne, 2012). These might be cases where the suspect also remains unknown. In such a scenario, the identification of these “linked” crimes could facilitate the pooling of other forensic evidence from each crime scene (Davies, 1991). Alternatively, for one or more “linked” crimes a suspect could have been identified thereby expediting the apprehension of a suspect for the entire series. Davies (1991) also argues that behavioural linking can enhance the credibility of victims because each victim gains credibility from the others. This has been demonstrated by Jordan (2001, as cited by Kelly, 2010) whereby cases first deemed as false allegations by the police were subsequently perceived to be credible when another similar offence occurred.

The use of crime linkage is not limited to advising police investigations; it has also been used to prosecute an individual for multiple crimes. Evidence of behavioural similarity and distinctiveness has been introduced into legal proceedings in the UK, the US, Australia and South Africa (Bosco et al., 2010; Charron & Woodhams, 2010; Hazelwood & Warren, 2004; Labuschagne, 2006; Meyer, 2007; Woodhams & Toye, 2007) to suggest that the same offender was responsible (or not) for two or more crimes (Bosco et al., 2010). Typically, at least one other form of evidence is also presented (e.g., eyewitness identification, confession) that links the offender to one or more of the crimes he/she is being tried for, but this evidence is absent or weak for other offences (see Labuschagne, 2006, for a case example).

The admittance of such evidence into legal proceedings is governed in some countries by particular rules. In the US, the admissibility of scientific evidence into the courts is controlled by a conglomeration of court cases and federal rules (Meyer, 2007). Often it is the decision of the individual state which precedent to follow. The generally accepted standard for many states is the Daubert criteria (1993), whereas others follow the older Frye standard (1923) or the more recent *Federal Rules of Evidence*, specifically Rule 702 (Groscup et al., 2002).

The Frye standard. This standard was the precursor to the Daubert criteria and Rule 702. It requires that the method by which the evidence was obtained is accepted by experts in that field.

The Daubert criteria. This has five main points that must be met in order for the evidence to be presented in the courts;

1. The ability for empirical testing of the theory or technique (and that it has been tested);
2. The evidence must have been subjected to peer review and publication;
3. There needs to be a known or potential error rate for the practice;
4. There must be standards and guidelines for the practice;
5. The degree to which the theory or technique is generally accepted by the scientific community.

In 2007, Woodhams, Bull and Hollin considered how well the field of crime linkage fared against each of the Daubert criteria. With respect to criterion 1, they explained that crime linkage is underpinned by two assumptions (or theories); the Assumption of Behavioural Consistency, which states that offenders are consistent in the way they commit their crimes (Canter, 1995), and the Assumption of Behavioural Distinctiveness, which states that offenders will commit their crimes in a relatively distinctive manner (Bennell & Canter, 2002). The study of behavioural consistency and distinctiveness has a long history in personality psychology (e.g. Allport, 1937) where models (e.g., the Cognitive Affective Personality System, Mischel & Shoda, 1995) have been proposed that suggest behavioural consistency will be observed in situations of psychological similarity and that distinctiveness in individuals' behaviour displayed in the same situation emerges because of differences in learning histories, personality dispositions and so on.

In terms of criterion 1, Woodhams et al. (2007a) concluded that while these two assumptions could be tested and that some efforts had been made to test them, there were some significant limitations with the research, including a lack of realism (see below for a fuller discussion). They further described how crime linkage had been subject to peer review and publication (criterion 2) but that there was not a known error rate (criterion 3). With

regards to the last two criteria (4 and 5), whether crime linkage theories or techniques are generally accepted by the scientific field and if there are standards and guidelines, Woodhams et al. concluded “not yet”. However, in the six years since Woodhams, et al. (2007a) presented this critique, several studies have been published, specifically on sex offending and crime linkage, which are discussed in more detail below.

Rule 702. The requirements of Rule 702 (*Federal Rules of Evidence, amended 2011*) are broader:

“A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:(a) the expert’s scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue; (b) the testimony is based on sufficient facts or data; (c) the testimony is the product of reliable principles and methods; and (d) the expert has reliably applied the principles and methods to the facts of the case.”

Of most relevance to the research of crime linkage is point (c). This rule requires expert testimony utilizing crime linkage analysis to be a product of reliable principles *and* methods. Specifically, the current paper focuses on the state of the research with regards to (c)(i), whether its principles (i.e., behavioural consistency and behavioural distinctiveness) are reliable. Other researchers have investigated (c)(ii), the methods, and interested parties are referred to Snook, Luther, House, Bennell and Taylor (2012).

In summary, the field of crime linkage must ensure that research meets the standards required for admission in court. Therefore, this paper aims to expand knowledge on the reliability of the underlying principles of crime linkage for serial sex offences.

Serial Sex Offending and Tests of the Crime Linkage Assumptions

Given the use of crime linkage analysis in legal proceedings, and that rules of evidence require its principles to have been tested (and supported), it is unsurprising that the main focus of crime linkage research has been to test their validity. Serial sex offences are one of the crime types most often the subject of these empirical tests. Studies have centred on sexual offences committed by offenders who are strangers to their victims because these cases are often more difficult to solve than offences committed by a victim's acquaintance (Canter, 1996; Roberts & Grossman, 1993) and it is on such cases that crime linkage would be conducted in practice.

The two basic assumptions have been studied in a variety of ways within the research on linking sexual offences. Some studies have assessed only the degree of behavioural consistency exhibited by serial sex offenders whereas others have assessed both assumptions simultaneously using a variety of statistical methods, including discriminant function analysis and multidimensional scaling (e.g., Santtila et al., 2005), and logistic regression and ROC analysis (e.g., Bennell, et al., 2009).

In the consistency studies, behavioural consistency has been quantified using Jaccard's coefficient, percentage agreement and kappa, with the former being most common. Sjöstedt, et al. (2004) found serial sex offenders, particularly those who had targeted stranger victims, to show some stability in their victim selection behaviours² ($\kappa > .40$). Grubin et al. (2001) assessed whether the serial sex offenders in their sample were consistent in behavioural domain types³ (types of control behaviours, sex behaviours, escape behaviours and style

² Victim selection behaviours include characteristics of the victim, such as vulnerabilities or physical appearance.

³ Control behaviours are those used to maintain control over the victim to facilitate the commission of the offence. Escape behaviours refer to those that enable the offender to quit the scene undetected. Style behaviours are those that do not assist in the commission of the offence but which reflect the offender's internal psychology (Grubin et al., 2001).

behaviours established from cluster analysis) across their series. Eighty-three percent of the offenders were consistent in at least one domain and 26% were consistent across all four domains.

Where Jaccard's coefficient has been used to quantify the amount of similarity in crime scene behaviour between two offences, a larger coefficient indicates greater similarity in behaviour. This translates to greater consistency in the case of two crimes by the same offender. Jaccard's coefficients range from 0 to 1, with 0 representing absolute inconsistency in behaviour and 1 representing perfect consistency. Once a Jaccard's coefficient has been calculated for all pairs in a dataset, researchers have tested the underlying assumptions of consistency and distinctiveness by contrasting the Jaccard's coefficients for linked crime pairs versus unlinked crime pairs. Linked crime pairs represent two crimes by the same serial offender whereas unlinked crime pairs are created by pairing two crimes committed by different (usually serial) offenders. If the assumptions of crime linkage are valid, the Jaccard's coefficients for the linked crime pairs should be larger (indicating greater behavioural similarity) than those of the unlinked crime pairs. For example, Mokros and Alison (2002) found the average Jaccard's coefficient for the linked crimes to be higher ($M=0.41$) than that of the unlinked pairs ($M=0.27$), suggesting support for the assumptions of crime linkage, however they did not determine if this difference was statistically significant. Other studies have used tests of difference to contrast linked and unlinked crime pairs. In these studies the average Jaccard's coefficient for the linked pairs has ranged from .39 to .52 but only .17 to .34 for the unlinked pairs (Bennell et al., 2009; Bennell et al., 2010; Woodhams, et al., 2007b; Woodhams & Labuschagne, 2012). In all cases, the average Jaccard's coefficient for the linked pairs was significantly larger indicating greater behavioural similarity.

The studies that have utilized more advanced statistical tests to assess the underlying principles of crime linkage with sex offences tend to fall into one of two categories: 1) statistical tests which assess the accuracy with which a query crime can be allocated to the correct series or with which crimes from the same series as the 'query crime' can be identified (e.g., Grubin et al., 2001; Santtila et al., 2005); or 2) statistical tests which determine how accurately linked crime pairs can be distinguished from unlinked crime pairs based on behavioural similarity (e.g., Bennell et al., 2009; Woodhams & Labuschagne, 2012). For the first approach, accuracy rate(s) are compared to what would be expected by chance alone to see if they differ. As Tonkin et al. point out in their 2012 study, comparing the statistical model against chance might not be a fair comparison, as practitioners may perform at a level better (or worse) than chance. For the second approach, Receiver Operating Characteristic (ROC) analysis is used to quantify discrimination accuracy with the area under the curve (AUC) indicating how accurately linked and unlinked crime pairs can be distinguished. AUC values range from 0 to 1.00 with a larger value representing greater accuracy.

With regards to the first approach, several studies have extracted a query crime from their research database and then rank ordered all other remaining offences according to their behavioural similarity to the query offence (Grubin et al., 2001; Santtila et al., 2005). This analysis has been conducted using bespoke computer algorithms (Grubin et al., 2001), multidimensional scaling, and discriminant function analysis (Santtila et al., 2005). Having done this, a pre-specified top percentage of ranked crimes are examined to determine how many are actually from the same series as the query offence and whether this is more than would be expected by chance. For all but two of the 117 series examined by Grubin et al. (2001) the figures were significantly higher than would be expected by chance. Santtila et al. (2005) reported that another crime from the same series was within the top five most similar

crimes more than 40% of the time and nearly 60% of the time within the top ten cases found by the linking model. Overall, the accuracy of offence allocation to series was significantly greater than chance (at 25.6%) and for 86% of the crimes (when using discriminant function analysis), the correct series was within the top 10 to which it was predicted to belong. Similarly, using a bespoke computer algorithm, Yokota, et al. (2007) used behavioural similarity to predict to which *offender* each offence in their database belonged. The top five percent of offenders in each ranked list were scrutinized to determine whether the correct offender was present. Twenty-four of the 81 offenders were correctly ranked number one for their offence, and the median rank position for the correct offender was four (Range = 1-339). Several studies have therefore demonstrated that it is possible to allocate offences to the correct series or to offender at rates significantly higher than chance. However, it should also be noted that these figures illustrate that there is still quite a considerable degree of error in making such predictions.

This approach to evaluating crime linkage principles has been criticized by Bennell and colleagues for using just one decision-threshold (e.g., specifying a particular cut-off – “top ten”), which can produce a distorted picture of linking accuracy (Bennell et al., 2009). Instead, Bennell (2005) proposed Receiver Operating Characteristic (ROC) analysis as the “gold standard” analysis since it is able to evaluate linking accuracy across a range of thresholds (as well as having a number of other advantages). A very recent study by Winter et al. (2013) compared two different statistical techniques for predicting the series to which each offence in the dataset belonged; Mokken scaling followed by discriminant function analysis and naïve Bayesian classifier analysis. However, in response to Bennell et al.’s criticism, ROC analysis was used to evaluate the accuracy of linking predictions. Winter et al.’s sample constituted 90 sex offences committed by 30 serial sex offenders and 129 apparent one-off

sex offences from the UK. The AUCs ranged from .74-.89 with greater accuracy found when the one-off offences were included in the dataset subject to analysis.

The remaining studies of the crime linkage principles with sex offences have utilized ROC analysis to assess how accurately linked crime pairs can be distinguished from unlinked crime pairs. These studies have calculated a Jaccard's coefficient for each pair in their dataset which are then used to predict whether a given crime pair in the dataset is the work of the same offender (linked) or two different offenders (unlinked). If the two assumptions underpinning crime linkage are valid this discrimination task should be achieved with a high degree of accuracy (reflected by a large AUC). With a UK sample of 126 serious sexual assaults committed by 42 offenders, Bennell et al. (2009) found an AUC of .75 representing a good level of accuracy. Using the same sample but a different coding scheme with 36 variables (compared to the 27 variables used in the 2009 study), Bennell et al. (2010) reported an AUC of 0.81. More recently, with a South African sample of 22 serial sex offenders, Woodhams and Labuschagne (2012) reported AUCs ranging from .77-.88.

Limitations of Previous Linkage Research

While the studies outlined above provide some support for the assumptions underpinning crime linkage with samples of serial sex offences, they have a number of limitations that have implications for the satisfaction of the rules of evidence outlined above. The first issue concerns the variation in how behavioural similarity is quantified and the statistical methods employed to test the principles of crime linkage. Disagreement in the approach to analysis presents difficulties when attempting comparisons between studies, or summation of the research. As noted above, Bennell and his colleagues (e.g., Bennell et al., 2009; Bennell, et al., 2014) have made a convincing argument that ROC analysis should be

adopted as the gold standard analysis since it is the only current method that is not impeded by threshold-specific results, producing a “pure measure of linking accuracy (i.e. the AUC)” (Bennell et al., 2009, p. 304). ROC analysis was therefore adopted as the analytical technique in the current study.

Another limitation of existing crime linkage research with sex offences is the sample sizes used. Most studies have sampled the crimes of 13 - 42 serial offenders ($N=42$ series (126 offences), Bennell et al., 2009; $N = 16$ series (43 offences), Santtila et al., 2005; $N = 30$ series (90 offences), Winter et al., 2013; $N= 22$ series (119 offences), Woodhams & Labuschagne, 2012). Yokota et al. (2007) is the exception to this with a sample of 188 serial offenders and 680 one-off offenders. The number of crimes included in statistical analyses in some previous studies has been further reduced by researchers adopting the practice of sampling a constant number of offences from each series rather than utilizing all offences in a series (e.g., Bennell et al., 2009, Santtila et al., 2005). As Woodhams and Labuschagne (2012) argued, police databases would not consist only of series of a constant number. The current study, therefore, sampled a larger number of serial sex offenders than most previous studies ($N = 50$ series) and included all known sex offences ($N= 194$ offences) comprising each series (thereby including series of differing length in the current study).

A further limitation is that most studies have used samples consisting solely of serial sex offenders (Bennell et al., 2009; Santtila et al., 2005; Woodhams & Labuschagne, 2012), whereas in reality crime linkage databases would contain both serial and one-off offences. This is problematic for a number of reasons. First, it means previous research lacks realism and therefore the findings may not generalize to practice. Second, by including only serial offenders in an analysis, the researchers may be artificially separating the distributions of Jaccard's coefficients for the linked and unlinked crime pairs (Woodhams, 2008). If it is

accepted that serial sex offenders are consistent and distinctive in their crime scene behaviour, in creating unlinked pairs from crime series, two crimes by two serial offenders with very different crime scene behaviour are being paired. These should therefore look very dissimilar to one another resulting in a small Jaccard's coefficient. This potential problem can be overcome by including one-off offenders in a sample. This also improves ecological validity.

Two recent studies have investigated if there are differences in the crime scene behaviour of serial and one-off rapists. Corovic et al. (2012) stated that serial rapists were more criminally sophisticated than the one-off rapists in their first rapes. However, after applying a Bonferroni correction in the second part of their study, where they tried to predict if a rapist was a serial or one-off, the only predictors of a rapist's type were "kissed victim" (one-off offenders more likely to show this behaviour) and "controlled victim" (more likely to be seen in serial offenders). Similarly, as discussed in the previous chapter, Slater et al. (2014) found that while there were some differences in the control and sexual behaviours between serial and one-off rapists, after a Benjamini–Hochberg correction, only one behaviour remained significant, whether the victim was solicited by the offender (more likely by serial offenders). In summary, few differences have therefore been found between one-off and serial rapists meaning that it might be quite difficult to distinguish between linked crime pairs and unlinked crime pairs composed of one-off offences.

To date, only a handful of studies have included one-off offenders in their samples of sexual offences (Grubin et al., 2001; Winter et al., 2013; Yokota et al., 2007), with only Winter et al. (2013) using ROC analysis. However, Winter et al.'s analysis utilized Mokken scaling, discriminant function analysis and naïve Bayesian classifier analysis to predict to which series an offence was likely to belong: this differs quite considerably from most research on the crime linkage assumptions that has adopted logistic regression and ROC

analysis to determine how accurately the linkage status (linked versus unlinked) of crime pairs within a sample can be predicted. The current study adopted the more common method of assessing the accuracy of differentiating linked and unlinked crime pairs based on crime scene behaviour using ROC analysis while still overcoming the other design flaws outlined. In addition to testing the validity of the underlying assumptions of crime linkage, this paper also considered Daubert criterion 3 (referring to the known error rate) by calculating figures for sensitivity and specificity.

Based on previous findings of studies of serial sex offending, it was hypothesized that linked crime pairs would be more similar in crime scene behaviour than unlinked crime pairs, and that behavioural similarity, as measured using Jaccard's coefficient, could accurately differentiate linked from unlinked crime pairs. No prediction was made as to the relative discrimination accuracy when using samples representing only serial sex offences versus also including one-off sex offences.

Method

Data

A national sample of stranger sex offences was obtained from the Serious Crime Analysis Section (SCAS) of the National Crime Agency, UK. SCAS is a police analytical unit with national responsibility to carry out analytical work on behalf of all police forces. A sample of sexual offences committed by 50 serial and 50 one-off male offenders was provided by SCAS. Since the true ratio of serial to one-off offenders is unknown, it was decided that an even 1:1 ratio would best serve this study. Each crime was committed against a lone, adult, female victim by a lone stranger, adult, male offender. In total, the sample consisted of 194

serial sex offences committed by the 50 serial offenders⁴ and 50 one-off sex offences. The serial offences spanned dates from 1977 to 2010, whilst the one-off offences occurred between 1984 and 2009. The slight difference in dates is due to the request made to SCAS that sample collection start from the date of the request and extend backwards in time until 50 offenders of each type were identified. The definition of “serial” adopted in this study corresponds with international research programs on various forms of serial offending (e.g., Grubin et al., 2001; Santtila et al., 2005; Tonkin et al., 2008) and the Federal Bureau of Investigation’s (2008) definition for serial murder, which is two or more crimes committed by the same individual. The term “one-off” is used within the paper to refer to apparent one-off offences. It is impossible to know whether these are the crimes of sex offenders who genuinely committed only one offence, as established by a conviction, or whether they are in fact serial offenders whose other crimes have not been attributed to them. This point is returned to in the discussion of the paper. All the crimes included in the sample were from closed cases, where the offender had been convicted of the offence.

Serial offenders and their offences. The 50 serial sexual offenders in the sample had a mean age at the time of offence of 31.69 years (Range = 18-58 years; *SD*=8.76). Seventy-two percent of the serial offenders were of White European ethnicity, the rest were of Dark European (8%), African or Caribbean (12%), Asian (2%), Arabic (2%), or Other ethnicity (4%). The mean series length was four offences and the mode was three offences (Range = 2-10 offences). One hundred and two of the offences were rapes, the rest were attempted rapes, assaults by penetration, indecent assaults, and indecent exposures (see Table 1). The

⁴ Information as to how the serial offences were originally linked (e.g. behavioural similarities, offender confessions, DNA) was not available to the researchers.

remaining 31 offences were other types of sexual offence (e.g., offences that are classed as another type of crime but where a sexual component was evident). The inclusion of these unclassified sexual offences for the serial offenders is a result of the sampling frame and the attempt to include all the sexual crimes in an offender's series. The victims of the serial offenders had a mean age at the time of offence of 29.46 years (Range = 18-76 years; $SD=11.58$). Seventy-two percent of the victims were White European, with the rest being Dark European (1.5%), African or Caribbean (1%), Asian (1%), Arabic (1%), or Other (1.5%), and for 22% ethnicity was not recorded.

Table 1: *Types of Offences Committed by Serial and One-Off Offenders*

Offence	Serial Offences N=194		One-Off Offences N=50	
	<i>n</i>	%	<i>n</i>	%
Rape	102	52.6	40	80.0
Attempted Rape	18	9.3	10	20.0
Assault by Penetration	6	3.1	-	-
Indecent Assault	32	16.5	-	-
Indecent Exposure	5	2.6	-	-
Other Sexual Offence	31	16.0	-	-

One-off offenders and their offences. The sample of 50 one-off sexual offenders had a mean age at the time of the offence of 30.92 years (Range = 18-55 years; $SD=9.59$). Seventy percent of the offenders were of White European ethnicity, the rest were of Dark European (2%), African or Caribbean (12%), Asian (10%), Arabic (4%), or Other ethnicity (2%). From the 50 offences they committed, 10 were classified as attempted rapes, while the other 40 were classified as completed rapes (see Table 1). The victims of the one-off offenders had a mean age at the time of offence of 28.20 years (Range = 18-59 years; $SD=9.51$). Eighty-four percent of the victims were of White European ethnicity, with the rest being African or Caribbean (2%), or Other (4%), and for 10% their ethnicity was not recorded.

Procedure

The information about the offenders' crime scene behaviours for the offences sampled was provided to the authors as a numerically coded spreadsheet which contained no personally identifying information. The spreadsheet contained 217 different modus operandi (MO) behaviours which included crime scene location descriptions, how the offender approached the victim, verbal themes, and sexual acts performed. Dichotomous coding was used for all the variables (1 = presence of a behaviour during the offence, 0 = absence or unknown for a given behaviour).

It was not possible for the authors to assess the inter-rater reliability of these data as the coding was completed before it was provided to the authors. However, all data inputted onto the SCAS database is completed in-house in a controlled environment by a team of highly trained individuals. Applicants are tested for their attention to detail and ability to identify relevant information prior to employment with SCAS. Recruits undergo several months of training before they are allowed to work autonomously, and only after they obtain a highly detailed knowledge of the system. To ensure accuracy and knowledge the training is rigorous and lengthy, and recruits must show clear understanding of behavioural vagaries. Initial training is not undertaken on a live database, and staff will not begin working on the live database until they have evidenced their capability to complete inputs accurately. Ensuring consistency in decision making in relation to difficult issues, a 'Quality Control Guide' is utilized by everyone inputting data on the database. Where an unusual aspect is encountered, for which no precedent has been set, a dedicated, experienced team meets to review the situation and make a decision. This decision is then recorded for future reference to ensure future consistency. Additionally, each inputted case goes through a detailed quality assurance process prior to any analysis taking place. This involves a review of the inputted

information in comparison to case details, by an analyst from within the team and anomalies or errors are fed back to the inputter and amended on the database.

Analysis of data

As was outlined in the introduction to this article, Bennell and colleagues (Bennell & Jones, 2005; Bennell et al., 2009) have argued convincingly for the use of ROC analysis to test the assumptions of crime linkage. This study therefore followed a method pioneered by Bennell and Canter (2002), which has now been utilized in a substantial number of crime linkage studies (e.g., Bennell et al., 2009, 2010; Bennell & Jones, 2005; Tonkin et al., 2008; Woodhams & Labuschagne, 2012; Woodhams & Toye, 2007).

First, the Jaccard's coefficient was calculated for each crime pair in the dataset using a computer program created by Dr. Craig Bennell, called B-LINK^{5,6}. After calculating the Jaccard's coefficients the sample was split into linked and unlinked crime pairs. As outlined in the Introduction, traditionally studies have created linked and unlinked pairs from samples composed solely of serial offences (hereafter referred to as the "traditional method"). This was also done in the current study to aid comparison with existing studies. In addition, sampling was extended to include one-off sex offences allowing comparison of linked crime pairs with unlinked crime pairs containing offences by one-off offenders (referred to hereafter as the "extended method"). These unlinked crime pairs were termed serial-serial, serial-one-off, and one-off-one-off pairs, respectively. The sample contained 365 linked crime pairs for

⁵ The Jaccard's coefficients reported here were calculated based on all offence behaviours rather than categorizing behaviours into domains and then calculating a Jaccard's coefficient for each domain. This is because in existing studies (e.g., Bennell et al., 2009) as well as with this dataset, prediction using the coefficients generated from all offence behaviours was more accurate than that based on any individual domain. The output for individual domains can be obtained from the first author on request.

⁶ B-LINK (Bennell, 2002) calculates Jaccard's coefficient from dichotomously coded data about the crime scene behaviour in each offence in the dataset. The output from B-LINK contains Jaccard's coefficient and information about whether each pair is linked or unlinked.

both the traditional and extended methods. For the traditional method there were 18,356 unlinked crime pairs and in the extended method there were 29,281 unlinked crime pairs. Using either method, a significantly larger Jaccard's value for linked crime pairs compared to unlinked crime pairs would support the similarity and distinctiveness principles. This was assessed using Kruskal-Wallis tests because the distributions of the Jaccard's coefficients were significantly different to a normal distribution, as assessed by Kolmogorov-Smirnov tests.

The Jaccard's data were also subject to a leave-one-out cross-validation (LOOCV) logistic regression analysis (Herrmann, 1998) which involves:

Taking each case out of the dataset one at a time. When a given case has been extracted, a logistic regression model is developed using the remaining dataset (representing the development data), which is then applied to the extracted case only (representing the validation data) to produce a predicted probability. This case is then returned to the dataset and the procedure repeated with the next case in the dataset until cases have been exhausted" (Woodhams & Labuschagne, 2012, p. 93).

This statistical procedure has been used in previous crime linkage studies (Tonkin, et al., 2012; Woodhams & Labuschagne, 2012). A Receiver Operating Characteristic (ROC) analysis was conducted on the predicted probabilities produced by the LOOCV logistic regression to assess how accurately using Jaccard's coefficients (behavioural similarity) crime pairs could be classified as linked or unlinked. Linkage status (linked or unlinked) was the state variable and the predicted probabilities were the test variable. These analyses were conducted with SPSS version 19.

Finally, Youden's index was calculated which represents the decision threshold (in this case, the Jaccard's coefficient) at which the proportion of hits is maximized while the

proportion of false alarms is minimized (Bennell, 2005). This was calculated for both the traditional and extended sampling method. The equation for Youden's index is $J = p_H + p_{CR} - 1$, where p_H is the probability of a hit and p_{CR} is the probability of a correct rejection (Bennell & Jones, 2005). Having identified the Jaccard's coefficient at which the proportion of hits is maximized and the proportion of false alarms minimized, the sensitivity and specificity could be calculated, giving an indication of the error rate associated with adopting this statistical means of predicting linkage status. As applied to crime linkage, the sensitivity refers to the correct identification of linked crime pairs, and the specificity is the correct identification of unlinked crime pairs. Together sensitivity and specificity can be used to calculate the error rates, of Type I errors (false positives) and Type II errors (false negatives), which is the necessary information for Daubert criterion 3.

Results

Traditional Method of Testing Crime Linkage Principles (Series only sample)

The linked crime pairs had a median Jaccard's of .37 (Range = .04-1.00), whereas the unlinked crime pairs had a median of .16 (Range = .00-1.00). A Kruskal-Wallis test established that this difference was significant ($\chi^2(1, N=18721) = 595.50, p < .001$). The ROC analysis produced an Area Under the Curve (AUC) of .87 ($p < .001, 95\% \text{ CI} = .85-.89$) which represents an excellent level of predictive accuracy (Hosmer & Lemeshow, 2000). The ROC curve can be seen in Figure 1.

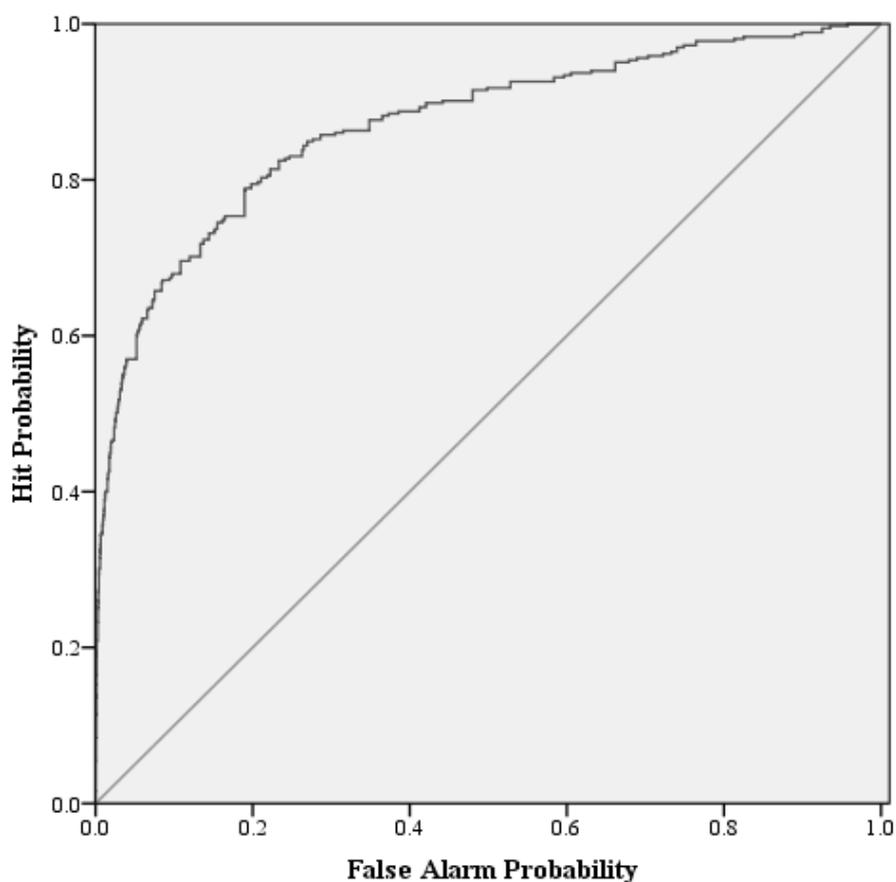


Figure 1. The ROC graph for the Traditional Method for differentiating linked and unlinked crime pairs using MO behaviours ($N = 18,721$). The Area Under the Curve (AUC), was .87 ($p < .001$, 95% CI = .85-.89).

Extended Method of Testing Crime Linkage Principles (Series and one-off offences sample)

The median of the linked crime pairs ($Mdn = .37$, Range = .04-1.00) indicated that they were more similar in crime scene behaviours than the unlinked crime pairs overall ($Mdn = .17$, Range = .00-1.00). This difference was significant ($\chi^2(1, N=29646) = 580.40, p < .001$). The AUC produced by the ROC analysis was .86 ($p < .001$, 95% CI = .84-.89) which represents an excellent level of discrimination accuracy. The ROC curve can be seen in Figure 2.

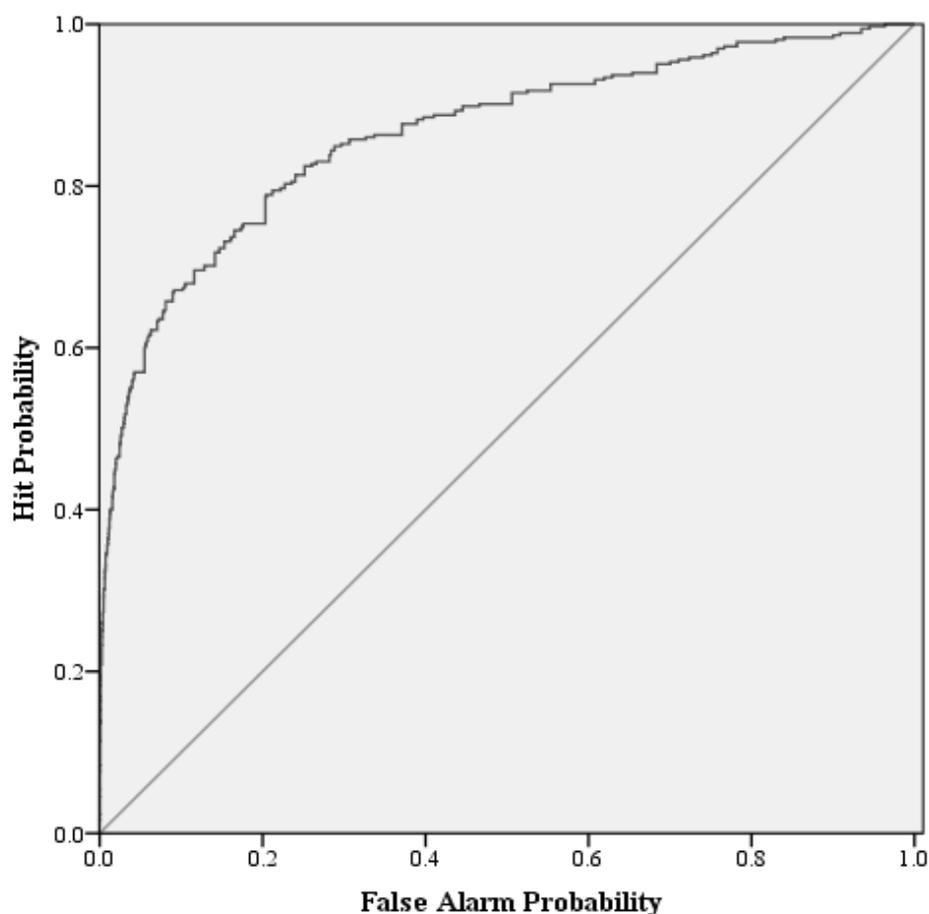


Figure 2. The ROC graph for the Extended Method for differentiating linked from unlinked crime pairs using MO behaviours ($N=29,646$) The Area Under the Curve (AUC) was .86 ($p<.001$, 95% CI= .84-.89).

The median Jaccard's coefficient for each type of unlinked crime pair was also calculated: serial/serial unlinked ($Mdn=.16$), serial/one-off ($Mdn= .17$), and one-off/one-off ($Mdn=.20$). Unlinked pairs created by pairing the crimes of two different serial offenders are therefore the most dissimilar in crime scene behaviour. A Friedman's test was conducted to compare the behavioural similarity of the three types of unlinked crime pair which produced a significant result ($\chi^2(2) = 94.30, p < 0.001$). Post hoc analysis using Wilcoxon signed-rank

tests with a Bonferroni correction indicated there were significant differences in Jaccard's coefficients between all types of unlinked crime pairs. When comparing serial/one-off unlinked to serial/serial unlinked it was found that $Z=-3.301$, $p=.001$, with a small effect size of $r=.0667$. For the one-off/one-off unlinked compared to the serial/serial unlinked $Z= -10.812$, $p<.001$, with a small effect size of $r=.218$. Lastly, when one-off/one-off unlinked were compared to serial/one-off unlinked $Z=-7.373$, $p<.001$, with a small effect size of $r=.149$.

When the Confidence Intervals (CI) for the AUCs produced using the traditional and extended method were compared they clearly overlap meaning that there is not a significant difference in discrimination accuracy (Bennell et al., 2009) whether distinguishing linked and unlinked pairs within a sample solely composed of sex offence series or within a sample comprising series and one-off sex offences. An attempt was made to further investigate the CI for the AUCs as there are times when overlapping CIs are not statistically equivalent (Knezevic, 2008), however ROCKIT 1.1B2 (copyright University of Chicago) could not handle the size of the dataset.

Decision-Making Thresholds

The Jaccard's coefficient that corresponded with the optimal threshold for the traditional sampling method was .245 and for the extended method was .241. The figures for specificity and sensitivity can be seen in Table 2. Under the traditional sampling condition, unlinked pairs were more accurately identified than linked pairs, as indicated by a larger proportion for specificity than sensitivity. The converse was true under the extended sampling condition although under both conditions the difference in size of proportions was only slight.

Table 2: Overview of the indices associated with the optimal decision thresholds (Youden's index) for the traditional method of creating unlinked pairs ($n = 18721$) and the extended method ($n = 29646$).

	Sensitivity	Specificity
Traditional (series only)	78.90	80.97
Extended (series and one-off offences)	79.45	78.63

Note: The equation for Youden's index is $J = p_H + p_{CR} - 1$, where p_H is the probability of a hit and p_{CR} is the probability of a correct rejection.

Discussion

In some jurisdictions, standards of admissibility (e.g., Daubert criteria and Rule 702) require the reliability of the assumptions of crime linkage to be empirically demonstrated and the error rate of crime linkage practice to be known. While several studies have attempted to assess these with serial sex offences, methodological limitations affect their ecological validity and therefore the conclusions that can be drawn. The current study was designed to address these limitations by including one-off sex offences in the dataset, ensuring a much larger sample of crime series than has been typical, and sampling all offences from each known series.

In 2008, Woodhams cautioned against using only series-series unlinked pairs in analyses of the crime linkage assumptions for fear of inflating the difference in behavioural similarity between the linked and unlinked pairs. The findings from the current study give credence to her concerns: the series-series unlinked crime pairs were the most dissimilar in crime scene behaviour. However, despite this, the linked crime pairs were significantly more similar in crime scene behaviour than the unlinked crime pairs under both testing conditions (traditional and extended). This provides support for the underlying principles of crime linkage. However, it should be noted that the linked crime pairs were characterized by a wide

range of Jaccard's coefficients. In theory, if crime scene behaviour is driven by personal characteristics and less so by the situation, linked crime pairs should be characterized by high behavioural similarity. This certainly appeared to be the case for some of the pairings in the sample which had Jaccard's coefficients of 1.00 (indicating perfect similarity). On further investigation it became apparent that these perfectly similar linked crime pairs had relatively few "present" behaviours for comparison (i.e., six or fewer). Within the linked crime pairs there were other pairs where the similarity in behaviour was virtually non-existent (with values of .04). Indeed, the distributions of Jaccard's coefficients for the linked and unlinked crime pairs overlapped quite considerably. These findings indicate that the principles of consistency and distinctiveness hold for some offence pairs better than others, which has implications both for the use of crime linkage in court but also for future research.

It is important that future research investigate the reasons for some offenders showing greater consistency than others. Possible avenues to explore include the psychological processes at work, specifically what is the function or meaning of the behaviour to the offender. It would be expected that those offenders who enact certain behaviours that hold a strong function or purpose would be more likely to repeat that behaviour. Alternatively, it may be that several different behaviours could all achieve the same, underlying function for the offender; hence, behavioural consistency would be less apparent, at least at the discrete behavioural level.

A more complete test of the principles underlying crime linkage was conducted using ROC analysis. Under conditions of traditional sampling, an AUC of .87 was found, representing an excellent level of discrimination accuracy. A similar figure (.86) was reported when sampling was extended to include apparent one-off sex offences in the dataset. Both

figures provide empirical support for the underlying principles of crime linkage; however, they also indicate that a degree of error still exists.

The AUCs found under both sampling conditions (.86-.87) are larger than the AUCs reported in existing studies of serial sex offenders (AUCs .75-.81) where researchers have artificially restricted the number of offences sampled per series to a constant value (e.g., Bennell et al., 2009; Bennell et al., 2010; Woodhams & Labuschagne, 2012). However, they are similar to the figure of .88 reported by Woodhams and Labuschagne (2012) where they included all offences from each series in the analysis ($N=119$ offences), which was the sampling method adopted in the current study. As Woodhams and Labuschagne (2012) argued, it is more ecologically valid to sample all offences from each series and it appears that artificially restricting the number of offences per series sampled might underestimate the potential for behaviourally linking crimes. Researchers are therefore urged to avoid restricting the number of crimes sampled per series in the future.

The inclusion of one-off sex offences in the analysis had the opposite effect to what was found by Winter et al. (2013). Unlike Winter and colleagues, who found a slight improvement in discrimination accuracy when including one-off offences, we found a slight decrease. This is likely attributed to the fact that in the current study the unlinked series-one-off pairs and the one-off-one-off pairs had larger Jaccard's coefficients than the series-series unlinked pairs. In this scenario it is more difficult to accurately distinguish linked from unlinked pairs because of the greater overlap in the Jaccard's distributions. However, the difference in AUC between the traditional and the extended method in this study was not found to be significant. Whether this would be the case if a larger sample of one-off offences was used is unknown at present. It is possible that this effect would be accentuated with a

larger sample of one-off offences and this is something that future research needs to investigate.

The Youden's indexes were also very similar. Assuming that the findings from this sample would generalize to real world practice the police could apply the threshold to proactively screen for potentially linked crimes. The police could maximize hits while minimizing the number of false alarms if when crime pairs exceeded a Jaccard's coefficient of .241 they were classified as linked. In terms of the error rate in this simulation of crime linkage decision-making (Daubert criterion 3), adoption of this threshold would result in 79% of linked pairs (sensitivity) being correctly identified and 79% of unlinked pairs (specificity). The sensitivity and specificity for both the traditional and extended methods are similar to the findings of Winter et al. (2013). In their study, the sensitivity was 77.78 and the specificity was 82.62 for serial offences only (traditional method) and 86.67 and 66.40 respectively for serial and one-off offences (extended method). It is, however, important to emphasize that, despite the current study more closely simulating the conditions under which practitioners make crime linkage decisions, it does not fully reflect how such procedures would be expected to perform in real life where human beings rather than statistical models are predicting linkage status.

Limitations

The dataset used in this study more closely reflected what investigators would be working with during an investigation, and therefore made progress towards closing the gap between how crime linkage is researched and how it is conducted in the real world. However, it still has a number of limitations associated with the method which mean that it does not fully represent how the crime linkage principles might operate in practice and this is

problematic when trying to produce research findings that would address criteria regarding admissibility.

As with much of the previous research in this area, the sample used here comprised the offences of convicted offenders (Mokros & Alison, 2002; Santtila et al., 2005). The crime linkage research community has previously raised concerns about this method of sampling and how well findings generated from such samples would apply to reality where crime linkage is conducted on unsolved offences (Bennell & Canter, 2002). However, a recent study by Woodhams and Labuschagne (2012) provides some reassurance since when comparing serial sex offence series first identified by the police (due to similar MO) to those first identified from DNA database hits, little evidence of a difference in behavioural similarity between the two types of series was found.

A further limitation, characteristic of any study that tries to sample one-off offenders, is that there can be no guarantee that those labelled as one-off offenders are not in fact serial offenders whose other offences have yet to come to the attention of the police. Some crime linkage studies label crime series on the basis of arrest and this has been criticized with recommendations that criminal convictions are used as a basis instead (Snook, et al., in press). Despite the crime series in the current study being labelled on the basis of a conviction, it is still not possible to completely guarantee that the offences included in a crime series are properly attributed because of the existence of miscarriages of justice. While none of these limitations can be overcome through improvements in design, it is still important that they be acknowledged.

It was not possible in the current study to know whether the analysts when coding the offences onto the ViCLAS database were blind to series membership. It is therefore unknown whether the coding of crime scene behaviour was influenced by knowledge of whether an

offence belonged to a series or not. However, a recent study by Pakkanen, et al. (2012), found that knowledge of the membership of an offence to a series did not appear to bias the coding of the behavioural data.

Finally, recent publications have queried the reliability of data contained within ViCLAS databases. Snook et al. (2012) tested the agreement between police officers coding a case file against the ViCLAS booklet. The study found only 10.38% of the variables reached acceptable levels of agreement, and the authors expressed concern about the implications for using such data for research. While these are valid concerns and indeed they warrant investigation, it is important to note that there are procedural differences between the coding of cases for ViCLAS in the UK compared to Canada (where Snook et al.'s study was based). In Canada, the case files are coded against the ViCLAS booklet by police officers; whereas in the UK, a select number of trained assistant crime analysts do the coding. This is the main task associated with their role. There are also a number of quality assurance procedures in place as was outlined above. Therefore, while an explicit test of inter-rater reliability for ViCLAS coding in the UK is needed, findings from Snook et al.'s study are not directly applicable.

Conclusion

In line with the standards of admissibility operating in some jurisdictions (e.g., Daubert, Federal Rules of Evidence 702), much of the research in the crime linkage field has assessed the reliability of its underlying principles. The findings have been largely supportive; however, these studies have a number of limitations which impact ecological validity. The current study sought to address many of these by sampling a much larger set of stranger sex offences than is typical, by sampling all offences from each crime series, and by including the

offences of one-off sex offenders in the dataset. Linked and unlinked crime pairs could be discriminated with excellent levels of accuracy as assessed by ROC analyses therefore providing further support for the underlying principles of crime linkage (behavioural consistency and distinctiveness), but this time with a more ecologically valid sample. However, the results also show that predictions of linkage status are not without error.

CHAPTER 4:
VARIATION IN BEHAVIOURAL CONSISTENCY AND DISTINCTIVENESS
ACROSS THE DIFFERENT STAGES OF RAPE

As mentioned in Chapter 3, one of the main principles underlying crime linkage is the assumption of behavioural consistency. This is the idea that an offender commits his/her offences in a consistent way, with similar behaviours displayed at multiple crimes. As discussed in chapters 1 and 3, there are several theories in personality psychology that support this assumption, such as the model called the Cognitive Affective Personality System (CAPS) that links personality and behaviour together (Mischel & Shoda, 1995). In this model it has been suggested that behavioural consistency will be observed in situations of psychological similarity (for more discussion on this please refer back to chapter 1). This concept has previously been applied to serial sexual assaults (Woodhams, et al., 2008). In addition, the literature reviewed in chapter 1 indicates that behavioural consistency would be expected in situations where the actor has greater control over the behaviour they display.

The similarities of situations constituting sexual assaults in a series could be affected by a number of factors including the reactions of the victims. This could account for the rarity of complete behavioural similarity observed between offences committed by the same serial sex offender in previous studies of the crime linkage principles (Bennell et al., 2009; Bennell et al., 2010; Slater, Woodhams, Hamilton-Giachritsis, 2015; Woodhams, et al., 2007; Woodhams & Labuschagne, 2012). For example, if the victim from the first crime complies with an offender's verbal threats, but the second victim does not and instead fights back, the offender would have to react differently. Previous authors of crime linkage studies (Bennell & Jones, 2005; Goodwill & Allison, 2006; Harbers, Deslauriers-Varin, Beauregard, & Van Der

Kemp, 2012; Oziel, Goodwill, & Beauregard, 2014; Woodhams & Labuschagne, 2012) have argued that some behaviours are more under the control of offenders than others.

The idea of situational similarity can be applied to crimes (and sexual crimes) at a number of levels (as argued by Woodhams et al., 2008). A single rape event could represent an entire situation, or it can also be broken down into multiple situations (or a series of situations) of separate interactions between the offender and victim. This chapter takes this idea further and considers how the three stages of rape, “approach,” “maintenance,” and “closure,” if thought of in this way could allow for greater/lesser situational interference and greater/lesser offender behavioural control and if this might manifest in varying levels of consistency across rape stages.

Offender Control and Behavioural Consistency and Distinctiveness

Hettema and Hol (1998) found that behaviours under primary control, rather than those produced in reaction to a stimulus, were more consistent over time. They defined primary control as, “behaviours directed at the external environment and involves attempts to change the world to fit the needs and desires of the individual” (p. 233). They have suggested that primary control is a major factor that increases the consistency of behaviours across situations. These findings are in line with the idea that the offender’s actions, when they are the sole motivator, should be the more consistent actions compared to those where the offender is reacting to victim behaviour or other situational factors (e.g., third-party disturbance).

There is also some empirical evidence to suggest that this observation holds with crime data. In their 2002 paper, Bennell and Canter proposed that many of the modus operandi behaviours used in crime linking are influenced by the context in which the crime is

committed. This would include what property is stolen during a burglary since this is dependent on what is available to steal at the scene. They contrasted such behaviours with inter-crime distance which is the distance between the locations of two crimes. They argued that inter-crime distance is a less situationally-dependent behaviour for linking because the offender decides where to commit his/her crimes. In 2005, Bennell and Jones, added to this argument when observing that inter-crime distance was a less useful linking feature when used with commercial as opposed to residential burglaries and they postulated that this was because commercial premises are clustered in their geographical location, meaning that the offender's decision about where to commit a commercial burglary is constrained by the environment more than is the case with residential burglaries. This clustering of the data does not allow the behavioural distinctiveness to become apparent. When the offender is able to choose his own targets, or cluster of targets, it can differentiate him from other offenders who would choose a different area. In theory, as the control the offender has over choices about modus operandi varies so too would his/her behavioural consistency.

Woodhams (2008) extended the investigation of inter-crime distance for linking to serial sex offences. In a sexual offence there are at least two crime locations; in her study the approach and offence location. She argued that the offence sites were actually where the offender had the most control over their behaviour, and therefore this more accurately reflected the offender's personality system. At these locations the offender is able to show consistency between their other offence locations, and differentiate them from others by those locations as well. In contrast, the approach sites would be determined by both offender and victim characteristics since this is where the routine activities of both coincide. As Cohen and Felson (1979) proposed with their Routine Activities Theory, for a crime to take place the time and space of the victim and offender's activities must coincide in the absence of a

capable guardian. Therefore, the approach location would be partially determined by the victim, and not the offender alone. Woodhams (2008) found that when comparing the geographic proximity of approach sites and offence sites for their utility in linking decision-making, that the offence sites ($AUC=.9937$) slightly outperformed the approach ($AUC=.9925$) sites.

Offender control of the offence can also reveal his signature behaviours. Hazelwood and Warren (2004) discussed that a signature is a unique combination of behaviours and actions which can be used to link a series to a single individual. Douglas and Munn (1992) even went so far as calling a signature the “calling card” of the offender, or the way to mark the crime as their own. The ability to control the situation allows the offender the time to display these signature behaviours, which can then be used to distinguish his offences from those of other offenders. It was the combination of behaviours that Hazelwood argued in the *State v. Fortin* case (as discussed in Chapter 1) that distinguished his crimes from other offenders. It was the combination of bites to specific locations combined with the method of strangulation, facial assault, and anal penetration that not only linked his two crimes together, but distinguished them from other severe sexual assaults (Labuschagne, 2014).

Situational Interference and Behavioural Consistency

At its most basic level, a rape is an interaction between two people, where the behaviours of one influence the reactions of the other. This idea of one actor’s behaviour being the situational input for the other actor in an interaction can be seen in the Cognitive Affective Personality System (Mischel & Shoda, 1995) as described in chapter 1. Grant and Woodhams (2007) argued that rape is a social interaction and that there may be aspects of a rape that are more constrained by the contact between the offender and the victim. It is

possible that in the stages where the victim has the least amount of ability to interfere, the offender may be the most consistent in their own behavioural pattern.

In their 2008 study, Woodhams, Hollin, and Bull, investigated the impact of situational similarity on behavioural consistency whereby they conceptualised situational similarity in terms of rape victim behaviour. They argued that victim behaviours vary in the demands they place on the offender, which could result in behavioural variability across offence series. They also suggested that if there is variation in the frequency of high demand behaviours (e.g., victim refuses to comply) during an offence it is expected that behavioural consistency should differ during the offence as well. In a follow-up paper to this, Woodhams, Hollin, Bull, and Cooke (2012) conducted a qualitative analysis of victim behaviours displayed during stranger sexual offences. This uncovered 122 different victim behaviours, highlighting the range of behaviour a rapist could encounter from victims within his series.

Three Stages of Rape

As noted above, researchers have argued that a rape offence can be divided up into three stages. Burgess and Holmstrom (1976) first discussed a rape offence as consisting of three separate stages that are temporally distinct from one another. The three stages they used when discussing how victims cope during a rape were before the attack, during the attack, and after the attack. In 1997 and later in 1999, Dale and colleagues (Dale, Davies & Wei, 1997; Kendall, McElroy & Dale, 1999) also used a three-stage approach when investigating the speech of rapists utilised during the offence. Their categories were “approach”, “maintenance” and “closure”. Each stage is described below.

Approach Stage. This stage includes the initial interaction between the rapist and the victim with the goal of the offender being to obtain control of the victim. Behaviours that

would be included in this stage include many that are completely reliant on the offender with no input from the victim as the victim will be unaware at this stage what the offender intends to do. These behaviours include such things as location selection and the way in which the offender approaches the victim (e.g., using a ruse such as asking for help). As outlined above, behaviours contained within this stage, such as these, could be argued to be less situationally-dependent, which would suggest that a greater degree of behavioural consistency would be observed in approach stage behaviours.

Past studies of linking serial sexual assaults have also classified behaviours into domains, finding that some domains are characterised by greater behavioural consistency than others (e.g., Grubin et al., 2001). Location selection would fall into the “control” domain (Grubin et. al., 2001) which was the domain characterised by the greatest behavioural consistency. However, not all the behaviours for the control domain fall solely in the Approach Stage, some can fall into all three stages.

It is important to remember that as part of the definition of the approach stage is that the victim is not aware of the intentions of the offender at this stage. This means it is the only stage that the offender may not have to alter his behaviours to accommodate the reactions of the victim. Based on the level of interaction between the offender and victim and the previous research on some of the control behaviours seen in this stage, it seems likely that this would be the stage where the offender will be most consistent across his offences.

Maintenance Stage. This is the stage that includes the sexual component of the offence and unlike the approach stage, the victim is fully aware of the offender’s intentions. As long as she has not been knocked unconscious during the approach phase (as could happen with a blitz rape), the victim may respond in a number of different ways. Her reaction could include fighting back or complying, very different reactions that lead to different responses

from the offender, and therefore different behaviours. Woodhams et al.'s (2012) study of rape victim behaviours, referred to above, found the greatest number of resistant behaviours from victims in this stage, including the most common behaviour of struggling. Behaviours in this stage could therefore place much higher task demands on an offender. There is also a chance that as more time has elapsed by this stage there is a greater chance of interruption from a third party, which would again force the offender to react depending on the stimulus provided. However, there are still controlling behaviours seen in this stage (e.g., binding the victim), which as noted above are believed to result in greater consistency across a series.

Closure Stage. The final stage is where the offender leaves the victim. Woodhams et al.'s (2012) analysis of rape victim behaviours found far fewer behaviours by victims at this stage compared to the other two, which is the same thing that was found in this study. This gives rise to conflicting hypothesis for this stage. First, fewer victim behaviours suggest less potential for victim resistance and interference. Greater situational similarity should follow and hence greater behavioural consistency. However, as this is the last stage in the offence, there is also greater potential for third party situational interference (mainly as a result in how the closure stage is coded in that it is the end of the offence, so when a third party intervenes it is then classified as the closure stage) which could result in behavioural variation within the same series.

Previous Crime Linkage Research and the Three Stages of Rape

As discussed in Chapter 4, within the study of crime linkage of sexual assaults, various different methodologies have been used to investigate behavioural consistency and distinctiveness. Some studies use overall similarity scores that include all the behaviours coded (Slater, Woodhams, & Hamilton-Giachritsis, 2015; Woodhams & Labuschagne, 2012),

while others split the behaviours into specific domains (Bennell & Canter, 2002; Bennell & Jones, 2005; Grubin et al., 2001; Woodhams, Grant & Price, 2007; Woodhams & Toye, 2007). With all these different approaches to analysing the datasets, previous studies have focused on the sexual offence in its entirety, coding for a certain behaviour if it is present at anytime during the offence, regardless of *when* it occurs during the offence.

In a more recent study, Oziel, Goodwill, and Beauregard (2014) separated the behaviours within each recorded sexual offence into four separate phases. These four stages were the pre-crime, victim selection, approach and assault. A sample of 147 offences with information collected during semi-structured interviews was used. They found that behaviours that were less dependent on situational influences were more stable, predictable, and consistent. They observed AUC scores of more than .80 in all four phases, and the linked crime pairs were more similar than the unlinked crime pairs. It was also noted that the behaviour in earlier phases (pre-crime and victim selection) were more consistent than the later phases (approach and assault), which led them to suggest that consistency may decrease with increased interaction between the victim and the offender. This would support the arguments made above.

However, this study had a number of limitations. One of the major drawbacks to this study is that they obtained their information about crime scene behaviour from interviews with offenders meaning it is highly likely that the data used to test the linkage principles is not equivalent to what would be available to a crime analyst. In addition, the study included a phase about pre-crime behaviour, which, again, is information that would not be available to practitioners attempting to link crimes together. In contrast the three stages of rape more typically referred to in the rape literature all equate with information that would be known to the police at the time of investigating an offence. The stages chosen by Oziel et al. would be

difficult to replicate with only knowledge held by the police at the time of the investigation. While they demonstrated that it is possible to split a rape offence into distinct phases and only code the behaviours for the phase in which each occurs, allowing for a better understanding of the context of the behaviours, it is unclear how applicable their research is to actual police investigations and court proceedings.

Rationale

There is merit in investigating how behavioural consistency and the validity of the crime linkage assumptions (behavioural consistency and distinctiveness) may fluctuate at different stages within a sexual assault. There may be stages in the offences that are more useful to investigators than others, and therefore in the future these stages can be focused on, thereby streamlining the coding process and subsequent analysis. Based upon studies of the consistency of behaviours when split into domains, and combined with the perceived capacity for interaction to occur between the offender and victim, it was expected that the approach stage would be the most consistent stage. It was thought most likely that this would be followed by the maintenance stage. It was difficult to predict the outcome for the closure stage, but it was not expected to outperform either of the previous two stages.

Method

Data

A sample of 50 serial offenders was obtained from the Serious Crime Analysis Section (SCAS), of the National Crime Agency, UK, as outlined in the Method section of Chapter 4.

A non-random sample of 193 serial, stranger sex offences was analysed⁷. All cases represented one lone offender assaulting a lone, adult, female victim, where the two were strangers to each other. The cases were all closed by conviction.

The 50 offenders were all adult males, with a mean age at the time of the offence of 31.69 years (range 18-58 years; $SD=8.76$). The majority of offenders were of White European ethnicity ($n=36$), the rest were Dark European ($n=8$), African or Caribbean ($n=6$), Asian ($n=1$), Arabic ($n=1$), or Other ethnicity ($n=2$). The mean series length was four offences and the mode was three offences (range 2-10 offences). One hundred and two of the offences were rapes, the rest were attempted rapes, assaults by penetration, indecent assaults, or indecent exposures (see Table 1 Serial Offences in Chapter 4). The remaining 30 offences were unclassified crimes with a sexual component.

The mean age of the victims at the time of offence was 29.46 years (range 18-76 years, $SD=11.58$). The majority of the victims identified as White European ($n=140$), the rest were Dark European ($n=3$), African or Caribbean ($n=2$), Asian ($n=2$), Arabic ($n=2$), or Other ($n=3$), and for 42 victims ethnicity was not recorded.

Procedure

The researcher stayed on site at SCAS facilities in Bramshill, UK, in order to code the 193 offences into the three stages of an offence. The researcher read through the narratives SCAS had developed from the victims' statements. The researcher recorded what behaviours occurred in each of the three separate stages. From the behavioural checklist, only behaviours that were present in a particular stage were included, leading to differing number of variables

⁷ One case was removed due to its unsuitability for the type of analysis presented here. Details regarding the nature of the offence and why it was removed cannot be given due to the need to protect the confidentiality of the data and protecting the victim's identity.

in the different stages. This meant that the Approach stage had 113 variables, the Maintenance stage 131 variables, and the Closure stage 92 variables. When a behaviour was present in more than one stage it was coded in every stage it was observed (e.g., a victim is bound in the approach, and stays bound for the maintenance stage it would be coded in both approach and maintenance in the dataset). Each variable was coded dichotomously, with a 1 representing the presence of an action or behaviour during that stage of the offence, and a 0 representing the absence or unknown data for that behaviour.

Analysis of data

The data were analysed using methods explained in Chapter 4, following the method pioneered by Bennell and colleagues (Bennell & Canter, 2002).

Results

Approach Stage

Using just the Jaccard's coefficient for the Approach stage behavioural variables, the linked crimes ($Mdn=.42$, Range= .06-1.00) were more similar than the unlinked crime pairs ($Mdn = .16$, Range =.00-1.00). As assessed by a Kruskal-Wallis test the difference was significant ($\chi^2(1, N=18528) = 490.35, p<.001$). The Area Under the Curve (AUC) produced by the ROC analysis was .83 ($p<.001$, 95% CI= .81-.86), which represents an excellent level of discrimination accuracy (Hosmer & Lemeshow, 2000).

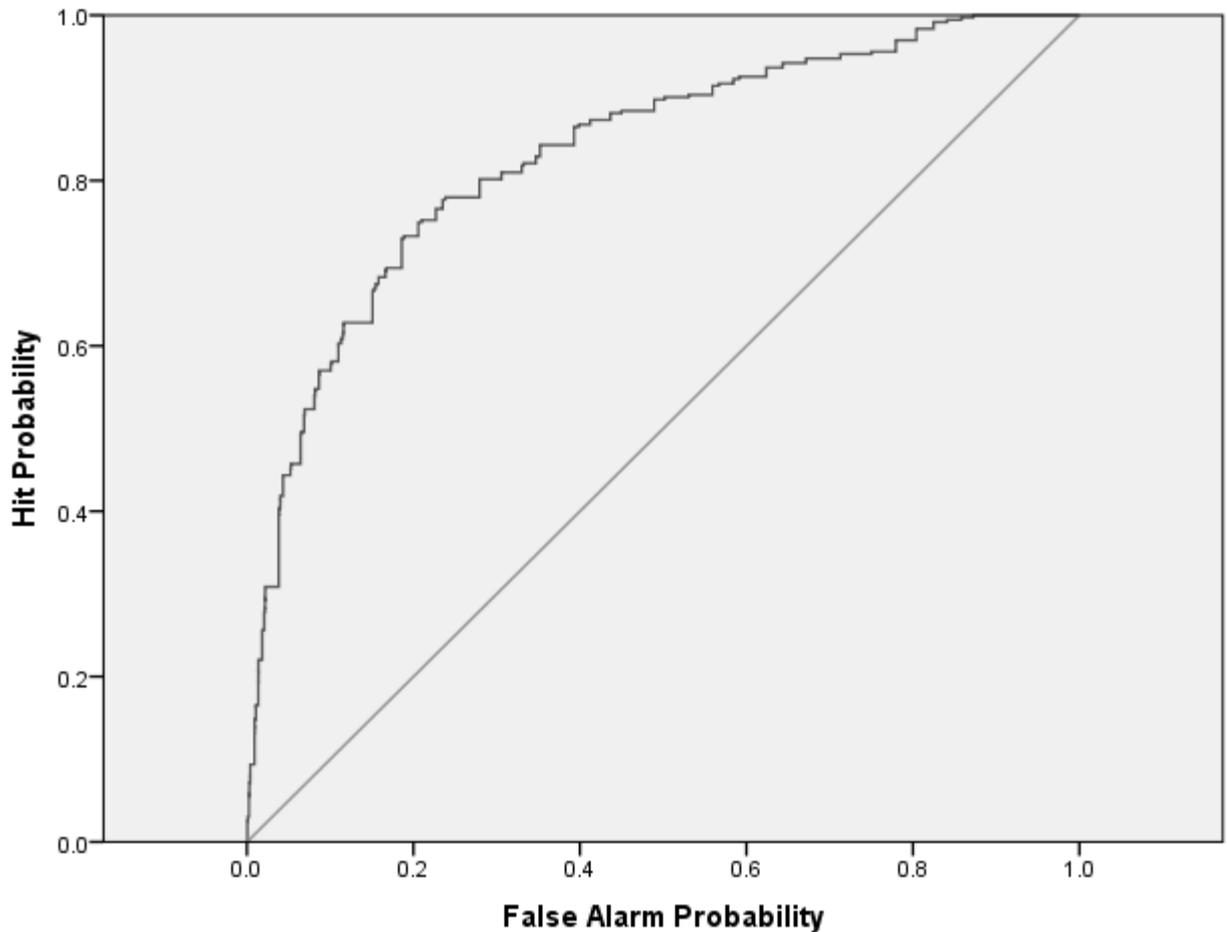


Figure 1: The ROC graph for the approach MO behaviours ($N=18,528$). The Area under the curve (AUC) was .83 ($p<.001$, 95% CI= .81-.86).

Maintenance Stage

The linked crime pairs ($Mdn=.35$, Range=.00-1.00) from the Maintenance stage were more similar in behaviour than the unlinked crime pairs ($Mdn=.15$, Range=.00-1.00). This difference was significant ($\chi^2(1, N=18528) = 486.88, p<.001$). The AUC of the ROC analysis was very similar to the previous stage at .83 ($p<.001$, 95% CI= .81-.86), which again is an excellent level of discrimination accuracy.

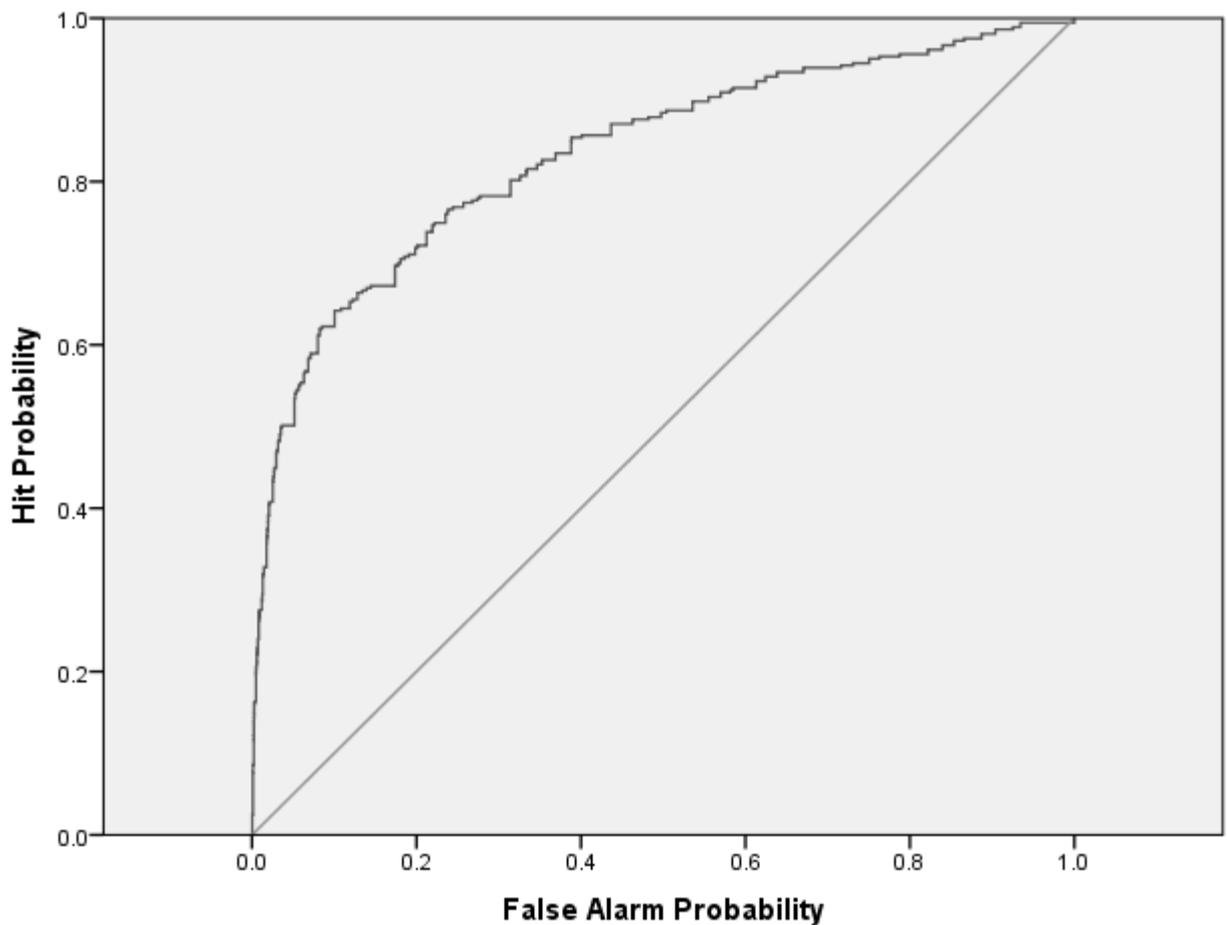


Figure 2: The ROC graph for the maintenance MO behaviours ($N=18,528$). The Area under the curve (AUC) was .83 ($p<.001$, 95% CI= .81-.86).

Closure Stage

The Jaccard's coefficients for the Closure stage for the linked crime pairs ($Mdn=.33$, Range=.00-1.00) were also larger and significantly different from the Jaccard's coefficients for the unlinked crime pairs ($Mdn=.16$, Range=.00-1.00) ($\chi^2(1, N=18528) = 301.38$, $p<.001$). The AUC for the Closure stage was .76 ($p<.001$, 95% CI= .73-.79), which represents a good level of discrimination accuracy (Hosmer & Lemeshow, 2000).

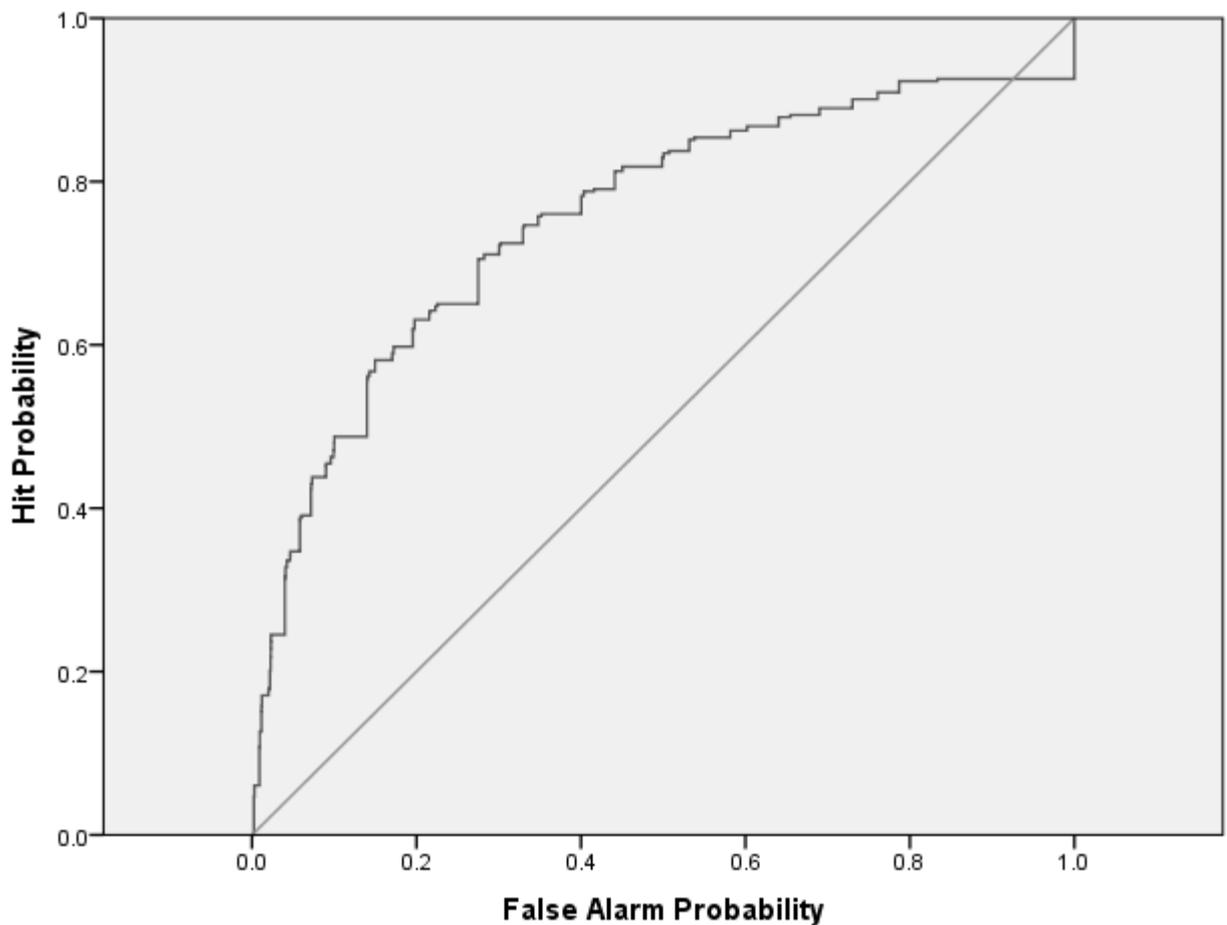


Figure 3: The ROC graph for the closure MO behaviours ($N=18,528$). The Area under the curve (AUC) was .76 ($p<.001$, 95% CI= .73-.79).

The Confidence Intervals (CI) for the AUCs of the three stages were compared. The Approach and Maintenance Stages had overlapping CIs, meaning it was assumed that there was not a significant difference in discrimination accuracy between these two stages (Bennell et al., 2009). When the CI of the Approach stage was compared to the CI of the Maintenance stage using an online program from VassarStats, it was found that there was no statistically significant difference in the two AUCs. However, the Closure stage CI did not overlap at all with the other two stages, meaning it was significantly different from the other two stages, which was confirmed when it was compared to the other two stages using the VassarStats

website ($Z= 3.526, p<.001$ for both comparisons). This means that similarity in behaviours in the Closure stage is less effective at distinguishing linked and unlinked crime pairs than similarity in behaviours displayed in the Approach and Maintenance stages.

Several post-hoc Wilcoxon signed rank tests were run to compare the Jaccard's coefficients derived for the linked crime pairs in each of the three stages. It was found that they all significantly differed from each other, but with small effect sizes. When the Approach Stage Jaccard's coefficients were compared with those of the Maintenance Stage it was found that they significantly differed ($Z= -6.980, p<.001, r=.259$). When the Approach Stage was compared to the Closure Stage it was $Z=-5.045, p<.001, r=.187$. Lastly, when the Jaccard's for Maintenance and Closure Stages were compared they were significantly different as well ($Z=-2.056, p=.040, r=.0763$).

Decision-Making Thresholds

The Jaccard's coefficient that corresponded with the optimal threshold for the Approach Stage was .292, the Maintenance Stage was .282, and .276 for the Closure Stage. The figures for specificity and sensitivity can be seen in Table 1. In all three stages the unlinked pairs were more accurately identified than linked pairs, as indicated by a larger proportion for specificity than sensitivity.

Table 1: *The sensitivity and specificity of the 3 stages*

Condition	Sensitivity	Specificity
Approach	73.28	81.13
Maintenance	64.19	89.95
Closure	63.09	80.24

Discussion

The purpose of this study was to investigate the possibility that behavioural consistency and the validity of crime linkage assumptions could fluctuate at different stages within a sexual assault. By giving attention to the stage in which a behaviour occurred, it allowed for the investigation of whether certain stages should be given greater weight when making linking decisions. It was predicted that the approach stage would be the most useful followed by the maintenance stage, based on the expected level of victim and offender interaction and previous studies on the domains to which behaviours occurring at different stages belong. The findings of this study were similar to what was predicted.

There were slight differences in the Jaccard's coefficients for the linked crime pairs for the Approach, Maintenance, and Closure stages. The ranges of the Jaccard's coefficients for the three stages significantly overlapped, with both the Maintenance and Closure stage coefficients ranging from 0 to 1. The Jaccard's coefficient for linked crime pairs is an indication of the behavioural consistency between offences by the same offender, and not behavioural distinctiveness.

When the confidence intervals of the three stages are considered, the Approach and Maintenance phase are significantly different from the Closure stage, but are not significantly different from each other. In all three stages Jaccard's scores were able to correctly predict linkage status at an acceptable level or higher. The Approach and Maintenance stages produced excellent levels of discrimination accuracy, whereas for the Closure stage only a good level of discrimination accuracy was reached (Hosmer & Lemeshow, 2000). The range of AUCs for this study, .76-.83, are of a similar range to other studies that have conducted a ROC analysis using *all* behaviours displayed during the crime rather than when the behaviours are separated into the three stages (.75, Bennell et al. 2009; .81, Bennell et al.

2010; .77-.88, Woodhams and Labuschagne, 2012; .74-.89, Winter et al. 2013). However, the AUCs for each stage were all smaller than the AUCs (.86-.87) found when all the behaviours from the whole offence were analysed with the same sample (chapter 4). Therefore, it should be noted that the use of all 217 behavioural variables was slightly more effective than when separating the behaviours by stages.

The lowest level of discrimination accuracy was achieved for the Closure stage of the offence. There are several possibilities as to why this stage had a lower level of behavioural consistency when compared to the other two stages. This stage had fewer variables (92 variables compared to the Approach stage with 113 variables and the Maintenance with 131 variables). In their 2012 paper, Tonkin, Woodhams, Bull, Bond and Santtila suggested that more variables could increase the potential for between-offender differences, which would allow for easier discrimination between offenders. It is also possible that the current behaviours coded for the Closure stage do not capture all possible behaviours that an offender displays and it would be worth investigating whether any additional behaviours are displayed that are not currently captured by the coding scheme used. There may also be a limitation on the information from this stage, as the data used in this study are based on victims' reports and are therefore constrained to the behaviours that the victim is able to observe.

Due to differences in methodology, it is difficult to directly compare the results from this study to those of Oziel, et al. (2014). However, it appears that the findings of their study and the current one are similar in that the behaviours that were less dependent on the situation were the more stable. The only two comparable stages are the approach stage which coincides with this study's approach stage, and the assault stage which is broadly comparable to the maintenance stage in this study. When the AUCs for these two stages are examined, they are very similar with all four scores ranging from .82 to .84. However, when the AUCs, for the

other stages are compared, those from the Oziel and colleagues study are higher than the AUCs in this study. This is most likely a result of the data used in the Oziel et al. study. Oziel et al. used data collected from semi structured interviews, the offender's file records, and court reports. The current studies, and many of the crime linkage studies, used ViCLAS data which are based upon victims' accounts, police systems, and other case papers to which the police would have access as part of the investigative process. As mentioned before, the different type of data included in Oziel et al.'s sample makes it difficult to gauge ecological validity, as some of the information included would not be known to the police during an initial investigation.

Separating each offence into three stages to examine consistency has suggested that behavioural consistency might vary across the offence. There are several possible explanations for what was found. It is possible, as previously mentioned, that there could be a restriction on how the behaviours in the Closure stage are coded. However, it could also be due to the influence of the victim on the offender, and the fact that the victim's influence may vary across all three stages of the offence. The last possibility is that there is some intrinsic variation in behavioural consistency (e.g., some offenders might be more relaxed at the end of the offence). With this last possibility, the application of the Hot/Cool framework proposed by Metcalfe and Mischel (1999), might explain the offender's actions. The play between the offender's "cool" cognitive system and a "hot", emotional system could explain the possible changes in actions and comfort levels during the offence. When the offender is in the hot mode, they are more intuitive and respond to the environment. Whereas during the cool phase, the offender is conscious of the possible repercussions to their actions and the potential ramifications of their actions. If the offender started in the hot phase and throughout the course of the offence switched to a cool mode of analysis. This could explain the change in

their responses to situational influences, as the cool mode is when the offender is less likely to just respond to the current situation.

In the future it might be advisable to separate the data by the approach style used by each offender. Certain approaches (e.g., a blitz approach, where an offender attacks straight away) severely limit victim interaction with the offender, which would allow for more offender control in those situations. It might be expected that blitz rapists would show greater consistency in their behaviour in subsequent stages than offenders who use a con approach (as mentioned in chapter 2, con approach is the use of confidence trickery in some way to mislead the victim). However, an unconscious victim can provide little information about how the offender acted with her beyond the approach stage which would negatively impact on the information available to calculate a similarity coefficient. It would be interesting to explore these possibilities and what they could mean for linkage accuracy.

Limitations

As with most other studies in this field, the reliance on convicted offenders for the dataset is a limitation (Mokros & Alison, 2002; Santtila et al., 2005). It is unknown if the findings based on convicted offenders will be applicable to crime linkage in the real world (Bennell & Canter, 2002). However, some new studies have started to include data from unsolved but linked by DNA offences, and these studies (Woodhams & Labuschagne, 2012) have provided some reassurance as their findings are similar to previous findings in the area.

Additionally, the allocation of behaviours into the three stages was conducted by a single researcher, with no inter-rater reliability check. The researcher was able to verbally check with another researcher on several difficult to classify points, but there was no opportunity to conduct a full inter-rater reliability assessment.

There may also be a limitation in the use of Jaccard's coefficient in conjunction with the ROC analysis in comparing the three stages of the offence. When there are more variables included in the calculation of the Jaccard's the predictive accuracy, as understood by the ROC curves, are slightly improved. This can be seen when comparing the full dataset ROC curve from Chapter 3 to the three stages ROC curves. Again this is present when the Approach and Maintenance are compared to the Closure, as both those stages had more variables included in their analysis and subsequently had better predictive accuracy.

Lastly, whilst it was still possible to achieve good levels of predictive accuracy with the stages, there may be better ways to divide the variables. Whilst previous researchers (Dale, Davies & Wei, 1997; Kendall, McElroy & Dale, 1999) have used the three stages, it would be useful to try other ways of dividing the variables. It may be possible to partition the offence into different stages than the current three. It may also be useful to talk with serial offenders and ask them to create behavioural groups based on their experience and planning. However, before any further research into dividing the variables takes place it would be useful to discuss with current or previous crime analysts to see if there is any useful application for them of splitting the variables into different categories.

Conclusion

Behavioural consistency was found to vary by stage of the rape. The higher AUCs were associated with stages (Approach and Maintenance Stages) where behaviours were perhaps under greater offender control with less potential for victim interaction (specifically the Approach Stage). However, an analysis that included all behaviours across all three stages outperformed any of the single stages of the offence, as revealed by Chapter 4. These findings, that utilising the behaviours from the whole crime rather than from one stage, results

in better discrimination accuracy, are similar to studies that have divided behaviours into domains (Bennell et al., 2009; Slater, Woodhams, & Hamilton-Giachritsis, 2015). It appears that the more information used in the analysis increases the discrimination accuracy. It is also likely that offenders vary in whether they show behavioural consistency at different stages as determined by actions earlier in the offence.

While it may not prove to be useful to code the data based on the stages of rape for crime linkage, it was useful to observe that good-excellent discrimination accuracy could be obtained with fewer variables. Even with less than 100 variables included in a data set, an acceptable range of predictive probability was achieved. This has wider implications on the coding of variables, as having fewer variables to code would help streamline the time-consuming nature of populating large-scale databases used in the linking task. However, it would be a larger undertaking to overhaul the way that offences are currently being coded. Until there is greater support from research for fewer necessary variables, it would be more work for the analysis to change the current system.

CHAPTER 5:

COMPARISON OF COEFFICIENTS USED IN CRIME LINKAGE ANALYSIS OF SEXUAL OFFENDING

In chapter 3, the main principles of crime linkage were tested according to one of the main methods in the area (Bennell & Canter, 2002), as well as expanded upon to make the test more ecologically valid. In the previous chapter, chapter 4, further expansions on this method were attempted. This chapter will continue to build upon the previous two chapters by examining the similarity coefficient that is used in the data analysis.

In the previous two chapters the methodology for crime linkage proposed by Bennell and Canter (2002) has been explained. This method includes the creation of crime pairs, linked pairs and unlinked pairs, which then have a similarity coefficient calculated for each pair. These similarity coefficients are then used as the input to leave-one-out cross-validation (LOOCV) logistic regression analysis and then Receiver Operating Characteristic (ROC) analysis. While different methods of analysis have been investigated, there are very few studies that examine if Jaccard's is the best coefficient to be using.

Coefficients of Similarity for Use with Binary Data

Jaccard's. As discussed in chapters 3 and 4, the current similarity coefficient that is used in many papers is Jaccard's coefficient (Jaccard, 1908). This coefficient has been widely used within the crime linkage literature, with Bennell, Mugford, Ellingwood and Woodhams (2013) finding at least 14 studies to have used Jaccard's. As argued by Melnyk, Bennell, Gauthier, and Gauthier (2011), compared to other measures, *J* is relatively straightforward to calculate.

$$J = \frac{a}{a + b + c}$$

J is calculated for a pair of crimes, where a is the number of behaviours shared in both crimes. The behaviours that are unique to each individual crime respectively, (C_1 and C_2) are represented in b and c . The value of J will then range from 0, where there is no similarity between the behaviours observed at the crime scenes, to 1, which is perfect similarity between the crimes.

As several other researchers have pointed out, one of the advantages of using Jaccard's is that the absence of a behaviour at both crimes is not included in the calculation, sometimes referred to as a joint non-occurrence (e.g. Bennell & Canter, 2002; Ellingwood et al., 2013; Goodwill & Alison, 2006; Melnyk et al., 2011; Woodhams & Toye, 2007). This is generally considered an advantage as it is not known whether that behaviour was indeed not present or if it was not witnessed, remembered, or reported to the police (Bennell & Canter, 2002; Alison, Snook & Stein, 2001).

Jaccard's is not without its drawbacks, however, and many have argued that it is relatively "crude" as a similarity metric (Bennell & Canter, 2002; Ellingwood et al., 2013; Melnyk et al., 2011; Woodhams et al., 2007). J is possibly overly sensitive to even slight variations in behaviours. When there are fewer behaviours present in the calculation of Jaccard's coefficient, slight variations can be given more weight than if there were more behaviours included in the calculation, meaning that, in some cases, a single behavioural difference can have a greater impact than with some of the other similarity coefficients.

Pearson's Phi. Sometimes referred to as the phi coefficient or Yule ϕ (Yule, 1912), Pearson's Phi estimates the association for two dichotomous variables (Cramér, 1946).

$$\varphi = \frac{ad - bc}{\sqrt{(a + b)(a + c)(d + b)(d + c)}}$$

For Pearson's Phi, a is the number of behaviours shared in both crimes; b and c , are behaviours unique to the individual crime. Additionally, d is the number of behaviours missing or absent from both crimes. Unlike Jaccard's the values of Pearson's Phi can range from -1 to 1. The -1 is perfect dissimilarity, and 1 is perfect similarity (Davenport & El-Sanhury, 1991).

The Simple Matching Index. Another possible similarity coefficient that has been suggested by others in the crime linkage literature is the Simple Matching Index (S ; Baroni-Urbani & Buser, 1976; Ellingwood, Mugford, Bennell, Melnyk, & Fritzon, 2103; Gower & Legendre, 1986; Kosman & Leonard, 2005.). One of the major appeals is the simplicity of the calculation of this coefficient, similar to the advantage seen in Jaccard's.

$$S = \frac{a + d}{a + b + c + d}$$

Like Jaccard's, S , is calculated for a crime pair, with a , b , and c , being the same as they were for Jaccard's (a , the number of behaviours shared in both crimes; b and c , behaviours unique to the individual crime). The addition of d is where the difference lies, where d is the number of behaviours missing or absent from both crimes.

As can be seen from the equation, the Simple Matching Index is similar to Jaccard's, with the main difference being that S accounts for the joint non-occurrences. Ellingwood and colleagues (2013) compared J and S to each other in cases of arson. They found that while S outperformed J in being able to accurately distinguish linked from unlinked crimes, it was not actually statistically significant. They argued that the slight difference was due to the joint non-occurrences providing more behavioural information to include in the analysis.

Sørensen–Dice. This coefficient comes from the work of botanists, Sørensen (1948) and Dice (1945). Differentiating it from Jaccard’s is the greater statistical “weight” that is given to the joint occurrences of behaviours in the two crimes.

$$D = \frac{2a}{2a + b + c}$$

The Sørensen–Dice is very similar to Jaccard’s. In the analysis, a is equal to the number of behaviours that occur in both crimes. As with Jaccard’s and the Simple Matching, b is where the behaviour occurs in C_1 but not C_2 , and c is where the behaviour does not occur in C_1 but does in C_2 .

Yule’s Q . Comes from Yule (1900) and Kendall and Stuart (1961, p.539). Unlike some of the other coefficients the results of the Yule’s Q can range from -1 to 1, and represent the correlation between two possibly related events, or in this case crimes, C_1 and C_2 . If the final Q is closer to -1, this is a negative correlation, whereas if it is closer to 1 it is a positive correlation of the behaviour. However, if it falls somewhere near 0, this is seen as there is no correlation between the two crimes.

$$Q = \frac{ad - bc}{ad + bc}$$

For this coefficient, a is the number of times behaviours appeared in both C_1 and C_2 . Counter to that is d , which covers the joint non-occurrences, or where behaviours did not happen in both crimes. Again similar to the b and c of Jaccard’s, Simple Matching Index, and Sørensen–Dice, b and c are where a behaviour occurs in one crime but not the other (b = the behaviour happening in C_1 but not C_2 ; c = the behaviour not occurring in C_1 but occurring in C_2).

Rationale

Currently Jaccard's coefficient is the most commonly used similarity coefficient in case linkage research. While there have been justifications for this on a statistical level (mainly the point that it does not include joint non-occurrences), a large scale comparison has not been completed to test if Jaccard's is the best coefficient. Specifically, comparing binary similarity coefficients has not been applied to serial sexual assaults. In the comparison of Jaccard's to the Simple Matching Index with cases of arson conducted by Ellingwood et al. (2013), the Simple Matching Index slightly outperformed Jaccard's. It would be useful to investigate if this holds true for sexual assaults as well or if any of the other coefficients outperform Jaccard's.

The decision of these four other binary similarity coefficients to include in the analysis were chosen for their overall simplicity and ease of understanding. Much of this thesis has focused on bridging the gap between academic crime linkage and practitioner linkage, and the relative ease of calculating these four coefficients was their main selection criteria.

In terms of application for crime linkage, it is important to see the impact of weighting different parts of the similarity coefficient on the overall predictive accuracy. This means they are operationalising behavioural similarity and consistency in slightly different ways. Some of the coefficients have more weight on joint occurrences, whilst others include joint non-occurrences.

Method

Data

The data used in this analysis is the same sample from Chapter 4, which included 50 one-off offenders and 50 serial offenders and their 193 sexual offences. The extended method

data set from Chapter 4 was used as it had been determined to be more ecologically valid, as it would hopefully better replicate police datasets with the mixture of serial and one-off offenders.

Procedure and Data Analysis

The coding of the behavioural variables followed the same procedure as in Chapter 4. There were 217 different MO behaviours, and all were coded dichotomously (1 = presence of a behaviour during the offence, 0 = absence or unknown for a given behaviour).

The analysis of the data followed the Bennell and Canter (2002) method that was used in Chapter 4 and 5. All the offences were paired together to create 365 linked crime pairs, and 29,281 unlinked crimes pairs.

Using the B-LINK program created by Dr. Craig Bennell, the five similarity coefficients were calculated for each crime pair. These similarity coefficients were then run through leave-one-out cross-validation (LOOCV) logistic regression analysis (Herrmann, 1998), followed by a Receiver Operating Characteristic (ROC) analysis, producing five separate ROC curves and AUCs. As with the previous Chapters (4 and 5), the ROC analysis used the predicted probabilities produced by the LOOCV logistic regression to assess how accurately crime pairs could be classified as linked or unlinked using the five similarity coefficients (behavioural similarity). Linkage status (linked or unlinked) was the state variable and the predicted probabilities were the test variable. These analyses were conducted using SPSS version 19.

Results

The linked crime pairs for all five coefficients had higher median scores than the corresponding unlinked crime pairs as can be seen in Table 1. All the ranges of the unlinked coefficient scores overlapped with the ranges of the linked coefficient scores.

Table 1: *Descriptive statistics for the linked and unlinked crime pairs for the five coefficients*

Coefficients	Range		Median	
	Linked	Unlinked	Linked	Unlinked
Pearson's Phi	.007 – 1.00	-.16 – 1.00	.48	.22
Simple Matching	.76 – 1.00	.65 – 1.00	.89	.85
Sørensen–Dice	.071 – 1.00	.000 – 1.00	.54	.29
Yule's Q	.045 – 1.00	-1.00 – 1.00	.91	.67
Jaccard's	.037 – 1.00	.000 – 1.00	.37	.17

The ROC analyses produced five Area Under the Curves (AUC) which can be found in Table 2. With these, the Confidence Intervals (CI) were also calculated and are included in the table. For the Pearson's Phi, Sørensen–Dice, Yule's Q and Jaccard's, the AUCs represented an excellent level of predictive accuracy (Hosmer & Lemeshow, 2000). Simple Matching coefficient only achieved a moderate level of predictive accuracy.

Table 2: *Comparison of the ROC analysis for the five coefficients*

Coefficients	AUC	Confidence Interval	Standard Error
Pearson's Phi	.88	.86 - .90	.010
Simple Matching	.75	.72 - .78	.013
Sørensen–Dice	.86	.84 - .89	.011
Yule's Q	.86	.84 - .88	.010
Jaccard's	.86	.84 - .89	.011

When the CIs for the AUCs were compared, all but those for Simple Matching coefficient overlapped, meaning that Pearson's Phi, Sørensen–Dice, Yule's Q and Jaccard's do not significantly differ in their discrimination accuracy⁸ (Bennell et al., 2009). The CIs for Simple Matching coefficient, however, do not overlap with those of the other similarity coefficients and are therefore significantly different, with a lower level of predictive accuracy.

Discussion

Whilst there exists much overlap between the range of coefficients for the linked and unlinked crime pairs, all five similarity coefficients were able to significantly differentiate between the linked and unlinked pairs as revealed by ROC analysis. For all coefficients except the Simple Matching coefficient, the levels of predictive accuracy were excellent. However, when the CIs were considered to compare the performances of the individual coefficients, none of them were able to statistically outperform Jaccard's. The only coefficient

⁸ As mentioned in the previous chapters (3 and 4), the dataset used in this analysis was too large to be able to compare the CIs in Rokit 1.1B.

that was statistically different was the Simple Matching coefficient, which was outperformed by all the other coefficients.

This finding differs from the findings of Ellingwood et al. (2013) who found that the Simple Matching coefficient slightly outperformed Jaccard's coefficient, although not statistically. This is possibly due to the fact that their study was on serial arson and the current study used a sample of serial sexual assaults. Not only are the crimes very different, so too was how the behaviours that formed the basis of the analysis collected. The Ellingwood et al. study was based on police records; the current study's data are based on victims' statements, police systems, and other case papers that were collected by the police. Therefore, some of the data for sexual assaults are based on the memories of the victims, whereas the arson reports rely almost entirely on observations from the police. This is potentially an important factor with the actual data analysis. When the Jaccard's is used, the non-occurrences are not included, whereas with Simple Matching Index they are. It may be that for arson, the non-occurrences are more reliable or stable and therefore more useful to the equation, giving Simple Matching the advantage. Whereas in a sexual assault the non-occurrences could be due to the victim not having observed a behaviour, forgetting a behaviour, or failing to report it in their account for whatever reason (Alison et al., 2001). This would give Jaccard's coefficient an advantage in this scenario because it does not include joint non-occurrences in its calculation.

Whilst it is useful to find support for the continued use of Jaccard's coefficient, there is still not perfect accuracy. In academic research this may prove frustrating for the researchers involved, but there are not larger consequences. However, for investigators and analysts there are larger implications of not having perfect accuracy with the statistical techniques employed. If a practitioner makes a mistake it can mislead investigations, miss

potential suspects, or even lead to conviction of innocent people; a set of consequences that practitioners have had to deal with when other areas of investigation, such as eye witness testimony, did not prove as reliable as originally thought (Clark, 2012). It will most likely never be possible to have perfect linking accuracy, every effort should be made to attempt to get as close as possible to perfect accuracy. To that purpose, the methods that are used in crime linkage should be tested to determine if and where improvements to the process are possible. The current study found that there is no added benefit of changing from the current procedures, and if a switch were made to simple matching, it would be less accurate. However, there is still a need to continue to test the statistical processes of crime linkage and accept improvements when they are found.

As mentioned in Chapter 2 the police are facing the strain of having to meet the guidelines of treating all stranger sexual offences as part of a potential series, a potentially costly process. An application of crime linkage that some researchers have started to consider is a computer program that would be able to run basic analysis and bring to the attention of analysts and investigators potential serial offences. In their 2007 paper, Yokota and colleagues designed a computer algorithm to predict to which offender each offence in their database belonged. It was moderately successful, but has not seen a wider adaptation; most likely due to the fact that they used a process that has not been replicated in other crime linkage research. However, their study was useful to show that there is potential for a computer program for crime linkage. The program would need to use the most accurate statistical process to be useful, and would need to meet specifications made by practitioners that would use the program. Continuing the research on the best statistical approach for crime linkage will bring the possibility of a computer program closer to being reality.

Limitations

As was mentioned in Chapters 4 and 5, this study has the same reliance on convicted offenders to form the dataset, and it is not possible to know how applicable the findings are to the real world. Additionally, this study used data from an interpersonal type of crime, where there is a victim who can provide information to the police; it is not clear if the same statistical findings would be found with other types of crime, such as acquisitional crime (e.g. burglary).

The main limitation of this study is that all the similarity coefficients chosen to be tested were all very similar in how they were calculated. Whilst this was useful in making more direct comparisons, there are many more similarity and also dissimilarity coefficients that should be considered as well. One that has been included in other crime linkage papers is Delta S (Woodhams, Grant, & Price, 2007a). The advantage of Delta S is that it can measure behavioural similarity and deal better with missing data than the similarity coefficients included in this study. It would be worth testing Delta S and several other similarity measures to find out if they are viable options and if they can outperform Jaccard's coefficient.

In addition to the reliance on similarity coefficients that were most similar to Jaccard's coefficient, this current study relied on analysis conducted using a cross-validation (LOOCV) and ROC. There have been questions raised in the crime linkage research as to possible other procedures for analysing the data (Winter et al., 2013). Other forms of analysis such as non-parametric Mokken scale analysis (MSA) paired with discriminant function analysis (DFA) or even including a naïve Bayesian classifier (NBC) (Winter et al., 2013). It would be useful to compare several of these other proposed statistical analysis against the different coefficients, and where a similarity coefficient is needed for the calculation test the other four

different similarity coefficients to gauge if one of them would work better than Jaccard's coefficient.

Conclusion

The current study found that Jaccard's coefficient did not outperform the other coefficients, with the exception of the Simple Matching coefficient. Instead, its performance was very similar to that of Pearson's Phi, Sørensen–Dice, and Yule's Q . Based on this study, it would be suggested that crime linkage research continue with the use of Jaccard's until there is a method found that can substantially improve predictive accuracy. The continued use of Jaccard's coefficient would allow for more direct comparisons with previous research. However, the study does suggest that future research may want to explore the use of different coefficients and other advanced statistical techniques in order to find the best way of running the statistical analysis of crime linkage.

CHAPTER 6: THESIS CONCLUSION

Thesis Aims

The overall aim of this thesis was to further our knowledge of crime linkage in its application to sexual assaults. By addressing some of the current gaps in the crime linkage literature, and addressing some of the limitations of past research, this thesis has tried to address some the differences that exist between the academic and practitioner application of crime linkage. The findings indicate some practical implications for crime linkage.

Summary of Findings

Chapter 2 investigated the behaviours of serial and one-off rapists to determine if certain behaviours were more prevalent for a certain type of offender. It was found that while there were some small differences between the two, overall, serial and one-off offenders were very similar in the way they commit rape. There was only a single behaviour that remained significantly different between the two types of offender after corrections were made, which was the solicitation of the victim by the serial offenders. Such findings mean that it is not practical for police to predict based on a few behaviours that an assault was committed by a serial or a one-off rapist. While it would be helpful to have a small number of behaviours that would be able to accurately predict if an offender was a serial or one-off offender, this study found that there is little difference in terms of behaviour between the two types. With the HMIC and HMICPS (2012) advising in their report to treat every stranger rape as a serial rape, this study supports that suggestion, especially in the case of the victim having been solicited by the offender.

The findings that the two types of offender are not significantly different does open the debate on whether they are truly different categories, or if the one-off offenders are just serial offenders who have been caught. If this is the case it is even more of an argument that the one-off offenders should be included in the datasets being used for crime linkage. If one-off offenders are really serial offenders there is a chance that at some point there will be another one of their offences to include in the dataset. The inclusion of the one-off offenders in academic data would better replicate the databases used by practitioners.

The aim of Chapter 3 was to re-examine the basic underlying assumptions of crime linkage but with a sample that improved on much of the previous research. The sample was larger than previous studies and broadened to expand upon the traditional method of conducting crime linkage. This expansion of the sample to include one-off offenders, which had not been extensively researched before with most samples relying solely on serial offences (where sexual offences are the main crime of the research), attempted to decrease the gap between the academic research of crime linkage and real world practice. Following the methods introduced by Bennell and Canter (2002), the traditional sample of only serial offenders was analysed. It was found that it was possible to predict the linkage status of crime pairs at an excellent level of accuracy. This was in line with previous research and further supported the basic assumptions of crime linkage.

The extension of the traditional method was the inclusion of one-off offenders. This had been done sporadically over the history of crime linkage research (Grubin et al., 2001; Winter et al., 2013; Yokota et al., 2007) but had not been done previously with the application of the Bennell and Canter (2002) method of analysis. It was found that it was possible to predict if a crime pair were linked or not at an excellent level of accuracy, which reflects what has been found with samples solely consisting of serial offenders (Bennell et al., 2009;

Bennell et al., 2010; Woodhams & Labuschagne, 2012). This was encouraging as police databases would consist of a mixed sample of serial and one-off offenders. However, as discussed in the chapter, the exact ratio of the two types of offenders is unknown. After only one such study it is also impossible to predict the impact of different ratios of one-off: serial offenders in the sample. It is possible with a higher ratio of one-off: serial offenders that the slight drop in the AUC could be more pronounced and therefore not as accurate for predicting crime pairs. However, overall the study supported the basic assumptions of crime linkage.

Chapter 4 attempted to build upon the previous chapter and some of the theories on situational similarities from Chapter 1. However, instead of including all the behaviours in one large dataset to analyse, the behaviours were split into the stages of the rape in which they occurred; the Approach, Maintenance, or Closure stage. There are fewer variables present in an individual stage of a rape than in the course of the full offences, which could potentially reduce the efforts involved in conducting crime linkage by requiring analysts to code fewer variables onto large-scale crime databases and to consider fewer in their analyses. The behaviours reported during an offence were split into the three stages of a rape: the Approach, Maintenance, and Closure stages. Then these three datasets were analysed following the procedure used in the previous chapter. It was found that the Approach and Maintenance stages slightly outperformed the closure stage. All three were found to have high levels of predictive accuracy. However, the findings from the full dataset, with all the variables included in one analysis, outperformed any of the three stages conducted separately. Therefore, despite any potential gains in reducing time in coding the large dataset, the data suggests that the accuracy is improved when all behaviours are coded for an offence.

In Chapter 5 the method used in Chapters 3 and 4 to analyse crime linkage principles was examined. Traditionally, crime linkage studies have adopted Jaccard's coefficient to

measure the degree of behavioural similarity between two crimes in a dataset, and are then used in a ROC analysis. However, there are several other coefficients available to researchers that might perform better than Jaccard's coefficient. This chapter tested a range of different coefficients that crime linkage researchers could use. To test this, a single sample was used to analyse the data, but 5 different coefficients were used. These coefficients were: Simple Matching, Yule's Q , Pearson's Phi, Sørensen–Dice, and Jaccard's.

It was found that all coefficients except the Simple Matching coefficient had overlapping Confidence Intervals. This means that Yule's Q , Pearson's Phi, Sørensen–Dice, and Jaccard's, while differing just slightly (with the Pearson's Phi slightly more accurate in predicting, than Jaccard's, Sørensen–Dice, and Yule's Q) were not significantly different from each other in terms of overall predictive accuracy. However, the Simple Matching coefficient was outperformed by all the other coefficients.

This result is different from the one other similar study by Ellingwood et al. (2013), which found that the Simple Matching coefficient slightly outperformed Jaccard's. This may be due to the types of crimes used in the sample, as Ellingwood et al. (2013) used a sample of arson cases, and the current study was on sexual assault. Within crime linkage research there are different variables that work better depending on the type of crime that is being investigated. With high volume crimes (e.g. robberies, arsons and car thefts) using temporal and geographic linking has worked best (Davies, 1992; Goodwill & Alison, 2006; Markson, Woodhams, & Bond; 2010). However, sexual offences can sometimes be missing this information and behavioural linking has been more accurate. It is possible that different similarity coefficients could be used depending on the type of crime being investigated. Additionally this may also have to do with the way that the similarity coefficients are calculated. Simple matching includes in its equation joint non-occurrences and Jaccard's does

not. It is possible that because of the variables being coded for it is better to leave joint non-occurrences out of the sexual offence based linking but include it for the volume crimes, where there may not be victim statements to assist in behavioural evidence. While further research will still need to be conducted, there is no reason to switch to another coefficient, especially as Jaccard's is one of the easiest to calculate, and does not include the joint non-occurrences in the calculation.

The findings of Chapter 2 showed that if there is any significant difference between one-off offenders and serial offenders it is not immediately apparent from their behaviours. This means that there is no quick and easy, or cost effective way, for police to determine from the early stages of an investigation if a crime is part of series or not. The only indication they would have is if the victim was solicited by the offender before the attack, if this is the case then it is more likely to be part of a series. However, there was no single behaviour or cluster of behaviours that would lead them to believe a crime was a one-off offence. Instead the findings from Chapter 2 support the HMIC and HMICPS recommendation (2012) to treat all of their investigations of stranger sexual offences as part of a series. As Rainbow (2014) mentioned in his response to this recommendation, it is potentially costly for the police not only in money and resources but also in time (2014). Crime linkage has the potential to assist in this process and help investigators focus on crimes that are more statistically likely to be committed by the same offender. This is where the findings from the remaining empirical chapters (Chapters 3, 4, and 5) assist in understanding how best to apply crime linkage to sexual offences.

In the three crime linkage focused empirical chapters (Chapters 3, 4, and 5), the main findings from these chapters is that crime linkage is not only possible at a significant level, it is also currently being conducted in the most efficient way. Chapter 3 followed the method

first established by Bennell and Canter (2002), which is now the most widely used statistical procedure in crime linkage (e.g., Bennell et al., 2009, 2010; Bennell & Jones, 2005; Tonkin et al., 2008; Woodhams & Labuschagne, 2012; Woodhams & Toye, 2007). This chapter replicated the previous findings that crime linkage was possible with sexual offences, and showed that it could work on a larger scale than the previous studies. When the extended method (the addition of one-off offences to the dataset) was analysed it was found that again crime linkage was possible and still at an excellent level of predictive accuracy. This supported the use of the Bennell and Canter method (2002) for crime linkage, even when the data started to more closely resemble the data that practitioners (e.g., crime analysts and investigators) of crime linkage would work with.

The last two empirical chapters (Chapters 4 and 5) focused on testing if there were ways of improving on the Bennell and Canter method (2002). Both of these chapters found that it was possible to achieve good to excellent levels of predictive accuracy with the Bennell and Canter method, even when alterations were made to the procedure. However, both chapters also found that there was no statistically significant improvement to the predictive accuracy of the new procedures over the original method. With Chapter 4, crime linkage with all behaviours included had a slightly higher AUC than splitting the behaviours by stages. In Chapter 5, none of the other similarity coefficients significantly outperformed Jaccard's, and Jaccard's did outperform one similarity coefficient (Simple Matching Coefficient). These two chapters show support to continue to use the Bennell and Canter method (2002) as the most effective statistically.

The empirical chapters when considered all together support the use of crime linkage and the current method. This method could be applied in a similar manner to how it was in Chapter 3 to a police database to determine if there are pairs of crimes that should be

investigated as potentially linked. However, that would still be a significant amount of work for practitioners to run the analysis after every new case was entered into the database. Instead there may be the possibility of designing a computer program or statistical package that would run a crime linkage statistical analysis for the practitioner and highlight any potentially linked cases. Currently the best statistical method would be the Bennell and Canter method (2002). The method has shown that it works with large datasets with mixed serial and one-off offenders, as seen in Chapter 3. The method is also the most widely used and accepted with crime linkage literature, especially for sexual offending. Until research supports a different method of conducting crime linkage, the Bennell and Canter method (2002) should continue to be the one that is used.

Future Directions

In regards to future directions in the area of crime linkage, this thesis highlights some areas for future enquires. Of the limitations mentioned, the one that should be the main focus of further research is addressing practitioner and court system needs for the area. In order for crime linkage to be wholly admitted to the courts and embraced as an admissible form of evidence, certain criteria still need to be met. As mentioned in Chapter 4, the rules for admitting evidence to the courts are stringent, and one of the areas that need to be prioritised in the research is the establishment of base rates. The priority would be on base rates of individual behaviours; the frequencies that the individual behaviour is observed in commission of that type of crime. These would be useful in informing not only analyst but also judges and juries on which behaviours are more common than others, and if certain behaviours by themselves are useful for distinguishing between offenders or if it is a behaviour shared amongst most offenders.

Another limitation that exists in much of the current crime linkage research is the reliance on solved crimes. As mentioned in Chapters 2, 4, 5, and 6, it is unknown how solved crimes differ from unsolved crimes, which could impact the application of the current research to real world crime linkage. There are several papers that have recently started to address this issue through the inclusion of cases in samples that are unsolved but linked by DNA (Tonkin, Woodhams, Bull, & Bond, 2012; Woodhams & Labuschagne, 2012). This allows for testing of the theories and processes of crime linkage with crimes that have yet to be solved.

Another future direction to investigate comes from Chapter 6. It would be useful to test the similarity coefficients, especially Jaccard's and the Simple Matching, on other types of volume crime and other samples of sexual offences. This could be done relatively easily upon datasets that have already been used for crime linkage. However, it would be useful to determine if volume crimes and sexual offences are able to be predicted more accurately with different similarity coefficients.

The last area of future research is also based on a current limitation in crime linkage, which is that there is a need for the offender to become a serial offender before linkage can be done. However, some criminals are diverse in the crimes that they commit. It would warrant further investigation to determine if offenders committed different types of crimes in similar ways. If this was found to be the case, investigators would not need to wait for an offender to become a serial sexual offender. By doing it this way it would increase the pool of suspects in which one could search for an offender. So if you had one or more suspected serial sex crimes you could look to other crime types for potential suspects if there is consistency across crime types. One chapter by Tonkin (2014) has started to explore this area, using two studies, Tonkin, Woodhams, Bull, Bond and Palmer (2011) and Tonkin, Woodhams, Bull and Bond

(2012). He was able to find moderate to high levels of discrimination accuracy with simple measures of spatial and temporal behaviours across crime categories. However, it remains to be seen if this applies to sexual offences. One of the key elements to this area of research is to find an indication in the MO as to what sort of “other crime type” you need to search within, or which other crime type would use a similar set of behaviours.

Conclusions

In conclusion, the thesis can be considered successful in furthering our understanding of crime linkage research in its application to sexual assaults. The empirical studies were able to provide a better understanding of how serial and one-off offenders are similar and where they differ, as well as the impact of the inclusion of one-off offenders in crime linkage research.

Furthermore, the process of analysing crime linkage was investigated, attempting to fill some of the gaps in the research on crime linkage. These new studies warrant replication.

Ultimately, further research that has been suggested would help bring the academic and the practical applications of crime linkage closer together and potentially aid many people and police forces.

REFERENCES

- Alison, L., Bennell, C., Mokros, A., & Ormerod, D. (2002). The personality paradox in offender profiling: A theoretical review of the processes involved in deriving background characteristics from crime scene actions. *Psychology, Public Policy, and Law*, 8(1), 115-135. doi:10.1037/1076-8971.8.1.115
- Alison, L., Goodwill, A., Almond, L., van den Heuvel, C., & Winter, J. (2010). Pragmatic solutions to offender profiling and behavioural investigative advice. *Legal and Criminological Psychology*, 15(1), 115-132. doi:10.1348/135532509X463347
- Alison, L. J., Snook, B., & Stein, K. L. (2001). Unobtrusive measurement: Using police information for forensic research. *Qualitative Research*, 1(2), 241-254. doi:10.1177/146879410100100208
- Allen, W. D. (2007). The reporting and underreporting of rape. *Southern Economic Journal*, 73(3), 623-641. doi: 10.2307/20111915
- Allport, G. W. (1937). *Personality: A psychological interpretation*. New York: Holt, Rinehart.
- Barnard, M. (1993). Violence and vulnerability: Conditions of work for streetworking prostitutes. *Sociology of Health and Illness*, 15, 683-705. doi:10.1111/1467-9566.ep11434434
- Bartels, R. M., & Gannon, T. A. (2011). Understanding the sexual fantasies of sex offenders and their correlates. *Aggression and Violent Behavior*, 16, 551-561. doi:10.1016/j.avb.2011.08.002

- Bateman, A. L., & Salfati, C. G. (2007). An examination of behavioral consistency using individual behaviors or groups of behaviors in serial homicide. *Behavioral Sciences & the Law*, 25(4), 527-544. doi: 10.1002/bsl.742
- Beauregard, E., & Leclerc, B. (2007). An application of the rational choice approach to the offending process of sex offenders: A closer look at the decision-making. *Sexual Abuse: A Journal of Research and Treatment*, 19, 115-133.
doi:10.1177/0093854807300851
- Beauregard, E., Rossmo, K., & Proulx, J. (2007). A descriptive model of the hunting process of serial sex offenders: A rational choice perspective. *Journal of Family Violence*, 22, 449-463. doi:10.1177/0093854807300851
- Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society. Series B (Methodological)*, 289-300. Retrieved from
www.math.tau.ac.il/~ybenja/MyPapers/benjamini_hochberg1995.pdf
- Bennell, C. (2002). *Behavioural consistency and discrimination in serial burglary* (Doctoral dissertation). Retrieved from OCLC WorldCat. (498749926).
- Bennell, C. (2005). Improving police decision making: General principles and practical applications of receiver operating characteristic analysis. *Applied Cognitive Psychology*, 19, 1157–1175. doi:10.1002/acp.1152
- Bennell, C., & Canter, D. (2002). Linking commercial burglaries by *modus operandi*: Tests using regression and ROC analysis. *Science and Justice*, 42, 1-12. doi:10.1016/S1355-0306(02)71820-0.

- 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 linkage analysis. *Forensic Science International*, 199, 85-92. doi: 10.1016/j.forsciint.2010.03.017
- Bennell, C. & Jones, N. J. (2005). Between a ROC and a hard place: A method for linking serial burglaries by modus operandi. *Journal of Investigative Psychology and Offender Profiling*, 2, 23-41. doi:10.1002/jip.21
- Bennell, C., Jones, N. J., & Melnyk, T. (2009). Addressing problems with traditional crime linking methods using receiver operating characteristic analysis. *Legal and Criminological Psychology*, 14, 293-310. doi:10.1348/135532508X349336
- Bennell, C., Mugford, R., Ellingwood, H., & Woodhams, J. (2014). Linking crimes using behavioural clues: Current levels of linking accuracy and strategies for moving forward. *Journal of Investigative Psychology and Offender Profiling*. Doi: 10.1002/jip.1395
- Bosco, D., Zappala, A., & Santtila, P. (2010). The admissibility of offender profiling in courtroom: A review of legal issues and court opinions. *International Journal of Law and Psychiatry*, 33, 184-191. doi:10.1016/j.ijlp.2010.03.009
- Bourke, P., Ward, T., & Rose, C. (2012). Expertise and sexual offending: A preliminary empirical model. *Journal of interpersonal violence*, 27(12), 2391-2414. doi:10.1177/0886260511433513
- Bownes, I. T., O'Gorman, E. C., & Sayers, A. (1991). Rape – a comparison of stranger and acquaintance assaults. *Medicine, Science and the Law*, 31, 102-109. doi:10.1111/j.1600-0447.1991.tb05507.x

- British Crime Survey and other surveys. *Home Office*. Retrieved October 29, 2015, from <http://webarchive.nationalarchives.gov.uk/20110314171826/http://rds.homeoffice.gov.uk/rds/bcs1.html>
- Burgess, A. W., & Holmstrom, L. L. (1976). Coping behavior of the rape victim. *American Journal of Psychiatry*, *133*(4), 413-418. doi:10.1176/ajp.133.4.413
- Canter, D. (1995). Psychology of offender profiling. In R. Bull, & D. Carson (Eds.), *Handbook of psychology in legal contexts* (pp. 343-355). Chichester, Hampshire : Wiley.
- Canter, D. (1996). A multivariate model of sexual offence behaviour: Developments in 'offender profiling'. In D. Canter (Ed.), *Psychology in action* (pp. 189-216). Hampshire, UK: Dartmouth Publishing Company.
- Canter, D. (2000). Offender profiling and criminal differentiation. *Legal and Criminological Psychology*, *5*(1), 23-46. doi:10.1348/135532500167958
- Canter, D., Bennell, C., Alison, L. J., and Reddy, S. (2003). Differentiating sex offences: A behaviorally based thematic classification of stranger rapes. *Behavioral Sciences and the Law*, *21*, 157-174. doi: 10.1002/bsl.526
- Canter, D. & Youngs, D. (2003). Beyond 'offender profiling': The need for an investigative psychology. In D. Carson, & R. Bull (Eds.), *Handbook of psychology in legal contexts* (2nd ed., pp. 171-206). Chichester: Wiley.
- Caspi, A., & Herbener, E. S. (1990). Continuity and change: assortative marriage and the consistency of personality in adulthood. *Journal of personality and social psychology*, *58*(2), 250. doi: 10.1037/0022-3514.58.2.250

- Charron, A. & Woodhams, J. (2010). A qualitative analysis of mock jurors' deliberations of linkage analysis evidence. *Journal of Investigative Psychology and Offender Profiling*, 7, 165-183. doi:10.1002/jip.119
- Clark, S.E. (2012). Costs and benefits of eyewitness identification reform. *Perspectives on Psychological Science*, 7(3), 238-259. doi: 10.1177/1745691612439584
- Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: A routine activity approach. *American sociological review*, 588-608. doi:10.2307/2094589
- Corballis, M. C. (2011). *The recursive mind: The origins of human language, thought, and civilization*. Princeton, NJ: Princeton University Press.
- Corovic, J., Christianson, S. Å., & Bergman, L. R. (2012). From crime scene actions in stranger rape to prediction of rapist type: Single-Victim or serial rapist?. *Behavioral Sciences and the Law*, 30(6), 764-781. doi: 10.1002/bsl.2026
- Cramér, H. (1946). *Mathematical methods of statistics*. Princeton, NJ : Princeton University Press.
- Dale, A., Davies, A., & Wei, L. (1997). Developing a typology of rapists' speech. *Journal of Pragmatics*, 27(5), 653-669. doi:10.1016/S0378-2166(96)00060-4
- Daubert v. Merrell Dow Pharmaceuticals, 509 U.S. 579 (1993).
- Davenport, E. C., & El-Sanhurry, N. A. (1991). Phi/phimax: Review and synthesis. *Educational and psychological measurement*, 51(4), 821-828. doi:10.1177/001316449105100403
- Davies, A. (1992). Rapist's behavior: A three-aspect model as a basis for analysis and the identification of serial crime. *Forensic Science International*, 55, 173–194. doi: 10.1016/0379-0738(92)90122-D

- Davies, K., Tonkin, M., Bull, R., & Bond, J. W. (2012). The course of case linkage never did run smooth: A new investigation to tackle the behavioural changes in serial car theft. *Journal of Investigative Psychology and Offender Profiling*, 9(3), 274-295. doi: 10.1002/jip.1369
- Dice, L. R. (1945). Measures of the amount of ecologic association between species. *Ecology*, 26(3), 297-302. doi :10.2307/1932409
- Douglas, J. E., & Munn, C. (1992). Violent crime scene analysis; Modus operandi, signature, staging. *FBI Law Enforcement Bulletin*, 1–10.
- Douglas, J. E., Ressler, R. K., Burgess, A. W., & Hartman, C. R (1986). Criminal profiling from crime scene analysis. *Behavioral Sciences and the Law*, 4, 401-421. Doi:10.1002/bsl.2370040405
- Dowden, C., Bennell, C., & Bloomfield, S. (2007). Advances in offender profiling: A systematic review of the profiling literature published over the past three decades. *Journal of Police and Criminal Psychology*, 22(1), 44-56. doi:10.1007/s11896-007-9000-9
- 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 cases. *Journal of Investigative Psychology and Offender Profiling*, 10, 1-27. <http://dx.doi.org/10.1002/jip.1364>
- Elliott, D. M., Mok, D. S., & Briere, J. (2004). Adult sexual assault: Prevalence, symptomatology, and sex differences in the general population. *Journal of traumatic stress*, 17(3), 203-211. 203–211. doi:10.1023/b:jots.0000029263.11104.23

- Farrington, D. P. & West, D. J. (1993). Criminal, penal and life histories of chronic offenders: Risk and protective factors and early identification. *Criminal Behaviour and Mental Health*, 3(4), 492-523.
- Federal Bureau of Investigation (2008). *Serial murder: Multidisciplinary perspectives for investigators*. US Department of Justice, Washington.
- Federal Rules of Evidence (Rule 702), Pub. L. No. 93–595, §1, 88 Stat. 1937 (2011).
<http://www.uscourts.gov/uscourts/RulesAndPolicies/rules/2011%20Rules/Evidence%20Procedure.pdf>
- Field, A. (2009). *Discovering statistics using SPSS* (3rd ed.). London, England: SAGE.
- Fox, J. A., & Levin, J. (1998). Multiple homicide: Patterns of serial and mass murder. *Crime and Justice*, 23, 407-455. Retrieved from <http://www.jstor.org/stable/1147545>
- Frazier, P. A., & Haney, B. (1996). Sexual assault cases in the legal system: Police, prosecutor, and victim perspectives. *Law and Human Behavior*, 20, 607-628. doi: 10.1007/BF01499234
- Frye v. United States, 293 F. 1013 (D.C. Cir. 1923).
- Gee, D. G., Devilly, G. J., & Ward, T. (2004). The content of sexual fantasies for sexual offenders. *Sexual Abuse: A Journal of Research and Treatment*, 16, 315–331.
doi:10.1177/107906320401600405
- Gee D, & Belofastov A (2007) Profiling sexual fantasy: Fantasy in sexual offending and the implications for criminal profiling. In: R.N. Kocsis (ed) *Criminal profiling: International theory, research and practice*. (pp 49–71). Totowa, NJ: Humana Press.
- Gee, D. G., Ward, T., Belofastov, A., & Beech, A. R. (2006). The structural properties of sexual fantasies for sexual offenders: A preliminary model. *Journal of Sexual Aggression*, 12, 213–226. doi:10.1080/13552600601009956

- Geberth, V. J. (1981). Psychological profiling. *Law and Order*, 29(1), 46-52.
- Goodwill, A. M., & Alison, L. J. (2006). The development of a filter model for prioritising suspects in burglary offences. *Psychology, Crime and Law*, 12(4), 395-416.
doi:10.1080/10683160500056945
- Goodwill, A. M. & Alison, L. J. (2007). When is profiling possible? Offense planning and aggression as moderators in predicting offender age from victim age in stranger rape. *Behavioral Sciences and the Law*, 25(6), 823-840. doi:10.1002/bsl.778
- Grant, T. D., & Woodhams, J. (2007). Rape as social activity: An application of investigative linguistics. In: J. Cotterill (ed.), *The language of sexual crimes* (pp. 1-15). Basingstoke, UK: Palgrave.
- Green, E. J., Booth, C. E., & Biderman, M. D. (1976). Cluster analysis of burglary M-Os. *Journal of Police Science and Administration*, 4(4), 382-388.
- Groscup, J.L., Penrod, S.D., Studebaker, C.A., Huss, M.T., & O'Neil, K.M., (2002). The effects of Daubert on the admissibility of expert testimony in state and federal criminal cases. *Psychology, Public Policy, and Law*, 8, 339-372. doi:10.1037/1076-8971.8.4.339
- Grubin, D. (1995). Offender profiling. *The Journal of Forensic Psychiatry*, 6(2), 259-263.
doi: 10.1080/09585189508409892
- Grubin, D., Kelly, P., & Ayis, S. (1997). *Linking serious sexual assaults*. London: Home Office Police Research Group.
- Grubin, D., Kelly, P., & Brunsdon, C. (2001). Linking serious sexual assaults through behaviour: HORS 215. *Home Office Research Development and Statistics Directorate*. Retrieved from <http://library.npia.police.uk/docs/hors/hors215.pdf>

- Hakkanen, H., Puolakka, P., & Santtila, P. (2004). Crime scene actions and offender characteristics in arsons. *Legal and Criminological Psychology*, 9(2), 197-214.
doi:10.1348/1355325041719392
- Harbers, E., Deslauriers-Varin, N., Beauregard, E., & Kemp, J. J. (2012). Testing the behavioural and environmental consistency of serial sex offenders: A signature approach. *Journal of Investigative Psychology and Offender Profiling*, 9(3), 259-273.
doi: 10.1002/jip.1368
- Harris, J., & Grace, S. (1999). A question of evidence? Investigating and prosecuting rape in the 1990s. *Home Office Research Study 196*. Retrieved from
<http://rds.homeoffice.gov.uk/rds/pdfs/hors196.pdf>
- Hazelwood, R.R., & Michaud, S.G. (2001). *Dark dreams: Sexual violence, homicide, and the criminal mind*. New York: St. Martin's Press
- Hazelwood, R. R., & Warren, J. L. (2004). Linkage analysis: Modus operandi, ritual, and signature in serial sexual crime. *Aggression and Violent Behavior*, 9, 307-318.
doi:10.1016/j.avb.2004.02.002
- Her Majesty's Inspectorate of Constabulary (HMIC) and Her Majesty's Inspectorate of the Crown Prosecution Service (HMICPS) (2012). *Forging the links: Rape investigation and prosecution*. Retrieved from <http://www.hmic.gov.uk/media/forging-the-links-rape-investigation-and-prosecution-20120228.pdf>
- Herndon, J. S. (2007). The Image of Profiling. In R.N.Kocsis (Ed.), *Criminal Profiling* (pp. 303-323). Humana Press.
- Herrmann, H. (1998). *Anwendung von kreuzvalidierung und bootstrap auf die logistische regression und diskriminanzanalyse*. Unpublished report.

- Hettema, J., & Hol, D. P. (1998). Primary control and the consistency of interpersonal behaviour across different situations. *European journal of personality*, 12(4), 231-247. doi:10.1002/(SICI)1099-0984(199807/08)12:4<231::AID-PER308>3.0.CO;2-0
- Hickman, S. E., & Muehlenhard, C. L. (1997). College women's fears and precautionary behaviors relating to acquaintance rape and stranger rape. *Psychology of Women Quarterly*, 21(4), 527-547. doi: 10.1111/j.1471-6402.1997.tb00129.x
- Hochberg, Y., & Benjamini, Y. (1990). More powerful procedures for multiple significance testing. *Statistics in medicine*, 9(7), 811-818. doi: 10.1002/sim.4780090710
- Hosmer, D.W., & Lemeshow, S. (2000). *Applied logistic regression* (2nd ed.). New York: John Wiley & Sons.
- Innes, M., Fielding, N., & Cope, N. (2005). The appliance of science? The theory and practice of criminal intelligence analysis. *British Journal of Criminology*, 45, 39–57. doi:10.1093/bjc/azh053
- Jaccard, P. (1908) Nouvelle recherches sur la distribution florale. *Bulletin de la Societe Vaudoise des Sciences Naturelles* 44, 223–270.
- Kelly, L. (2010). The (in) credible words of women: False allegations in European rape research. *Violence against Women*, 16(12), 1345-1355. doi: 10.1177/1077801210387748
- Kelly, L., Lovett, J., & Regan, L. (2005). *A gap or a chasm?: Attrition in reported rape cases*. London: Home Office.
- Kendall, D., McElroy, H., & Dale, A. (1999). Developments in offender profiling: The analysis of rapists' speech. *Police Research and Management*, 3(3), 1-24.
- Kendall, M. G., & Stuart, A. (1961). *The advanced theory of statistics* , vol. II. London, England: Griffin.

- Kent, J., Leitner, M., & Curtis, A. (2006). Evaluating the usefulness of functional distance measures when calibrating journey-to-crime distance decay functions. *Computers, Environment and Urban Systems*, 30(2), 181-200.
doi:10.1016/j.compenvurbsys.2004.10.002
- Knezevic, A. (2008). Overlapping confidence intervals and statistical significance. *Cornell University, StatNews*, 73.
- Koss, M. P., Dinero, T. E., Siebel, C. A., & Cox, S. L. (1988). Stranger and acquaintance rape: Are there differences in the victim's experience? *Psychology of Women Quarterly*, 12, 1-24. doi:10.1111/j.1471-6402.1988.tb00924.x
- Kraemer, G. W., Lord, W. D., & Heilbrun, K. (2004). Comparing single and serial homicide offenses. *Behavioral Sciences and the Law*, 22, 325-343. doi: 10.1002/bsl.581
- Labuschagne, G. (2006). The use of a linkage analysis as evidence in the conviction of the Newcastle serial murderer, South Africa. *Journal of Investigative Psychology and Offender Profiling*, 3, 183-191. doi:10.1002/jip.51
- Labuschagne, G. (2012). The use of a linkage analysis as an investigative tool and evidential material in serial offenses. In K. Borgeson & K. Kuehnle (Eds.), *Serial offenders: Theory and practice* (pp. 187-215). Sudbury, Massachusetts: Jones & Bartlett Learning.
- Labuschagne, G. (2014). The use of linkage analysis evidence in serial offense trials. In J. Woodhams & C. Bennell (Eds.), *Crime linkage: Theory, research, and practice*. (55-82). Boca Raton, FL: CRC Press.
- Laub, J. H. (2004). The life course of criminology in the United States: The American society of criminology 2003 presidential address. *Criminology*, 42(1), 1-26.
doi:10.1111/j.1745-9125.2004.tb00511.x

- LeBeau, J. L. (1987). The journey to rape: Geographic distance and the rapist's method of approaching the victim. *Journal of Police Science and Administration*, 15, 129-136.
- Retrieved from
<http://heinonline.org/HOL/Page?collection=journals&handle=hein.journals/jclc78&type=Image&id=321>
- Leitenberg, H., & Henning, K. (1995). Sexual fantasy. *Psychological Bulletin*, 117, 469-496.
doi:10.1037/0033-2909.117.3.469
- Lin, S., & Brown, D. E. (2006). An outlier-based data association method for linking criminal incidents. *Decision Support Systems*, 41, 604-615. doi:10.1016/j.dss.2004.06.005
- Lindqvist, P. & Skipworth, J. (2000). Evidence-based rehabilitation in forensic psychiatry. *The British Journal of Psychiatry*, 176(4), 320-323. doi:10.1192/bjp.176.4.320
- Lynch, M. (2003). God's signature: DNA profiling, the new gold standard in forensic science. *Endeavour*, 27(2), 93-97. doi:10.1016/S0160-9327(03)00068-1
- MacCulloch, M., Gray, N., & Watt, A. (2000). Brittain's Sadistic Murderer Syndrome reconsidered: An associative account of the aetiology of sadistic sexual fantasy. *The Journal of Forensic Psychiatry*, 11, 401-418. doi:10.1080/09585180050142606
- Markson, L., Woodhams, J., & Bond, J. W. (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(2), 91-107. doi:10.1002/jip.120
- Melnyk, T., Bennell, C., Gauthier, D. J., & Gauthier, D. (2011). Another look at across-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.
doi:10.1080/10683160903273188

- Metcalfe, J., & Mischel, W. (1999). A hot/cool-system analysis of delay of gratification: Dynamics of willpower. *Psychological review*, *106*(1), 3. doi:10.1037/0033-295X.106.1.3
- Meyer, C. B. (2007). Criminal profiling as expert evidence? An international case law perspective. In R. N. Kocsis (Ed.), *Criminal profiling: International theory, research and practice* (pp. 207–247). Totowa, NJ: Humana Press. doi:10.1007/978-1-60327-146-2_10
- Ministry of Justice, the Home Office, and the Office for National Statistics. (2013). An overview of sexual offending in England and Wales. Retrieved from <https://www.gov.uk/government/statistics/an-overview-of-sexual-offending-in-england-and-wales>
- Mischel, W., Mendoza-Denton, R., & Shoda, Y. (2002). Situation-behavior profiles as a locus of consistency in personality. *Current Directions in Psychological Science*, *11*(2), 50-54. doi: 10.1111/1467-8721.00166
- Mischel, W., & Shoda, Y. (1995). A cognitive-affective system theory of personality: Reconceptualizing situations, dispositions, dynamics, and invariance in personality structure. *Psychological review*, *102*(2), 246. doi: 10.1037/0033-295X.102.2.246
- Mokros, A., & Alison, L. J. (2002). Is offender profiling possible? Testing the predicted homology of crime scene actions and background characteristics in a sample of rapists. *Legal and Criminological Psychology*, *7*, 25-43. doi:10.1348/135532502168360
- Muller, D. (2000). Criminal profiling: Real science or just wishful thinking?. *Homicide Studies*, *4*(3), 234-264. doi:10.1177/1088767900004003003

- Muram, D., Hostetler, B. R., Jones, C. E., & Speck, P. M. (1995). Adolescent victims of sexual assault. *Journal of Adolescent Health, 17*, 372–375.
- Oziel, S., Goodwill, A., & Beauregard, E. (2014). Variability in behavioural consistency across temporal phases in stranger sexual offences. *Journal of Police and Criminal Psychology, 30*(3), 1-15. doi: 10.1007/s11896-014-9150-5
- Pakkanen, T., Santtila, P., & Bosco, D. (2014). Crime linkage as expert evidence: Making a case for the Daubert Standard. In J. Woodhams & C. Bennell (Eds.), *Crime linkage: Theory, research, and practice*. (55-82). Boca Raton, FL: CRC Press.
- Pakkanen, T., Zappalà, A., Grönroos, C., & Santtila, P. (2012). The effects of coding bias on estimates of behavioural similarity in crime linking research of homicides. *Journal of Investigative Psychology and Offender Profiling, 9*(3), 223-234. doi: 10.1002/jip.1366
- Pallant, J. (2007). *SPSS survival manual* (3rd ed.). Maidenhead: Open University Press.
- Park, J., Schlesinger, L. B., Pinizzotto, A. J., & Davis, E. F. (2008). Serial and single-victim rapists: Differences in crime-scene violence, interpersonal involvement, and criminal sophistication. *Behavioral Sciences and the Law, 26*, 227-237. doi:10.1002/bsl.804
- Peduzzi, P., Concato, J., Kemper, E., Holford, T. R., & Feinstein, A. R. (1996). A simulation study of the number of events per variable in logistic regression analysis. *Journal of clinical epidemiology, 49*(12), 1373-1379. doi: [10.1016/S0895-4356\(96\)00236-3](https://doi.org/10.1016/S0895-4356(96)00236-3)
- Pervin, L. A. (2002). *Current controversies and issues in personality* (3rd ed.). New York: Wiley.
- Piquero, A. R., Farrington, D. P., & Blumstein, A. (2007). *Key issues in criminal career research: New analyses of the Cambridge study in delinquent development*. Cambridge, England: Cambridge University Press.

- Pithers, W. D., Kashima, K. M., Cummings, G. S., & Beal, L. S. (1988). Relapse prevention: A method of enhancing change in sex offender. In A. C. Salter (Ed.), *Treating child sex offenders and victims: A practical guide* (pp. 131–170). London: Sage
- Police Funding. (2012). Retrieved from <http://www.politics.co.uk/reference/police-funding>
- Rainbow, L. (2014). A practitioner's perspective: Theory, practice and research. In J. Woodhams & C. Bennell (Eds.), *Crime linkage: Theory, practice and research*. Boca Raton, FL: CRC Press.
- Reisig, M. D., & Parks, R. B. (2000). Experience, quality of life, and neighborhood context: A hierarchical analysis of satisfaction with police. *Justice quarterly*, *17*(3), 607-630. doi:10.1080/07418820000094681
- Roberts, J. V., & Grossman, M. G. (1993). Sexual homicide in Canada: A descriptive analysis. *Annals of Sex Research*, *6*, 5-25. <http://dx.doi.org/10.1007/BF00849743>
- Royal Canadian Mounted Police (n.d.). *Violent Crime Linkage System (ViCLAS)*. Retrieved January 25, 2013, from <http://www.rcmp-grc.gc.ca/tops-opst/bs-sc/viclas-salvac-eng.htm>
- Salfati, C. G. (2003). Offender interaction with victims in homicide: A multidimensional analysis of frequencies in crime scene behaviors. *Journal of Interpersonal Violence*, *18*, 490-512. doi:10.1177/0886260503251069
- Salfati, C. G., & Bateman, A. L. (2005). Serial homicide: An investigation of behavioural consistency. *Journal of Investigative Psychology and Offender Profiling*, *2*, 121-144. doi:10.1002/jip.27
- Santtila, P., Hakkanen, H., Canter, D., & Elfgren, T. (2003). Classifying homicide offenders and predicting their characteristics from crime scene behavior. *Scandinavian Journal of Psychology*, *44*(2), 107-118. doi:10.1111/1467-9450.00328

- Salfati, C. G. & Haratsis, E. (2001). Greek homicide: A behavioral examination of offender crime-scene actions. *Homicide Studies*, 5(4), 335-362.
doi:10.1177/1088767901005004006
- Santtila, P., Junkkila, J., & Sandabba, N. K. (2005). Behavioural linking of stranger rapes. *Journal of Investigative Psychology and Offender Profiling*, 2, 87-103.
doi:10.1002/jip.26
- Santtila, P., Laukkanen, M., & Zappalà, A. (2007). Crime behaviours and distance travelled in homicides and rapes. *Journal of Investigative Psychology and Offender Profiling*, 4(1), 1-15. doi: 10.1002/jip.56
- Santtila, P., Laukkanen, M., Zappalà, A., & Bosco, D. (2008). Distance travelled and offence characteristics in homicide, rape, and robbery against business. *Legal and Criminological Psychology*, 13(2), 345-356. doi: 10.1348/135532507X238673
- Santtila, P., Pakkanen, T., Zappala, A., Bosco, D., Valkama, M., & Mokros, A. (2008). Behavioural crime linking in serial homicide. *Psychology, Crime and Law*, 14, 245-265. doi:10.1080/10683160701739679
- Schroeder, J., Xu, J., Chen, H. C., & Chau, M. (2007). Automated criminal link analysis based on domain knowledge. *Journal of the American Society for Information Science and Technology*, 58(6), 842-855. doi:10.1002/asi.20552
- Serious Organised Crime Agency (SOCA). *Serious Crime Analysis Section (SCAS)*. Retrieved January 25, 2013, from <http://www.soca.gov.uk/about-soca/serious-crime-analysis-section/>
- Sexual Offences Act (2003). Retrieved from http://www.legislation.gov.uk/ukpga/2003/42/pdfs/ukpga_20030042_en.pdf

- Shoda, Y., & Smith, R. E. (2004). Conceptualizing personality as a cognitive-affective processing system: A framework for models of maladaptive behavior patterns and change. *Behavior Therapy, 35*(1), 147-165.
- Silbert, M. (1981). *Sexual assault of prostitutes*. San Francisco: Delancey Street Foundation.
- Silbert, M. H., & Pines, A. M. (1982). Entrance into prostitution. *Youth and Society, 13*, 471-500. doi:10.1177/0044118X82013004005
- Silbert, M. H., & Pines, A. M. (1984). Pornography and sexual abuse of women. *Sex Roles, 10*, 857-868. doi:10.1007/BF00288509
- Sjöstedt, G., Långström, N., Sturidsson, K., & Grann, M. (2004). Stability of modus operandi in sexual offending. *Criminal Justice and Behavior, 31*, 609-623.
doi:10.1177/0093854804267094
- Slater, C., Woodhams, J., & Hamilton-Giachritsis, C. (2014). Can serial rapists be distinguished from one-off rapists?. *Behavioral Sciences and the Law, 32*(2), 220-239.
doi: 10.1002/bsl.2096
- Slater, C., Woodhams, J., & Hamilton-Giachritsis, C. (2015). Testing the assumptions of crime linkage with stranger sex offenses: A more ecologically-valid study. *Journal of Police and Criminal Psychology, 30*(4), 261-273. doi: 10.1007/s11896-014-9160-3
- Snook, B., Luther, K., House, J.C., Bennell, C., & Taylor, P. (2012). The violent crime linkage analysis system: A test of interrater reliability. *Criminal Justice and Behavior, 39*, 607-619. doi: 10.1177/0093854811435208
- Snook, B., Luther, K., & MacDonald, S. (2014). Linking crimes with spatial behavior: A need to tackle some remaining methodological concerns. In J. Woodhams, & C. Bennell (Eds.), *Crime linkage: Theory, research and practice*. Boca Raton, FL: CRC Press.

- Sørensen, T. (1948). {A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons}. *Biologiske Skrifter/Kongelige Danske Videnskabernes Selskab*, 5, 1-34.
- Sorochinski, M., & Salfati, C. G. (2010). The consistency of inconsistency in serial homicide: Patterns of behavioural change across series. *Journal of Investigative Psychology and Offender Profiling*, 7, 109-136.
- Sullivan, B. (2007). Rape, prostitution and consent. *Australian and New Zealand Journal of Criminology*, 40, 127-142. doi: 10.1375/acri.40.2.127
- Temkin, J. (2000). Prosecuting and defending rape: Perspectives from the bar. *Journal of Law and Society*, 27(2), 219-248. doi: 10.1111/1467-6478.00152
- Temkin, J., & Krahe, B. (2008). *Sexual assault and the justice gap: A question of attitude*. Oxford: Hart Publishing.
- Tjaden, P. G., & Thoennes, N. (2000). *Extent, nature, and consequences of intimate partner violence : Findings from the national violence against women survey*. Washington, DC: US Department of Justice, Office of Justice Programs, National Institute of Justice.
- Tonkin, M. (2014). Extending crime linkage to versatile offenders. In J. Woodhams & C. Bennell (Eds.), *Crime linkage: Theory, research, and practice*. (279-302). Boca Raton, FL: CRC Press.
- 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. doi:10.1002/jip.74

- Tonkin, M., Woodhams, J., Bull, R., & Bond, J. (2012). Behavioural case linkage with solved and unsolved crimes. *Forensic Science International*, 222, 146-153.
doi:10.1016/j.forsciint.2012.05.017
- Tonkin, M., Woodhams, J., Bull, R., Bond, J. W., & Palmer, E. J. (2011). Linking different types of crime using geographical and temporal proximity. *Criminal Justice and Behavior*, 38(11), 1069-1088. doi: 10.1177/0093854811418599
- Tonkin, M., Woodhams, J., Bull, R., Bond, J. W., & Santtila, P. (2012). A comparison of logistic regression and classification tree analysis for behavioural case linkage. *Journal of Investigative Psychology and Offender Profiling*, 9(3), 235-258.
doi:10.1002/jip.1367
- Ward, T., & Hudson, S. M. (2000). Sexual offenders' implicit planning: A conceptual model. *Sexual Abuse: A Journal of Research and Treatment*, 12, 189-202.
- Wilcox, P., Jordan, C. E., & Pritchard, A. J. (2006). Fear of Acquaintance versus Stranger Rape as a. *Violence and Victims*, 21(3), 355-370. doi:10.1891/vivi.21.3.355
- Williams, V. S., Jones, L. V., & Tukey, J. W. (1999). Controlling error in multiple comparisons, with examples from state-to-state differences in educational achievement. *Journal of Educational and Behavioral Statistics*, 24(1), 42-69. doi: 10.3102/10769986024001042
- Winter, J. M., Lemeire, J., Meganck, S., Geboers, J., Rossi, G., & Mokros, A. (2013). Comparing the predictive accuracy of case linkage methods in serious sexual assaults. *Journal of Investigative Psychology and Offender Profiling*, 10, 28-56.
doi:10.1002/jip.1372
- Woodhams, J. (2008). *Juvenile sex offending: An investigative perspective* (Doctoral dissertation).

- Woodhams, J. (2012). Offender profiling and crime linkage. In G. Davies, & A. Beech (eds), *Forensic psychology: Crime, justice, law, interventions (2nd edition)* (pp.171-188). Chichester, UK: John Wiley & Sons Ltd.
- Woodhams, J., & Bennell, C., (2011). Detecting serial offenders in the absence of physical evidence. *Police Review magazine*.
- Woodhams, J. & Bennell, C. (2014). Consistency and distinctiveness of criminal behaviour. In J. Woodhams & C. Bennell (Eds.), *Crime linkage: Theory, research, and practice*. (11-33). Boca Raton, FL: CRC Press.
- 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*. (pp. 117–133). Totowa, NJ: The Humana Press Inc.
- Woodhams, J. & Grant, T. (2006). Developing a categorization system for rapists' speech. *Psychology, Crime and Law*, 12, 245-260. doi:10.1080/10683160500151134
- Woodhams, J., Grant, T. D., & Price, A. R. G. (2007a). From marine ecology to crime analysis: Improving the detection of serial sexual offences using a taxonomic similarity measure. *Journal of Investigative Psychology and Offender Profiling*, 4, 17-27. doi: 10.1002/jip.55
- Woodhams, J., Hollin, C. R., & Bull, R. (2007b). The psychology of linking crimes: A review of the evidence. *Legal and Criminological Psychology*, 12, 233-249. doi: 10.1348/135532506X118631
- Woodhams, J., Hollin, C., & Bull, R. (2008). Incorporating context in linking crimes: An exploratory study of situational similarity and if-then contingencies. *Journal of Investigative Psychology and Offender Profiling*, 5(1-2), 1-23. doi:10.1002/jip.75

- Woodhams, J., Hollin, C. R., Bull, R., & Cooke, C. (2012). Behavior displayed by female victims during rapes committed by lone and multiple perpetrators. *Psychology, Public Policy, and Law*, 18(3), 415. doi:10.1037/a0026134
- Woodhams, J. & Komarzynska, K. (2014). The effect of mental disorder on crime scene behaviour, its consistency, and variability. In J. Woodhams & C. Bennell (Eds.), *Crime linkage: Theory, research, and practice*. (55-82). Boca Raton, FL: CRC Press.
- Woodhams, J., & Labuschagne, G. (2012). A test of case linkage principles with solved and unsolved serial rapes. *Journal of Police and Criminal Psychology*, 27, 85-98.
- 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. doi:10.1037/1076-8971.13.1.5
- Woodworth, M. & Porter, S. (2000). Historical foundations and current applications of criminal profiling in violent crime investigations. *Expert Evidence*, 7(4), 241-264. doi:10.1023/A:1016655103536
- Yokota, K., Fujita, G., Watanabe, K., Yoshimoto, K., & Wachi, T. (2007). Application of the behavioural investigative support system for profiling perpetrators of serial sexual assaults. *Behavioral Sciences and the Law*, 25, 841-856. doi:10.1002/bsl.793
- Yule, G. U. (1900). On the association of attributes in statistics: with illustrations from the material of the childhood society, &c. *Philosophical Transactions of the Royal Society of London. Series A, Containing Papers of a Mathematical or Physical Character*, 257-319.
- Yule, G. U. (1912). On the methods of measuring association between two attributes. *Journal of the Royal Statistical Society*, 579-652.

APPENDIX

Ethical Approval

Approval from the Science, Technology, Engineering and Mathematics Ethics Committee at the University of Birmingham was obtained for all analyses reported in this thesis (ERN_11-0098). In addition, the British Psychological Society guidelines on ethics were adhered to at all times. Additional approval and security clearances were obtained from the Serious Crime Analysis Section (of the National Crime Agency).