

AN EMPIRICAL TEST OF THE ASSUMPTIONS OF CASE LINKAGE AND OFFENDER PROFILING WITH SERIAL COMMERCIAL ROBBERIES

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Case linkage, the identification of crimes suspected of being committed by the same perpetrator on the basis of behavioral similarity, and offender profiling, the inference of offender characteristics from offense behaviors, are used to advise police investigations and, in relation to case linkage, have been admitted in legal proceedings. Criteria for expert evidence, such as the *Daubert* criteria (*Daubert v. Merrell Dow Pharmaceuticals*, 1993), place stringent conditions on the admissibility of expert evidence. The future contribution of these practices to legal proceedings depends, in part, on whether they are underpinned by hypotheses that are testable and supported. The 3 hypotheses of offender behavioral consistency, of offender behavioral distinctiveness, and of a homology (direct relationship) between offender characteristics and behavior were empirically examined using a sample of serial commercial robberies. Support was found for the former 2 hypotheses but not for the last. The findings of the 2 studies have implications for the future development of these practices, for legal practitioners evaluating expert evidence, and for the implementation of public policy.

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In many countries, government policy has required police forces to focus their investigative efforts on the minority of offenders who commit the majority of the crimes (Innes, Fielding, & Cope, 2005). This has motivated the police and professionals working with them to develop effective means of identifying crimes committed by the same offender (called serial crime or crime series). Behavioral and forensic scientists have developed methods for identifying serial crime. In the absence of suitable physical evidence, such as DNA evidence, to link different crime scenes, case linkage (also referred to as comparative case analysis and linkage analysis) can be used to examine the likelihood of a series of offenses being committed by the same unidentified offender (Grubin, Kelly, & Brunsdon, 2001; Hazelwood & Warren, 2003). Case linkage is typically conducted by crime analysts and involves the analyst engaging in a detailed behavioral analysis of criminals' crime scene actions (modus operandi [MO]) to determine whether there is a sufficient degree of similarity in behavior for the crimes to be attributed to a common offender.

Similarly, science has played an important role in developing means of identifying offenders from the physical evidence left at the crime scene (Innes et

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al., 2005). However, in some crimes, physical evidence is not available for identification means, and if the offender was a stranger to the victim, the offender cannot be identified in this alternative manner. Although offender profiling is not able to identify an offender, it is a behavioral method that has emerged as a potential means of narrowing down the search for an unknown offender by predicting characteristics that the offender is likely to possess.

The findings of offender profiling and case linkage have the potential to be of great use to police investigations. Offender profiling can inform the prioritization of suspects possessing specified characteristics (Oldfield, 1997), and through behaviorally linking crimes thought to be committed by the same offender, police investigative efforts and information from the different crime scenes can be combined (Grubin et al., 2001). If the findings of offender profiling and case linkage are accurate, the outcome for police investigations and potentially for the general public can therefore be very positive. On the other hand, the provision of inaccurate advice could mislead a police investigation and be costly in human and financial terms (Alison, Bennell, Mokros, & Ormerod, 2002; Grubin et al., 2001; Gudjonsson & Copson, 1997). It is therefore important that research demonstrates the hypotheses of case linkage and offender profiling to be valid and that the practice of offender profiling and case linkage is developed to be as accurate as possible.

The accuracy of case linkage and offender profiling has implications not only for successful and efficient policing but also for legal proceedings. There are some examples of evidence of behavioral similarity being admitted to legal proceedings in the United States and in the United Kingdom (e.g., see Alison et al., 2002; Hazelwood & Warren, 2003; *R v. Straffen*, 1952); however, in some cases, limits have been placed on the nature of the testimony (e.g., *State of New Jersey v. Fortin*, 2000).

In the English case *R v. Straffen* (1952), the defendant had been committed to a secure psychiatric hospital for the murder of two young girls in Bath. Following the defendant's escape from custody, another young girl was found murdered in a similar manner. At the trial, the prosecution sought to introduce evidence of the two murders at Bath with a view to establishing the identity of the culprit through the similarities in offense behavior shared by the three cases. This evidence was allowed, and Straffen was convicted of the third murder. At appeal, the original decision to admit this evidence was upheld.

In the more recent case of *State of New Jersey v. Fortin* (2000), Steven Fortin had been charged with a sexual homicide. The Law Division had ruled that the prosecution could introduce evidence of a similar crime that the defendant had committed in Maine, where he had sexually assaulted and strangled a state trooper. The first issue the Supreme Court of New Jersey considered was whether the decision to admit this evidence was correct. Second, it considered whether Robert Hazelwood would qualify as an expert on this topic and whether he could testify, through the use of linkage analysis (case linkage), that the perpetrator of the New Jersey sexual homicide was the same as the perpetrator of the sexual assault and strangulation in Maine. Hazelwood's testimony was that the two crimes shared 15 MO behaviors and five types of ritualistic behavior. Hazelwood explained that

While each element of the killer's MO had been individually observed in other crimes by the analyst, this group of features combined with the ritualistic behaviors identified in the two crimes formed a unique combination and, therefore, a signature for this particular series. (Hazelwood & Warren, 2003, p. 595)

He therefore concluded that it was improbable that different offenders had committed these two crimes (*State of New Jersey v. Fortin*, 2000). Having considered the circumstances of the case, the Supreme Court of New Jersey agreed with the Superior Court's previous decision that linkage analysis lacked sufficient scientific reliability to establish that the same person was responsible for the New Jersey and Maine crimes but that the evidence of behavioral similarity was considered admissible with an appropriate limiting instruction. It also noted that linkage analysis evidence is beyond the knowledge of an average juror, and the expert status of Robert Hazelwood was recognized.

With regard to expert testimony based on offender profiling, in no previous case has evidence of a perpetrator's guilt or innocence been admitted (Alison et al., 2002). Whether such evidence is admitted in the future depends in part on a number of obstacles being overcome (Ormerod, 1999; Ormerod & Sturman, 2005).

The *Daubert* criteria (*Daubert v. Merrell Dow Pharmaceuticals*, 1993) are one way in which expert evidence is evaluated (Groscup, Penrod, Studebaker, Huss, & O'Neil, 2002) and are a useful benchmark against which practices such as offender profiling and case linkage can be scrutinized. The guidance for evaluating expert evidence given by the U.S. Supreme Court within *Daubert* includes considering

whether the theory or technique in question can be (and has been) tested, whether it has been subjected to peer review and publication, its known or potential error rate and the existence and maintenance of standards controlling its operation, and whether it has attracted widespread acceptance within a relevant scientific community. (*Daubert v. Merrell Dow Pharmaceuticals*, 1993, p. 580)

When framed as a question, the first point would be, Are the theories and practices of offender profiling and case linkage testable, and have they been tested?

The Underlying Theories and Hypotheses of Offender Profiling and Case Linkage

With regard to whether testable theories and hypotheses underlie offender profiling and case linkage, the answer to this question is affirmative. Offender profiling and case linkage both rest on theories from personality psychology. Offender profiling rests on several assumptions or hypotheses (for a comprehensive discussion of these, see Alison et al., 2002). The first is the homology assumption (Mokros & Alison, 2002), the hypothesis that there will be a relationship between offenders' characteristics and their crime scene behavior. An implication of this hypothesis is that offenders with similar characteristics will therefore display similar crime scene behaviors (Mokros & Alison, 2002). It follows that offenders with different crime scene behavior should possess different characteristics.

A second hypothesis of offender profiling is the offender (behavioral) consistency hypothesis (Canter, 1995). This hypothesis predicts that offenders will show consistency (or similarity) in their criminal behavior across their series of crimes. As explained by Mokros and Alison (2002), this hypothesis is necessary for offender profiling to work because "one person has to remain rather consistent in his or her actions if the correspondence of similarity associations holds between a person's characteristics and behavior" (p. 26).

The offender behavioral consistency hypothesis also underlies the practice of case linkage. If offenders were not consistent in their criminal behavior, it would be impossible to assign crimes to a common offender on the basis of their behavioral similarity. However, case linkage has an additional hypothesis of offender behavioral distinctiveness. If offenders were consistent in their behavior across their crime series but all behaved in the same way, it would be impossible to distinguish the crimes of one offender from those of another offender (Santtila, Junkkila, & Sandnabba, 2005). Offenders must therefore commit their crimes in a consistent but distinctive manner.

Tests of the Hypotheses of Offender Profiling and Case Linkage

A number of studies have demonstrated some evidence of predictive accuracy of offender characteristics from crime scene variables for crimes including homicide (Salfati & Canter, 1999), burglary (Santtila, Ritvanen, & Mokros, 2004), and the more commonly studied area of sexual assault (Davies, Wittebrood, & Jackson, 1998). Farrington and Lambert (2000) also studied burglary and less serious violent offenses, including assault, actual bodily harm, violent disorder, and robbery. The predictive accuracy of offender characteristics was greater for violent offenses, such as robbery, than for burglary.

The implication of the homology assumption, that offenders with similar characteristics will display similar crime scene behavior, was tested by Mokros and Alison (2002) for stranger rapes. The characteristics they examined were age, ethnicity, employment, education, marital status, and criminal record. Correlational analyses were used to investigate whether there were correlations between offense behavior similarity and similarity on the various offender characteristics. Mokros and Alison found no evidence for the homology assumption. No subsequent study has investigated the homology assumption in this manner.

The offender behavioral consistency hypothesis has received rather more scrutiny. These investigations have largely originated from studies evaluating the assumptions of case linkage but equally apply to the assumption of offender behavioral consistency underlying offender profiling. Whether people are consistent in their behavior across situations is a question that has received substantial investigation in the field of personality psychology. It has been hypothesized that each person possesses a cognitive-affective personality system that affects the behavior produced in a given situation (Mischel & Shoda, 1995). One implication of this theory is that when people encounter situations that have a similar psychological meaning to them, they produce similar behavior. Research by personality psychologists has confirmed this theory (Funder & Colvin, 1991; Furr & Funder, 2004; Shoda, Mischel, & Wright, 1993; J. C. Wright & Mischel, 1987).

If the situations in which an offender's crimes are committed have similar

psychological meaning to him or her, it follows that consistency in his or her criminal behavior would be expected. Research has investigated offender behavioral consistency for sexual crimes (Canter et al., 1991; Grubin et al., 2001; Knight, Warren, Reboussin, & Soley, 1998; Santtila, Junkkila, & Sandnabba, 2005), homicide (Salfati & Bateman, 2005), burglary (Bennell & Canter, 2002; Bennell & Jones, 2005; Green, Booth, & Biderman, 1976), and arson (Santtila, Fritzson, & Tamelander, 2005). All studies have found a degree of offender behavioral consistency.

Researchers have also investigated whether offenders show more consistency in some criminal behaviors than in others. Research in personality psychology demonstrating variation in the consistency of different types of noncriminal behavior (Funder & Colvin, 1991; Furr & Funder, 2004; Hettema & Hol, 1998) suggests that variation in the consistency of different types of criminal behavior should be observed. This proposition has been investigated with criminal behavior by grouping individual behaviors into overarching behavioral domains that reflect the function of the criminal behaviors within the domain. For example, with their sample of serial stranger sex offenders, Grubin et al. (2001) created the behavioral domains of control and escape. The control domain contains behaviors that function to control the victim, such as blindfolding and the use of a weapon. Their escape domain contains behaviors that ensure the offender successfully escapes the scene without being identified, such as destroying semen and wearing a mask. Similarly, Bennell and Canter's (2002) behavioral domains for serial burglars include target selection behaviors relating to the choice of the burglary target and entry behaviors comprising how the offender gains entry to the premises.

Having grouped the specific offender behaviors into domains, researchers have investigated whether offenders show greater behavioral consistency across their series of crimes for some behavioral domains compared with others. They have found evidence supportive of this. Grubin et al. (2001) found greater behavioral consistency in the control and escape behavioral domains compared with the sex and style behavioral domains. Grubin et al. explained that the behaviors within the domains of control and escape are less dependent on the situation and the victim's behavior. With their sample of commercial burglaries, Bennell and Canter (2002) found target selection and entry behaviors to be relatively consistent aspects of behavior and property stolen to be less consistent. The last type of behavior is arguably more situation dependent. In personality psychology, variation in the consistency of types of noncriminal behaviors has been explained in a similar manner (Funder & Colvin, 1991; Hettema & Hol, 1998).

Some studies have combined the testing of the hypotheses of offender behavioral consistency and distinctiveness. These studies have created pairs of *linked* crimes (two crimes committed by the same offender) and pairs of *unlinked* crimes (two crimes committed by two different offenders) and have investigated whether linked and unlinked pairs could be accurately distinguished from one another. Three studies (Bennell & Canter, 2002; Bennell & Jones, 2005; Grubin et al., 2001) have now demonstrated that linked offenses and unlinked offenses can be reliably distinguished on the basis of behavioral consistency and distinctiveness. However, some behavioral domains are more accurate at distinguishing linked and unlinked crime pairs than others. For example, Bennell and Jones

(2005) and Bennell and Canter (2002), in their studies of linking commercial and residential burglaries, found intercrime distance to be the most accurate predictor of linkage. Linked pairs were geographically more proximal than unlinked pairs. The success of intercrime distance as a predictor of linkage is similarly attributed to it being a behavior that is more under the offender's control (Bennell & Jones, 2005).

That some behaviors show greater consistency and are more accurate predictors of linkage than others has implications for the practice of case linkage. For example, such findings would allow crime analysts to maximize the accuracy with which crimes are linked while at the same time minimizing the number of variables that must be analyzed. However, this also has implications for evaluating expert evidence. Expert evidence of behavioral similarity derived from an analysis of behaviors suggested by the research to be inappropriate could be considered suspect.

Returning to the question of whether the hypotheses of offender profiling and case linkage have been tested, the answer is therefore partially affirmative. The homology assumption of offender profiling has received little attention thus far. The offender behavioral consistency hypothesis and the hypothesis of offender behavioral distinctiveness have received greater scrutiny; however, these hypotheses remain to be tested with certain crime types for which case linkage is used in practice. Although both offender profiling and case linkage are most often utilized for more serious offenses, such as homicide, rape, and abduction, they can be and are used with less serious types of crime, such as robbery.

Robbery

Robberies fall into two categories: personal robberies and commercial robberies. Personal robberies are perpetrated against individuals and are often unplanned, situation-based offenses involving younger offenders against younger victims targeted for small monetary gain, mobile telephones, or other personal property. Commercial robberies are perpetrated against commercial establishments where the gain is potentially much higher but with much greater associated risk (Feeney, 1986).¹ For commercial robbery in particular, the behaviors required to execute the offense successfully can be quite complex.

Researchers have investigated whether different types of robber exist (e.g., Walsh, 1986). In a recent study of armed robbery, Alison, Rockett, Deprez, and Watts (2000) argued that robbers have strong and consistent roles that are part of their everyday social functioning and that these are expressed during the commission of an offense. By examining the narrative accounts of convicted robbers, they argued that roles manifest themselves in the degree of planning (proactive–reactive) and impulsivity (impulsive–rational) during an offense that reflect the overall self-image of the robber. On the basis of these two themes of planning and impulsivity, Alison et al. identified three behavioral styles or typologies of armed robber: *Robin's men*, who are characterized by professionalism, planning, and

¹ By definition, for an offense of robbery to have occurred, the offender must have threatened or placed the victim or victims in fear of their safety in an effort to obtain property, whether or not actual violence was used.

experience; *bandits*, who display behavior with a degree of planning but who can also be extremely violent if control is lost; and *cowboys*, whose behavior is reckless, impulsive, and indicative of those acting simply to obtain money for drugs. Although such research suggests that different styles of robbery exist, it remains to be investigated whether a homology exists between offender characteristics and offense behavior that would be reflected in differences in the characteristics of the offenders in each group.

Research Questions

Robbery is one of the most frequent stranger-to-stranger crimes involving violence and is one of the most feared (Feeney, 1986). Its prevalence and its associated financial and human cost have made the reduction of robberies a government priority in countries such as England and Wales (Prolific and Other Priority Offenders Strategy, 2004) and make it a potential candidate for offender profiling and case linkage. Considering the use of offender profiling and case linkage in guiding police investigations, the potential for such evidence to be admitted in legal proceedings, and in light of public policy requiring the effective identification of priority offenders, it is essential that their theoretical underpinnings are demonstrated by empirical research to be valid. These hypotheses have yet to be investigated with robbery offenses.

Reported in this article is a study that, using the methodology of Bennell and colleagues (Bennell & Canter, 2002; Bennell & Jones, 2005), investigated the offender behavioral consistency and distinctiveness hypotheses with serial commercial robberies. On the basis of previous findings for serial stranger sexual assaults (Grubin et al., 2001) and residential and commercial burglary (Bennell & Canter, 2002; Bennell & Jones, 2005) and theory from personality psychology (Funder & Colvin, 1991; Furr & Funder, 2003; Hettema & Hol, 1998), it was hypothesized that behaviors used to control witnesses, behaviors reflecting planning, and intercrime distance would be more accurate predictors of linkage and that behaviors reflecting the type of property stolen would be less accurate predictors. A second study investigated the homology assumption underpinning offender profiling, that is, whether commercial robbers with different styles of crime scene behavior possess different characteristics.

Method

The data for both studies were obtained from the crime information systems used by two U.K. police forces.

Study 1 Procedure

Solved crimes of commercial robbery recorded in the 5-year period from 1998 to 2003 were searched for all solved series of commercial robbery, which were extracted to form the study's data set. Serial offenders were defined as those known to be responsible for two or more commercial robbery crimes. Eighty serial robbers were identified. In research on case linkage, it is standard practice to include in the analysis a constant number of offenses per offender (see Bennell & Canter, 2002; Bennell & Jones, 2005). This is to ensure that prolific offenders with high behavioral consistency do not unduly influence the results (Bennell & Canter, 2002). Because over 50% of the offenders in the current data set had committed just two robberies, a constant of two offenses per

offender was chosen. For offenders who had committed more than two robberies, their two most recent offenses were chosen. This was because advances in commercial premises' security procedures may affect offenders' behaviors, and it was important that the findings of the study were as applicable to current policing as possible. The data set therefore comprised 160 commercial robberies committed by 80 offenders, each responsible for two robberies. These two offenses committed by the same offender represented the linked pairs subset. A comparison subset of unlinked pairs was created from the sample of linked offenses. This was done by randomly selecting two offenses from the sample of 160 linked robberies that were known to have been committed by different offenders to form each unlinked pair.

Content analysis was conducted to create a checklist of 71 offender behaviors, which are displayed in Table 1. All behaviors were compiled from the information readily available in each crime report, which would also therefore be readily available to crime analysts and police officers. The more descriptive behavioral categories of manner, language, and violence were also developed from the data set but, in relation to the latter two, were additionally informed by armed robber behaviors reported in Alison et al. (2000). Each offense was dichotomously coded against the checklist indicating the presence or absence of each behavior where 1 = present and 0 = absent. Previous research has demonstrated that content analysis of police records that is any more refined than simple presence-absence dichotomies is likely to be unreliable (Canter & Heritage, 1990).

In the absence of any model within the published literature describing the components of commercial robbery, the four behavioral domains identified (target selection, planning, control, and property) were adapted from the findings of a cluster analysis of burglary MOs (Green et al., 1976), the offense domains published for burglary (Bennell & Canter, 2002; Bennell & Jones, 2005), and the offense domains published for serious sexual assaults (Grubin et al., 2001). Previous studies in which behavioral domains have been created (e.g., Bennell & Canter, 2002; Grubin et al., 2001) have similarly relied on the research literature to inform their creation of domains.

Each of the offense behaviors was assigned to the behavioral domain it best described by Kirsty Toye by considering the function of the behavior and the placement of similar behaviors in previous research studies (Alison et al., 2000; Bennell & Canter, 2002; Bennell & Jones, 2005; Green et al., 1976; Grubin et al., 2001). For example, behaviors relating to the number of offenders were included within the control domain rather than the planning domain because an increase in the number of offenders does not necessarily mean an offense is better planned. An offense could still be spontaneous with a group of offenders, yet more offenders would help to control situations arising during the offense. The allocation of offense variables into the appropriate domain was also performed independently by Jessica Woodhams to assess interrater reliability. We agreed perfectly (100%) on the allocation of variables to domains. In addition to these four behavioral domains, a fifth aspect of the crimes was examined, that is, the distance in kilometers between every pair of robbery offenses. The distance between each pair of offenses was calculated on the basis of the postcodes of the offense locations entered into a Web-based location finder.² This program calculated the shortest distance by road between each pair of offenses.

Taking all of the dichotomously coded offense behaviors as the input, we calculated a Jaccard's coefficient, a measure of similarity, between every pair of crimes. Jaccard's coefficient is expressed as a value from 0 to 1. A value of 1 indicates perfect similarity in behaviors, and a value of 0 indicates no similarity in behaviors. If offenders are consistent in their criminal behavior, a larger Jaccard's coefficient would be predicted for each linked pair because consistency would be reflected in greater behavioral similarity between the two crimes. Jaccard's coefficient as a measure of association does not take account of joint nonoccurrences, and thus, the similarity between two crimes would not increase if a behavior were absent in both (Bennell & Canter, 2002). An important advantage of discounting joint nonoccurrences in the calculation of similarity for police crime data

² The directions facility on www.multimap.co.uk was used to calculate the shortest distance in kilometers between two postcodes.

is the possibility that the absence of a behavior may simply reflect the fact that it was not seen or not reported by the witness or indeed not transferred onto the crime report, rather than that it did not actually occur.

Having generated similarity measures for both linked and unlinked pairs using all offense behaviors, we repeated this process to assess behavioral similarity within each behavioral domain. This would establish whether certain elements of an offense were more similar across crimes committed by the same offender than others.

The Jaccard's coefficients calculated for each of the 80 linked and 80 unlinked pairs for the behavioral domains formed the basis for a subsequent logistic regression analysis. In addition, the fifth domain pertaining to the distance between pairs of offenses in kilometers was added at this stage. It is important to note that 43 of the 160 pairs did not have a value for distance. The pairs of linked crimes had all occurred within the same county; however, in the random pairing of unlinked crimes, some from different counties had been paired together. The distance between such offenses would inevitably be longer because they occurred in two different counties and not necessarily because they were committed by different offenders. As it was only offenses within the same county that formed the linked pairs, it was decided that the distance between unlinked pairs should be compared on the same basis. This meant that whereas the linked pairs all had a value for distance, only 37 of the 80 unlinked pairs did. All analyses for which distance is included have therefore been based on the 117 pairs for which this information was available.

Study 2 Procedure

For the first stage of this study, we conducted a hierarchical cluster analysis, using the average linking between groups method, to identify whether different robbery styles existed. This analysis used the dichotomously coded data on behaviors from Study 1 as its input. Although the present research had a sample of 160 commercial robberies, this was made up of 80 pairs of crimes that, as would be determined by Study 1, might show sufficient similarity to be statistically linked. Thus, to identify different offense styles, it was necessary to delete one crime from each pair so that all offenses making up the cluster analysis were committed by different offenders. This resulted in a sample of 80 robberies committed by serial offenders. Because offender profilers are often consulted on suspected serial crime and because serial offenders were included in Mokros and Alison's (2002) sample, the serial nature of the data set was not considered problematic. The sample size of 80 was also not considered problematic because other peer reviewed, published studies have conducted cluster analysis with sample sizes of between 53 and 65 (see Långström, Grann, & Lindblad, 2000). To maintain a suitable ratio of behavioral variables to number of robberies, the number of variables entered into the cluster analysis had to be reduced to 22 (Farrington & Lambert, 2000). This was achieved in two ways.

Prior to reducing the sample size from 160 to 80, the distinct offender behaviors were collapsed into groups based on their general theme. The whole sample was used for this process to ensure the final groupings were as representative as possible. The four time variables of 0600–1359, 1400–1759, 1800–2259, and 2300–0559 were collapsed into day and evening/night (Smith, 2003). The 17 types of premise were collapsed into three categories of high street retail premises, residential premises, and banking premises depending on what type of premises they were (Alison et al., 2000). The days of the week were collapsed into two variables Monday–Friday, hence capturing weekdays, and Saturday/Sunday, for the weekend (Alison et al., 2000). The three variables of single, duo, and team were collapsed into lone offender and team (Smith, 2003; Woodhams, Gillett & Grant, in press). The eight different types of covering that an offender could use to disguise him- or herself could be described by the offender covering either his or her face or his or her head. It was therefore decided to collapse these eight variables into two, which are face covered and head covered. The nine weapon variables were collapsed into four types of weapon: stabbing implement, firearm, bludgeoning instrument, and toxic. The three types of offender manner were collapsed into two types: calm/confident and anxious/aggressive. This was done because the two variables of anxious/

Table 1
The Offender Behavior Checklist and Behavioral Domains

Offense behavior	Behavioral domain			
	Target selection	Planning	Control	Property
Premise				
Off-license	x			
Bank/building society	x			
Post office	x			
General store	x			
Travel agent	x			
Petrol station	x			
Video shop	x			
Supermarket	x			
Newsagent	x			
Café	x			
Betting shop	x			
Takeaway restaurant	x			
Public house	x			
Retirement home	x			
Dry cleaners	x			
Hotel	x			
Chemist	x			
Time				
0600–1359	x			
1400–1759	x			
1800–2259	x			
2300–0559	x			
Day				
Monday	x			
Tuesday	x			
Wednesday	x			
Thursday	x			
Friday	x			
Saturday	x			
Sunday	x			
Number of offenders				
Single			x	
Duo			x	
Team			x	
Disguise				
Dustmask		x		
Stocking		x		
Balaclava		x		
Baseball cap		x		
Wool hat		x		
Scarf/cloth over face		x		
Top with hood		x		
Sunglasses		x		
Helmet		x		
Gloves				
Gloves		x		
Weapon ^a (including imitation and implied existence)				
Knife			x	

Table 1 (continued)

Offense behavior	Behavioral domain			
	Target selection	Planning	Control	Property
Firearm			x	
Metal bar			x	
Screwdriver			x	
Ammonia			x	
Bottle			x	
Needle			x	
Bat			x	
Fuel			x	
Property				
Cash				x
Cigarettes				x
Phone cards				x
Alcohol				x
Scratch cards				x
DVDs				x
Bag use				
Brought to scene		x		
Improvised		x		
Manner				
Calm/confident			x	
Anxious/agitated			x	
Loud/aggressive			x	
Language				
Reassuring			x	
Apologetic			x	
Instructional			x	
Victim restraint				
Restraint			x	
Violence				
Implied			x	
Threat only			x	
Spontaneous harm			x	
Harm following noncompliance			x	
Getaway				
Vehicle		x		
CCTV ^b				
CCTV taken from scene		x		
Total variables	28	14	23	6

Note. CCTV = closed-circuit television.
^a Weapon use—although there is an element of planning required to have a weapon at an offense, it was included in control as the main object of the weapon is to assist in the control of victims.
^b The removal of CCTV was categorized into planning as this reflects attempts to avoid capture rather than obtaining property for use or monetary gain.

agitated and loud/aggressive were not sufficiently distinctive. Implied violence and threat only were combined to form threat for the same reasons because violence was interpreted by the victim as being threatened by the offender whether it was spoken aloud or implied by the suspect showing the victim a weapon. This resulted in an amended list of 35 variables.

Second, 12 offense variables appearing in less than 10% of cases and one offense variable occurring in more than 90% of cases were removed from the analysis (Davies et al., 1998; Grubin et al., 2001; Salfati & Canter, 1999). Excluding such variables avoided clusters containing only a few offenders displaying unusual behaviors or very common behaviors that would not prove useful discriminators. Table 2 contains the 22 variables used for the cluster analysis.

In anticipation of different styles being identified, the second part of this study required information on offender characteristics to be obtained. The characteristics of age, ethnicity, employment, previous convictions, and distance traveled from home to the offense location were chosen. Approximately 60% of the solved commercial robbery offenses were committed by just one offender, and hence, the characteristics for this offender were collected. However, for offenders committing robberies in a pair or with a group, it was important to avoid duplication of a crime in the cluster analysis that had already been included for one offender. For example, if Offender 1 and Offender 2 together committed Offense A, the crime A could be included only once, either for Offender 1 or for Offender 2. In such cases, one offender was selected at random for inclusion in the sample to represent the crime. Therefore, each crime in the sample was included only once. An alternative method of selecting an offender would have been to choose the offender whose behavior was most reflected in the offense characteristics. However, the content of police reports was often not sufficiently detailed to be able to ascertain this. For this reason, the offender was chosen at random to represent the offense.

Information about each selected offender's age, ethnicity, and employment was obtained from police files. The distance between the offense location and the offender's home address was calculated on the basis of the postcodes that were entered into the Web-based location finder used in Study 1. To obtain information related to previous offending behavior, we accessed the record of each offender held on the Police National Computer and noted any relevant offending prior to the index offense.

These variables were selected because it was important that the variables chosen reflect the

Table 2
The 22 Variables Entered Into the Cluster Analysis

Behavioral domain	Offense behavior
Target selection	Retail premises
	Banking premises
	Day
	Evening/night
	Monday–Friday
Planning	Saturday/Sunday
	Face covered
	Head covered
	Gloves
	Bag
Control	Vehicle
	Lone
	Team
	Stabbing implement
	Firearm
Property	Calm/confident
	Anxious/aggressive
	Instructional
	Restrained witness
	Threatened witness
	Harmed witness
	Cigarettes

content of police files and the content of offender profiles (Mokros & Alison, 2002). To ensure that the characteristics used reflected information available to the police, we utilized police files as the data source for offender characteristics, and thus, the choice of variables for investigation was restricted to the information that was available in these files. Distance traveled from home to the crime scene was chosen as an additional variable because this information is also available to the police and because previous studies have reported an association between distance traveled and the value of the property stolen (e.g., Snook, 2004) and there was the possibility that the value of property stolen would be reflected in the styles of robbery.

Results

Study 1: Testing Hypotheses of Offender Behavioral Consistency and Distinctiveness

If offenders are consistent across their crimes, as predicted by the offender behavioral consistency hypothesis, the similarity in behavior between two offenses committed by the same offender (the linked pairs subset) should be greater than that between two offenses committed by different offenders (the unlinked pairs subset). The average similarity scores, as measured by Jaccard's coefficient, for the linked pairs subset and for the unlinked pairs subset were calculated. The median was chosen as the average because the distribution of Jaccard's coefficients was not a normal distribution (Brace, Kemp, & Snelgar, 2000). To test whether the difference in average similarities for the linked and unlinked pairs was statistically significant, a Wilcoxon matched-pairs signed ranks test was computed. A related test was chosen because the unlinked pairs subset had been generated from the linked pairs subset and, hence, the two samples could not be considered statistically independent of one another. This process was repeated for each of the three behavioral domains. The fourth domain, property, was discounted as a useful discriminator between crime pairs because cash was targeted in 94% of the robberies.

The larger median Jaccard's coefficients, shown in Table 3, for linked compared with unlinked crime pairs indicate greater similarity in behavior exhibited between offenses committed by the same offender than between offenses committed by different offenders. Furthermore, the difference in behavioral similarity between linked and unlinked offenses is significant both overall and within each behavioral domain ($p < .001$). These findings provide initial support

Table 3
Similarity Scores for Linked and Unlinked Pairs

Variables tested	Median Jaccard's coefficient		Wilcoxon	Significance
	Linked	Unlinked		
All variables	.55	.20	-7.77	.00
Domain 1: Target selection	.50	.00	-7.33	.00
Domain 2: Planning	.23	.00	-5.52	.00
Domain 3: Control	.67	.25	-7.73	.00
Domain 4: Property	—	—	—	—

for the offender behavioral consistency hypothesis underlying case linkage and offender profiling.

This hypothesis and the hypothesis that offenders will be distinctive in their behavior were simultaneously tested using logistic regression and receiver operating characteristic (ROC) analysis. Direct logistic regression analysis was first performed on each of the behavioral domains separately to determine if similarity in each single behavioral domain could predict whether crime pairs were linked or unlinked. In addition to the three behavioral domains of target selection, control, and planning, the distance in kilometers between each pair of robberies was added as a separate linking feature. The findings of the logistic regression analysis are summarized in Table 4.

Models 1–4 represent the regression models for each single domain. All models have chi-square values that are significant at the $p < .001$ level, indicating that the models fit the data well (Bennell & Canter, 2002). Both the chi-square and R^2 values indicate that the model including control is the most accurate, with 59.3% of the variance explained. This is followed by distance, target selection, and planning. The Hosmer and Lemeshow test suggests that all models show acceptable fit except distance, which has a significant result ($p < .05$). However, with a relatively large sample size ($n = 117$), this is not a concern (Tabachnick & Fidell, 2001).

The signs of the logit coefficients indicate that crime pairs committed by the same offender have greater behavioral similarity for target selection, planning, and control and have shorter intercrime distances than crime pairs committed by

Table 4
Summary of Logistic Regression Analyses

Statistical output	Model 1: Target selection	Model 2: Planning	Model 3: Control	Model 4: Distance	Model 5: Combined
Constant					
Logit coefficient	−1.15	−0.53	−3.34	2.15	−1.57
SE	0.27	0.20	0.53	0.37	0.76
Target					
Logit coefficient	4.38				
SE	0.84				
Planning					
Logit coefficient		2.83			2.11
SE		0.67			1.05
Control					
Logit coefficient			7.31		6.68
SE			1.10		1.57
Distance					
Logit coefficient				−0.09	−0.07
SE				0.02	0.02
Model χ^2	39.27	25.62	94.08	38.60	79.80
Significance of χ^2	<.001	<.001	<.001	<.001	<.001
R^2	0.29	0.20	0.59	0.39	0.69
Hosmer & Lemeshow Test					
χ^2	3.20	0.82	11.71	19.33	7.14
Significance of χ^2	>.1	>.5	>.1	<.05	>.5

different offenders. This is similar to what has been found in previous research with other crime types (Bennell & Canter, 2002; Bennell & Jones, 2005; Grubin et al., 2001).

The strong predictive accuracy of the models is reinforced by the percentages of correct assignment in Table 5. The probability of selecting a crime pair at random and assigning it correctly to the linked or unlinked subset is 50% for each of the domains of target selection, planning, and control and 68% for distance. However, the predictive ability of each model improves accuracy, with the models including control and distance predicting linkage correctly in over three quarters of cases.

To determine the extent to which the behavioral domains and intercrime distance could be combined to create an optimal model for accurately predicting whether crimes are likely to have been committed by the same offender, we performed forward stepwise logistic regression analysis. The results are shown in the last column in Table 4. The optimal model contains three of the four predictors (control, planning, and intercrime distance). As would be expected, the optimal model has a high chi-square value, indicating that these variables in combination are able to distinguish linked pairs from unlinked pairs more accurately than most of the models for single behavioral domains, with the exception of control. Sixty-nine percent of the variance in the dependent variable can be explained by this optimal model. The last column of Table 5 shows that the combination of these three variables results in the accurate prediction of cases being linked or not linked 89.7% of the time.

When conducting logistic regression analysis, the dependent variable used is typically independent (Lewis-Beck, 1980, as cited in Bennell & Canter, 2002). In the present study and those of Bennell and Canter (2002) and Bennell and Jones (2005), the pairs of linked crimes and the pairs of unlinked crimes constituting the dependent variable are not statistically independent, which can affect some of the measures of predictive accuracy reported in logistic regression, such as the Wald test. ROC analysis has been used previously by Bennell and Canter and by Bennell and Jones to overcome this difficulty. An accessible and comprehensive discussion of the advantages of using ROC analysis to assess accuracy of linking crimes has been presented elsewhere (Bennell & Jones, 2005).

ROC analysis produces the statistic *area under the curve* (*A*), which is a measure of predictive accuracy. *A* can range from 0 to 1, with an *A* of .5 indicating performance no better than chance and an *A* of 1 indicating perfect prediction of category membership (Swets, 1988), in this case linked or unlinked. Estimated probabilities for each crime pair were calculated using the function in logistic regression that formed the basis of the ROC analysis. The computer package

Table 5
Predictive Accuracy of Models

% correct assignment	Model 1: Target selection	Model 2: Planning	Model 3: Control	Model 4: Distance	Model 5: Combined
Random	50.00	50.00	50.00	68.38	68.38
Model	70.63	65.63	79.38	75.21	89.74

ROCKIT, available from the Department of Radiology, University of Chicago, was used. A ROC analysis was computed and a ROC curve plotted for each individual behavioral domain and for the optimal model (the combination of planning, control, and distance), as identified by the logistic regression.

The ROC curves for the individual behavioral variables and the optimal model are displayed in Figure 1. The curves, along with the *A* statistics, indicate

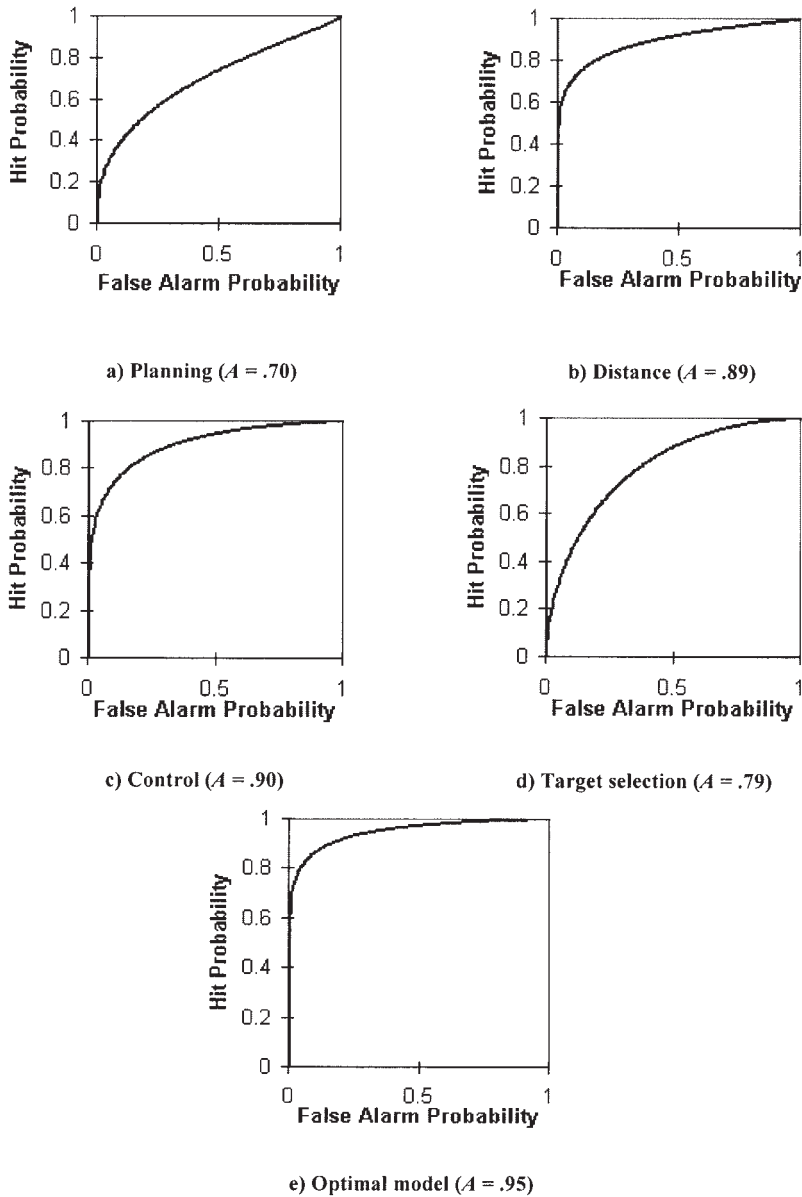


Figure 1. Receiver operating characteristic curves for planning, distance, control, target selection, and the optimal combination of variables. *A* = area under the curve.

that, of the individual behavioral domains, similarity in control behaviors is the most accurate at identifying linked and unlinked pairs ($A = .90$, 95% confidence interval [CI] = .84, .94), closely followed by intercrime distance ($A = .89$, 95% CI = .82, .94). According to published parameters, the predictive accuracy of control is outstanding, and the predictive accuracy of intercrime distance is excellent (Hosmer & Lemeshow, 2000). The next most accurate linking feature is similarity of target selection behaviors ($A = .79$, 95% CI = .71, .86) and, finally, similarity of planning behaviors ($A = .70$, 95% CI = .56, .82). These latter two A s indicate acceptable levels of predictive accuracy (Hosmer & Lemeshow, 2000). The optimal model shows even greater predictive accuracy with an A of .95 (95% CI = .90, .98), which can also be considered outstanding. All ROC curves demonstrate a degree of predictive accuracy significantly greater than that expected by chance alone ($p < .001$). These findings are similar to the logistic regression findings, suggesting support for the validity of the logistic regression analyses.

To ascertain if there were significant differences between the predictive accuracy of the behavioral domains, we used the A_z test. Seven significant differences were found. The optimal combination of behaviors, as identified by the logistic regression, had significantly greater predictive accuracy than all other predictors (planning $p < .001$; target selection $p < .001$; distance $p < .05$; control $p < .01$). Control-type behaviors had significantly greater predictive accuracy than target selection behaviors ($p < .05$) and planning behaviors ($p < .01$). Intercrime distance had significantly greater predictive accuracy than planning behaviors ($p < .05$).

In response to Bennell and Jones's (2005) call for researchers to consider the setting of decision thresholds for linkage, we followed their methodology of calculating Youden's indexes. As explained by Bennell and Jones, by calculating the Youden's index at each decision threshold used in the ROC analysis, it is possible to identify the decision threshold that minimizes the number of incorrect linking decisions for each behavioral domain. The decision thresholds correspond with p values produced from the logistic regression analysis (Bennell & Jones, 2005). For control-type behaviors, the optimal decision-making threshold corresponds to a Jaccard's coefficient of .535. For target-selection-type behaviors and for planning-type behaviors, the corresponding Jaccard's coefficients are .350 and .230, respectively. For distance, the optimal decision-making threshold corresponds to a distance between a pair of robberies of 6.4 km.

These findings all indicate some support for the hypotheses of offender behavioral consistency and distinctiveness. However, they also suggest that offenders show greater consistency and distinctiveness in some behavioral domains compared with others.

Study 2: Testing the Homology Assumption of Offender Profiling

The hierarchical cluster analysis, conducted to investigate the existence of different robbery styles, resulted in a three-cluster solution. The characteristics of the offenses composing each cluster are summarized in Figure 2.

Violent opportunists were offenders whose behavior seemed impulsive, attacking relatively low-risk targets with no weapon, using violence to obtain any

Cluster 1: Violent opportunists	Cluster 2: Organized risk takers	Cluster 3: Bladed nocturnal planners
1. Target retail outlets	1. Target banking outlets	1. Target retail outlets
2. Attack during the day	2. Attack during the day	2. Attack during evening and night
3. Attack on weekdays	3. Attack on weekdays	3. Disguises worn or hood or hat used to cover face
4. Little evidence of planning	4. Often a lone offender	4. Often a lone offender
5. Attacker appears anxious/aggressive	5. Disguises worn, bag taken to premises, and getaway vehicle used	5. Knife or other stabbing implement used
6. Always harm victim	6. Firearm used	6. Instructional or aggressive manner
7. No weapon used	7. Instructional manner	7. Little risk of harm to victim
8. Property other than cash taken	8. Little risk of harm to victims	
	9. Cash is sole property stolen	

Figure 2. The three clusters representing three different robbery styles, identified through hierarchical cluster analysis.

property that was available. Organized risk takers tended to be more professional, planning the offense before targeting banking outlets with the sole purpose of obtaining cash. Firearms were often carried by these individuals, but there was little risk of harm to victims. Bladed nocturnal planners seemed to fall between the other two styles. They attacked mostly lower risk establishments at night, but there was some evidence of planning with the use of disguises. Some were aggressive, and some threatened victims with a knife, but few actually caused harm.

The homology assumption of offender profiling would predict that offenders with similar offense behaviors would share similar characteristics. Conversely, offenders with different offense behaviors (as represented by different robbery styles) would possess different characteristics. The offender characteristics of ethnicity, employment, age, previous convictions, and distance from home to offense were tested for any significant differences between the three robbery types.

Kruskal-Wallis tests were used for age and distance because the data for both variables were not normally distributed (Kinnear & Gray, 2000). The robbers represented by the three robbery styles did not differ significantly on the characteristics of age ($p = .26$) or distance traveled between home and the offense location ($p = .47$). For previous convictions, ethnicity (White European, non-White European) and employment (unemployed, manual laborer, other employment) chi-square tests were performed. No significant associations were found between the previous convictions held by offenders in each of the typologies (burglary $p = .36$; robbery $p = .75$; violence $p = .32$). No significant associations were found for ethnicity ($p = .73$) or employment status ($p = .45$). There was therefore no statistical evidence of significant differences in offender characteristics between the three robbery types for any of these variables.

Discussion

The two studies reported in this article investigated the validity of the theories and hypotheses underlying offender profiling and case linkage. The findings and their implications for realizing government policy, for meeting legal criteria, such as the *Daubert* criteria, and for improving policing practice follow.

Offender Consistency and Offender Distinctiveness

The findings of the first study offer empirical support for the offender behavioral consistency hypothesis and the offender behavioral distinctiveness hypothesis in line with previous research (e.g., Bennell & Canter, 2002; Bennell & Jones, 2005; Grubin et al., 2001). Thus, the hypothesis that crimes committed by the same offender will display greater across-crime similarity than those committed by different offenders is supported. Pairs of crimes committed by the same offender were found to show greater similarity in target selection, planning, and control behaviors and were characterized by shorter intercrime distances than pairs composed of crimes perpetrated by different offenders.

Understanding the components of an offense that accurately predict whether or not crimes are committed by the same perpetrator can be of great assistance to an investigative team (Hazelwood & Warren, 2003) and is important in evaluating expert evidence of case linkage. The findings from the logistic regression analysis and the ROC analysis demonstrate that each of the behavioral domains individually is able to distinguish between linked and unlinked offenses with some accuracy; however, the control domain is the most accurate. This domain comprises offense behaviors such as the number of offenders, the use of weapons, the offender's manner, the language used, and the level of violence, including any restraint of victims. These features seem to represent behaviors that reflect the individual's demeanor and style of offending rather than behaviors that are adapted according to the particular situation. These findings are similar to Grubin, et al.'s (2001) findings that the two domains that best predict which sexual assaults are linked are those pertaining to control and escape, behaviors that are less dependent on situational factors or the response of the victim.

That control behaviors are the most accurate single-domain predictor contrasts with Bennell and Canter's (2002) and Bennell and Jones's (2005) findings that intercrime distance is the most accurate predictor of linkage for commercial and residential burglary. This could be because, within burglary, there is not usually the opportunity for interaction between offender and victim(s), and hence, control behaviors would not feature in these offenses. Alternatively, as noted previously, robbery is defined by the victim being threatened or placed in fear of his or her safety. More details might have been recorded in the initial crime report about control behaviors because of their evidential value and their relevance in establishing the correct classification for the alleged crime. That control behaviors have been found to be an accurate linking feature contrasts with assertions that the use of traditional MO-type linking features would likely cause law enforcement personnel difficulty (Bennell & Canter, 2002; Bennell & Jones, 2005). For some types of crime, it appears that such behaviors might be accurate predictors of linkage.

Planning, which refers to efforts by the offender to avoid detection and to facilitate the commission of the offense, is most comparable with the escape domain in Grubin et al.'s (2001) study, which also contains variables such as wearing a disguise. Like control behaviors, planning behaviors also seem to reflect behaviors that are less situation dependent, and hence, it might be expected that this domain would be as accurate a predictor as control. Contrary to what was expected, although planning behaviors can distinguish linked from unlinked pairs

with some accuracy, planning is the least accurate of all the domains. In their study of stranger sexual assaults, Grubin et al. suggested that one reason why the control and escape domains perform well is because such behaviors are less dependent on accurate victim recall. However, accurate recall by distressed victims and witnesses regarding details such as disguises, gloves, and the use of a bag by offenders who were potentially visible for only a matter of minutes may affect its reliability as an effective predictor of case linkage for robbery.

Target selection, as with planning, has less predictive accuracy than control. This is consistent with previous findings of target characteristics being associated with less predictive accuracy (Bennell & Canter, 2002; Bennell & Jones, 2005) and further suggests that such situation-dependent features can change across crimes because of external factors (Davies, 1992). These unquantifiable factors may make one target more or less viable at any given time, such as the presence of numerous staff or customers or revised security measures making a favored choice too risky. Similar factors have been reported to affect burglars' choices of properties to target (R. Wright, Logie, & Decker, 1995).

Crimes committed by the same offender were found to have shorter intercrime distances than those committed by different offenders, and these intercrime distances are one of the most reliable predictors of linkage. These findings are similar to Bennell and Canter's (2002) and Bennell and Jones's (2005) findings for burglary and suggest that offenders have relatively defined areas of criminality in which they are most comfortable and familiar, again reflecting behavior that is more offender initiated and less situation dependent. One explanation why intercrime distance might have been a less accurate predictor of linkage in the current article compared with Bennell and colleagues' studies could be because commercial premises are more dispersed than other crime targets and concentrated in particular areas, which can result in overlapping offending areas, reducing the ability of intercrime distance to distinguish between linked and unlinked crimes (Bennell & Jones, 2005). If commercial premises are clustered in specific areas, distance traveled then becomes more situation dependent, a characteristic that seems to reduce the accuracy of a linking feature.

Following stepwise logistic regression, the optimal model for linkage with this data set includes the three domains of control, intercrime distance, and planning but excludes target selection. This model's superior predictive accuracy in comparison to the individual domains is evident from the ROC analysis. With regard to the relative usefulness of variables for predicting linkage with this sample of robberies, the A_z test identified that the optimal combination of variables is the only model to be significantly more accurate at predicting whether pairs of robberies are linked or not than all others. For any application of this model within the investigative arena, this highlights the importance of discovering ways "of achieving maximum predictive power using the fewest possible linking features" (Bennell & Canter, 2002, p. 163). This requires further studies with robberies to determine if the findings reported in the current study generalize to other samples of robberies. If possible, such an approach would reduce the amount of information that crime analysts and the police need to collect about crimes, in favor of concentrating on fewer, more accurate behavioral predictors of linkage.

Although statistical measures of similarity, similar to those used in Study 1,

could be and are used by crime analysts to prioritize crimes for linkage analysis, the question of how similar two crimes must be for them to be analyzed requires an answer. In Study 1, Youden's index was used to calculate the decision threshold at which the least number of inaccurate linking decisions would be made. Youden's index suggested that for control-type behaviors, target selection behaviors, and planning behaviors, the decision to link crimes could be made when the Jaccard's coefficient is $>.535$, $>.350$, and $>.230$, respectively, and when the distance between crimes is <6.4 km. Questions have however been raised as to the appropriateness of the use of Youden's index for the setting of such thresholds (Bennell & Jones, 2005), and hence, this is a topic that would benefit from future research attention.

Variation across different crime types (e.g., burglary, robbery) in the predictive accuracy of the behavioral domains raises an important point. It appears unlikely that one behavioral domain will accurately predict linkage for all types of crime. In addition, the extent to which the decision thresholds identified in studies such as this can be generalized is unclear. Previous studies would suggest that any findings should be generalized with caution. Bennell and Jones (2005) found variation in optimum thresholds with type of burglary (residential or commercial) and across different geographical areas. These points have implications for the practice of behaviorally linking offenses with different crime types because they suggest that different behavioral domains need to be used for the accurate behavioral linking of different types of crime. If evaluating expert evidence of case linkage, the appropriateness of the behaviors used in the linkage analysis would require consideration in relation to what the empirical research shows to be the most accurate domains for linking that particular type of crime. Although the number of research studies on the behavioral linking of crimes is growing, there are still some crime types that require investigation. The most suitable behavioral domains and decision thresholds to use in linkage analysis for these crime types require empirical research, and those studies already conducted require replication.

The findings reported in this article and in previous studies (e.g., Bennell & Canter, 2002; Bennell & Jones, 2005) suggest that the perfect prediction of linkage based on behavioral similarity is not possible. This is likely to be because no criminal behavior can be truly situation independent. Although commercial robbers might be less constrained by the crime scene environment in deciding how to control the witnesses, the offender will still have to react to the witnesses' behaviors, which introduce the potential for behavioral variation between the offender's crimes. Therefore, although statistical models for linking and decision thresholds might prove to be useful in determining whether or not particular offenses are likely to have been committed by the same offender, they cannot confirm this. It will remain the remit of the investigative team and the crime analysts to utilize this output in the light of all other information available to them. This also has implications for the reliance on such evidence in prosecutions.

Before discussing the implications of Study 2, we consider the limitations of Study 1. The data were obtained from two U.K. police forces and may not be representative of robberies in other parts of the United Kingdom or of robberies in other countries. Indeed, studies based on offenses within the London Metropolitan Police District record many more robberies involving firearms and of-

fenses targeting security vans than have been recorded here (O'Donnell & Morrison, 1997). It is therefore important that this study is replicated with samples of serial commercial robberies from large-scale metropolitan areas and other countries. This limitation would equally apply to Study 2.

All robberies included in this sample have, by definition, been solved. This was necessary to investigate the current research hypotheses; however, it is important to recognize that robberies that have been solved might be characterized by higher levels of behavioral similarity than those that have not. Indeed, such similarity may be exactly the reason they were solved. This bias was similarly observed by Bennell and Canter (2002) with their sample of solved commercial burglaries. Also, by selecting the two most recent offenses for the series comprising more than two offenses, the degree of similarity between the linked pairs could have been inflated in these cases (Pervin, 2002). ROC analysis requires that the data used be representative of reality (Swets, 1988); however, in reality, case linkage would be applied to offenses that are unsolved and that might be more temporally disparate. It is therefore important to note these limitations because they can impact on how much the findings of this study can be generalized.

Similarly, it is important to note that the process of linking crimes using statistical analysis, as demonstrated in Study 1, is not commonplace. However, in England and Wales at least, criminal intelligence units that have computerized part of the linking process do exist, and similar steps are being taken by other forces. Indeed, Jessica Woodhams has been engaged with a regional police force developing a system similar to that used in the current study to link robberies. If the assumptions of case linkage can be supported by empirical research and if accurate behavioral predictors of linkage can be identified, advancements in computerizing at least part of the linkage process could be made. Such systems could increase the number of offenses that are cleared up by the police and would go some way to standardizing the practice of linking crimes, which would have implications for its admittance as expert evidence (Ormerod, 1999). In addition, case linkage is a cognitively intense process (Santtila, Korpela, & Häkkinen, 2004), and the computerization of part of this process would reduce the cognitive load on the analyst and reduce the amount of time taken to identify behaviorally similar crimes within large databases of crimes.

This research is entirely based on police records of offenses as contained within the respective crime information systems of two forces, and it must be acknowledged that these can be inaccurate. The MO available via this database is often the first account of the offense before many of the victim or witness statements have been obtained. Clearly, other evidence may come to light that may alter or embellish the MO or the descriptions of the suspects. Limitations of police data have been well documented (Alison, Snook, & Stein, 2001; Farrington & Lambert, 2000). It should also be noted that distance between crimes was not included for all pairs of unlinked crimes where they spanned two counties. That this information was missing in some cases should be considered when interpreting the findings.

The categorization of offenses as linked or unlinked was based on police convictions or physical evidence (e.g., DNA). Although there is greater confidence in the accuracy of DNA evidence, the possibility of wrongful convictions remains. This difficulty, along with the questionable accuracy of police data, is

difficult to overcome; however, it is perhaps not as problematic as originally thought. As noted by Bennell and Jones (2005) the effect of these factors is to “add ‘noise’ to the data, reducing the probability of significant results” (p. 14). Despite the limitations of police data, crime information systems are the one medium that is readily accessible and utilized by police forces around the United Kingdom. This research has highlighted the potential to use the relatively limited information available on these systems to predict with some accuracy whether pairs of offenses are committed by the same offender or not. Clearly, though, there is a need for further research in this area.

The Homology Assumption

The current study failed to find supportive evidence of the homology assumption of offender profiling using the offender characteristics of age, ethnicity, employment status, criminal history, and distance traveled from home to offense location. It is possible that this failing could relate to the three different robbery styles sharing some offense characteristics. However, the three styles of robbery identified by the cluster analysis share similarities with the three dominant roles that emerged from a study of armed robbers’ narrative roles (Alison et al., 2000). Violent opportunists share characteristics with Alison et al.’s (2000) cowboys, whose behaviors are “indicative of little planning, of spontaneity and opportunistic violence. . . . it could indicate they are in fact unarmed and they have robbed on impulse” (p. 99). The style labeled organized risk takers in the current study appears to correspond to the role labeled Robin’s men by Alison et al., whose behaviors are “non-impulsive, well planned, tactical attacks on establishments with high yields. The intention is not to indulge in violence but to keep witnesses calm” (Alison et al., 2000, p. 95). The style bladed nocturnal planner does not clearly map onto a role previously identified by Alison et al. However, these individuals share some similarities with Alison et al.’s bandits. This role is characterized by

a much more haphazard approach to the offence than the Robin’s Men. Whilst there is still some evidence of planning the robbery, such as the use of improvised disguises, the robbery is subject to the reactive side of the robber’s behavior. (Alison et al., 2000, p. 97)

However, unlike bladed nocturnal planners, whose aggressive manner and threats with a blade often negate the need for actual harm, bandits have been reported to engage in acts of gratuitous violence, terrorizing victims in a blitz attack (Alison et al., 2000). With fewer firearms used in offenses in the current sample compared with that of Alison et al., perhaps this goes some way to explaining the lack of actual harm in these cases.

It is also possible that the absence of significant differences in offender characteristics between the three styles is a result of the offender characteristics included. Significant differences might have been found had different offender characteristics been investigated. Indeed, personality psychology would suggest that a relationship between behaviors and demographic characteristics is unlikely to be found. Models from personality psychology, such as the cognitive–affective personality system (Mischel & Shoda, 1995), instead suggest that one might

expect to find a relationship between offenders' criminal behavior and characteristics related to their personality systems, such as past learning experiences or how offenders might behave in noncriminal situations. Future researchers may wish to begin investigating the possible relationships between offender behavior and offender personality characteristics as suggested by personality psychologists. Although evidence for a homology between such characteristics and behavior might be more forthcoming, it is questionable how useful such predictions would be to the police (Alison et al., 2002). Police records of known offenders contain information such as demographic characteristics and previous criminal history, reflecting the selection of such characteristics in Mokros and Alison's (2002) study and in Study 2 reported in the current article.

With more than a third of the offenses in the sample committed by two or more offenders, it was necessary to select just one offender from the team who would represent that offense. This has obvious implications when looking at offender characteristics, as the offender chosen may not have been the dominant character in the offense and thus the offense characteristics may reflect those of another team member rather than the particular offending style of the individual of interest. This limitation must be recognized.

Conclusion

In conclusion, government policy that aims to reduce crime by prioritizing prolific offenders could be partly realized through the use of case linkage and offender profiling. Their potential in this regard has been recognized. Both are used to guide police investigations, and case linkage evidence has been presented in legal proceedings with this aim in mind. However, the provision of inaccurate advice in either setting has associated human and financial costs. It is therefore important that these practices receive scrutiny.

In the current article, the *Daubert* criteria have been introduced as a means of scrutinizing these two practices, criteria that are particularly relevant in relation to the provision of expert evidence on offender profiling or case linkage. These criteria require a novel technique to have a scientific hypothesis or theory that has been tested. The two studies reported in this article contribute to the limited research on the validity of the hypotheses and theories that underlie case linkage and offender profiling and suggest some support for the hypotheses of offender behavioral consistency and distinctiveness but not for the assumption of a homology between offender crime scene behavior and offender demographic characteristics.

The former two findings confirm those from previous research with other types of crime that offenders are to some degree consistent and distinctive in their offending behavior and extend this to the previously unstudied crime of commercial robbery. The last finding is similar to that of Mokros and Alison (2002) and potentially suggests the need to exercise some caution in offender profiling where demographic characteristics, such as age, employment, ethnicity, criminal history, and distance traveled, are being predicted from crime scene behavior. However, much more research is needed in this area before any firm conclusions can be drawn. *Daubert* also requires a novel technique to have been subjected to peer review and publication, and this article contributes in this regard.

That different types of offender behavior vary in their consistency within serial robbery has important implications. As the research literature on case linkage grows, behaviors shown to be more accurate predictors of linkage could be prioritized for case linkage analysis, whereas less accurate predictors would be used with caution. In this way, standards can be set for the practice of case linkage. Such findings would also be relevant in informing the decision making of legal professionals tasked with evaluating expert evidence of case linkage. Guidelines for good practice could recommend that practitioners cite the empirical research supporting their choice of behaviors for case linkage. Such steps could go some way to addressing the third *Daubert* criterion, namely, that standards exist and are maintained for the operation of case linkage.

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