Testing the Impact of Group Offending on Behavioural Similarity in Serial Robbery

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Abstract

Behavioural case linkage assumes that offenders behave in a similar way across their crimes. However, group offending could impact on behavioural similarity. This study uses robbery data from two police forces to test this by comparing the behavioural similarity of pairs of lone offences (LL), pairs of group offences (GG), and pairs of offences where one crime was committed alone and the other in a group (GL). Behavioural similarity was measured using Jaccard's coefficient. Kruskal-Wallis tests were used to examine differences between the three categories within the linked samples. No statistically significant differences were found for linked GG compared to linked LL pairs. However, differences emerged between GL and the other categories for some behaviours (especially control) suggesting caution should be applied when linking group and lone offences committed by the same perpetrator. Differences between linked and unlinked pairs were assessed using Receiver Operating Characteristic. The results suggest it is possible to distinguish between linked and unlinked pairs based on behaviour especially within the GG and LL categories. There were, however, fewer significant findings for the GL sample, suggesting there may be issues linking crimes where the offender commits one crime as part of a group and the other alone.

Keywords: case linkage; behavioural similarity; group offending; serial; robbery

Introduction

In the United Kingdom, robbery is defined as the theft of property with the threat or use of force against a person. This includes where the victim resists or where anyone is assaulted, or if the victim feels the offender might use force due to their language or actions. Where force is targeted at the property (as in snatching a handbag, wallet, or mobile phone) rather than the person, the offence is classified as theft from the person rather than robbery (Home Office, 2012).

Group crimes are offences committed by two or more offenders against one or more victims. The prevalence of group offending varies by type of offence (Alarid, Burton, & Hochstetler, 2009; Deakin, Smithson, Spencer, & Medina-Ariza 2007; Erikson, 1971; Hindelang, 1976; Hochstetler, 2001; Weerman, 2003) and is more common in predatory street crimes like robbery compared to other offence types such as sex offences and fraud (van Mastrigt & Farrington, 2009). In fact, the majority of robberies are committed by groups (e.g. Kapardis, 1988; Walsh, 1986); a phenomenon that is not surprising given that robbery benefits from a division of labour more than other offence types (van Mastrigt & Farrington, 2009). Research on group offending has highlighted a number of characteristics that differ between group and lone offending.

Characteristics of group and lone offending

Group offences are more likely than lone offences to involve some level of planning (Alarid et al., 2009). This makes sense for crime types where individual members of the group will be assigned roles (e.g. commercial robbery). Even in more spontaneous crimes (e.g. personal robbery) the offenders may need to discuss, however briefly, the method of approach. This is

in contrast to the lone offender who only needs to consider his/her own actions to commit the crime.

Group offenders' victims tend to be younger than victims of lone offenders (e.g. Lloyd & Walmsley, 1989; Morgan, Brittain, & Welch, 2012). Groups have been found to target lone victims – for example, Porter and Alison (2004) reported that 87% of group rapes (194 out of 223) were against a lone victim – but groups are also more likely to attack multiple victims than is a lone offender (Alarid et al., 2009; Hauffe & Porter, 2009). The latter perhaps is not surprising as a group allows victims to be controlled more easily. However, Alarid et al. (2009) found no significant differences between how groups and lone offenders selected victims indicating that there are likely to be other factors also influencing victim selection. For example, offenders may respond to a spontaneous opportunity or the offence could be targeted against a particular person (e.g. as a means of debt collecting or gang related).

The group context encourages violence (Morgan et al., 2012) and group offenders commit more violent offences than do lone offenders (Conway & McCord 1995, cited in Conway & McCord, 2002). Group offences are more likely to involve physical violence than lone offences (Alarid et al., 2009; Porter & Alison, 2006a; Porter & Alison, 2006b; Woodhams, Gillett, & Grant, 2007), and young offenders are more likely to behave violently (e.g. punching, kicking) towards the victim(s) when committing a crime with others than when offending alone (Conway & McCord 1995, cited in Conway & McCord, 2002). Furthermore, group offences are more likely to involve multiple acts of violence during the event (e.g. Hauffe & Porter, 2009). With regards to injury, Alarid et al. (2009) reported that the probability of (robbery) victims receiving a slight injury was comparable across group and

lone offences, but that group offences were associated with all of the serious injuries sustained by victims in their sample.

Group offenders are less likely to use weapons than lone offenders (Lloyd & Walmsley, 1989) suggesting there are different methods of controlling victims. Group offenders have strength in numbers which can be used to control the victim (Porter & Alison, 2006b), if only through intimidation rather than physical violence. It may not, therefore, be surprising to learn that victims (of rape) are less likely to resist against a group of offenders (Hauffe & Porter, 2009). The lone offender, on the other hand, is more likely to need a weapon to achieve the same level of control, and as such, the weapon could be a substitute for an accomplice (Alarid et al., 2009).

Group offending and case linkage

The theoretical assumptions for case linkage are (1) behavioural consistency - that offenders behave consistently across their crime series, and (2) behavioural distinctiveness - that offenders are sufficiently heterogeneous from each other for series committed by different offenders to be separated from one another. Offenders must therefore commit crime in a consistent but distinctive manner in order for case linkage to be feasible (Santtila, Junkkila, & Sandnabba, 2005). The impact of group dynamics on behavioural consistency and distinctiveness is as yet untested in the case linkage literature. However, research on co-offending has found that group offences are more likely to be planned (Alarid et al., 2009), to target multiple victims (Hauffe & Porter, 2004), and be more violent than lone offences (Porter & Alison, 2006a; Porter & Alison, 2006b; Woodhams, Gillett, et al., 2007). This suggests that the crimes an offender commits with a group might differ from those they

commit alone, potentially reducing behavioural similarity between cases and thus making their crimes more difficult to link.

Methodology

Sample

The data for this study were extracted from police records for solved personal robbery offences for two UK police forces; Northamptonshire (the third most rural police force) and West Midlands (the second most urban police force) (Bond, 2012).

The Northamptonshire dataset comprised 160 offences committed by 80 offenders between 1st January 2005 and 31st December 2007. Seventy-four offenders were male, and five were female (the gender was recorded as unknown for one offender). The offenders were aged between ten and 44 years with an average age of 18 at the time of the offence. Females were a little older than males (mean = 23, range = 12 to 44 compared to mean = 28, range = 10 to 41 for males). Over 70% (n=55) of the offenders were recorded as being White (including four out of five of the females), 13 were recorded as Black, and 12 (including one female) of mixed heritage.

The West Midlands dataset comprised 554 offences committed by 277 offenders between 1st April 2007 and 30th September 2008. The majority of offenders were male (n=258 or 93%). The offenders were aged between 11 and 45 years with an average age of 19 at the time of the offence. Females were slightly younger than males (mean = 16, range = 12 to 24 years compared to mean = 19, range = 11 to 45 years for males). Almost half of the offenders (n=138) were recorded as being from a Black background (including nine females). Just

under 30% were White (n=78) (of which eight were female), and 15% (n=42) were recorded as Asian. Less than 1% (n=2) were recorded as being from a mixed or other minority background. Ethnicity was unknown in 17 (6%) of cases (of which two were female)[1].

Procedure

Selecting linked pairs

All offenders who had committed two or more recorded offences in the respective timeframes were identified; 135 in Northamptonshire and 438 in the West Midlands. The two most recent offences for each offender were used to create a linked offence pair (this mirrors the approach used by other case linkage researchers (e.g. Woodhams & Toye, 2007)). However, there were some cases where the two most recent offences could not be used for fear of compromising the independence of the datasets. This is because the Home Office Counting Rules (Home Office, 2012) state that a separate crime should be recorded by the police for each victim rather than each incident, and so a single incident can result in multiple offences being recorded if there is more than one victim. There were cases in both datasets where the date, time, and location of offences were identical and the modus operandi information suggested that the two most recent offences were actually part of the same incident. To include such pairs in the analysis would falsely inflate the level of similarity in linked pairs. Therefore, data for 19 offenders from Northamptonshire and 70 from West Midlands were removed from the analysis.

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[1] Note that the ethnicity of offenders is only included for reference and this study does not examine the relationship between ethnicity and crime. However it may be of interest to note that population estimates from mid-2009 (sourced from the Office for National Statistics) indicated that White offenders were underrepresented and offenders from Black background were overrepresented in the samples from both police forces.

In a similar vein, a further 21 offenders were omitted in Northamptonshire and 91 from West Midlands because one or both of the offences associated with the offender already appeared in the respective datasets as part of the crime series of another offender (i.e. their co-offender) and so the inclusion of the pair would again compromise the independence of the sample. A further 15 offenders were excluded from the Northamptonshire dataset due to missing data about their offences.

The final linked samples contained the two most recent offences (that were not part of the same incident) for 80 offenders from Northamptonshire and 277 offenders from the West Midlands.

Selecting unlinked pairs

The current research mirrors previous case linkage research utilising an unlinked sample with the same number of pairs as the linked sample (e.g. Markson, Woodhams, & Bond, 2010; Tonkin, Grant & Bond, 2008; Tonkin, Woodhams, Bull, Bond & Palmer, 2011). The unlinked pairs were generated using the =RAND() function in Microsoft Excel to randomly re-order the rows within each linked sample. The unlinked pairs were created using row 1 and row 2 as unlinked pair 1, row 3 and 4 as unlinked pair 2 and so on. The data were checked manually to ensure that all the unlinked pairs were indeed unlinked and two linked crimes were not randomly reassigned back together.

Identifying group and lone offences

The data for both police forces included a variable relating to the number of defendants/ offenders involved in the crime. However, it is likely that this information under-represents group offending as there were cases where only one offender in a group was identified.

Therefore, for the purposes of the current research, group and lone offences were identified by the first author using the modus operandi information.

In Northamptonshire of the 160 robberies, 104 (65%) were committed by groups, and 56 (35%) by lone offenders. The ratio of group versus lone offending was similar in the West Midlands, with 68% of robberies (377 out of 554 cases) identified as group crimes and 32% as lone offences (177 out of 554 cases).

Crime pairs were split into the three categories for analysis; (1) crime pairs where the offender committed both offences as part of a group (labelled GG), (2) crime pairs where both offences were committed by the same lone offender (labelled LL), and (3) crime pairs where the offender committed one offence as a part of a group and one alone (labelled GL). Table 1 shows how many linked and unlinked pairs fell into each category for the two police forces.

[INSERT TABLE 1 HERE]

Identifying crime behaviour

The linked pairs were identified based on the criminal history of individual offenders and the classification of group / lone was based on whether the offender in question committed their offence as part of a group or not. It was not possible to isolate which actions or behaviours were committed by which offenders (e.g. who determined the timing /location of the robbery or who committed violent acts) and so the behaviours identified in group robberies were associated with the offence rather than with an individual offender. Therefore, the research focuses on behaviours associated with group robberies compared to behaviours associated

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with lone robberies rather than considering the roles or actions of any individual group member.

A description of how the offence was reported to have been committed (i.e. the modus operandi) was included in the police records. Content analysis of these descriptions was conducted and a checklist of dichotomously coded behaviour variables created. Binary coding, where 1 denoted the presence of a behaviour and 0 the absence of a behaviour, was used because previous research has indicated that more complex coding methods are difficult to apply to police data in a reliable way (Canter & Heritage, 1990).

Two people independently coded the modus operandi data into dichotomous variables (for 10% of the overall samples) and their level of agreement was assessed using kappa. A total of 15 modus operandi behavioural variables, each of which had a very good overall inter-coder reliability score ($\kappa = 0.95$, range = 0.81 to 1.00 for individual behaviours), were selected for inclusion in this study. These variables were combined with other variables extracted from the recorded crime data (e.g. time of day, day of week, property stolen, the distance between offences) to form a final 'behaviour' checklist of 48 behaviours (see Appendix).

Behavioural domain formation
Individual offence behaviours can be arranged into clusters, each thought to serve a different purpose in the offence (Tonkin et al., 2008). For example, weapon use and threatening language are both examples of how to seek to control victims during an offence. Thus, the behaviours were grouped into behavioural clusters or domains for analysis.

A *Target Selection* domain was developed that was formed of 16 variables relating to the day of week and time of day of the offence, whether the offender was known to the victim, and whether the victim was at a cashpoint at the time of the offence. The *Control* domain included 15 variables relating to weapon use (e.g. whether a weapon was present during the offence), violent actions, offender commands, and whether the victim and/or offender were alone or part of a group when the offence occurred. The *Property* domain contained 14 types of property stolen plus whether any property was returned to the victim by the robber(s) during or following the offence.

Temporal Proximity (i.e. the number of days between offences) and *Inter-Crime Distance* (calculated using Pythagoras' theorem on the six digit geographic co-ordinates for each offence) were also included in the analysis. These were included because they have proved to be useful predictors of linkage in previous research (e.g. Tonkin, Santtila, & Bull, 2011). Furthermore, an analyst survey (Burrell & Bull, 2011) revealed that the majority of analysts (15 out of 18) use spatial and temporal behaviours to support linkage decisions. It is therefore important to test the usefulness of these variables.

Measuring behavioural similarity

The similarity of pairs across each behavioural domain was measured using Jaccard's coefficients. These do not take joint non-occurrences into account (Porter & Alison, 2004; Porter & Alison, 2006a; Real & Vargas, 1996) therefore the level of similarity does not increase if the behaviour is not reported to have occurred within an offence pair (Woodhams, Grant, & Price, 2007). This is an important issue when working with police data as the absence of a behaviour does not necessarily mean that the behaviour did not occur (Porter &

Alison, 2004; Porter & Alison, 2006a), but perhaps that it was not reported or was not recorded (Tonkin et al., 2008).

Jaccard's coefficients are expressed as a value of between 0 and 1, with 0 indicative of no similarity and 1 denoting perfect similarity. Jaccard's coefficients were calculated using the Statistical Package for the Social Sciences (SPSS) version 18.0[©] (IBM Corporation, NY United States). SPSS calculates the similarity of pairs of offences based on the binary coding of behaviours input into the analysis producing a matrix containing the Jaccard's coefficients for all possible pairings of offences in the dataset. Jaccard's coefficient matrices were produced for each behavioural domain (i.e. *Target Selection, Control, Property*). The relevant Jaccard's coefficients for each domain were then manually extracted from each matrix for each linked pair in the LL, GG, and GL samples (i.e. the Jaccard's coefficient for *Target Selection* for LL pair 1, the Jaccard's coefficient for *Target Selection* for LL pair 2 etc.). This was repeated for the unlinked pairs. All other Jaccard's coefficients were excluded from the analyses. The Jaccard's coefficients for each domain plus the variables *Temporal Proximity* and *Inter-Crime Distance* formed the dataset for the next stage of analysis.

Comparing behavioural similarity of GG, LL, and GL linked pairs
In the first phase of the study, we explored how behavioural similarity might be influenced by group offending by comparing the average Jaccard's scores, *Temporal Proximities*, and *Inter-Crime Distances* of the three categories (GG, LL, and GL). The data were not normally distributed (contact the first author for details of the Kolmogorov-Smirnov outcomes) and were considered to be independent. The dependent variable (group/lone) has three categories, therefore, a Kruskal-Wallis test (a non-parametric version of the ANOVA) was performed to assess whether there were any statistically significant differences between the three

categories. As with the one-way ANOVA, the Kruskal-Wallis test can determine if there is a difference between categories but does not identify where differences lie. Therefore, post-hoc tests are needed, in this case the Mann-Whitney U test. To allay concerns about increasing the risk of Type I errors (i.e. identifying a significant difference where there isn't one) through repeated Mann-Whitney U tests (Field, 2005), the Bonferroni correction is used to adjust the critical value for significance. This is achieved by dividing the critical value (0.05) by the number of tests conducted (in this case three). This means any p value of 0.0167 (i.e. 0.05/3) or below is considered to be significant to the p<0.05 level for the purposes of the Mann-Whitney U analysis in this case.

Comparing the behavioural similarity of linked versus unlinked pairs

The second phase of the study compared the behavioural similarity of linked and unlinked pairs in each category (GG, LL and GL) to determine if there are any significant differences between them. Analysis was conducted on each behavioural domain independently using Receiver Operating Characteristic (ROC). ROC produces a measure of discrimination accuracy called the area under the curve (AUC) which, in this study, indicated how well linked crime pairs can be distinguished from unlinked crime pairs using Jaccard's coefficients, *Temporal Proximity* and *Inter-Crime Distance*. An AUC of 0.5 indicates chance level and an AUC of 1.0 indicates perfect discrimination, meaning the larger the AUC, the higher the predictive accuracy (Woodhams, Bull, & Hollin, 2007). In each analysis the test direct was selected according to how the data was coded (i.e. a larger value indicates a more positive result for Jaccard's coefficients and a smaller value indicates a more positive result for *Inter-Crime Distance* and *Temporal Proximity*). The state variable in all analyses was linkage status with a value of 1 (denoting linked). AUCs of between 0.5 and 0.7 are

indicative of low levels of accuracy, 0.7 to 0.9 indicate moderate levels of accuracy and 0.9 to

1.0 high levels (Bennell & Jones, 2005). The ROC analysis was also conducted using SPSS.

Hypotheses

For the first phase of the study, it is hypothesised that there will be no difference in the level

of behavioural similarity between GG and LL because groups behave in a homogenous way

across offences (Porter & Alison, 2006a) and so will not differ from lone offenders in terms

of behavioural consistency (tested using Kruskal-Wallis). However, where one offence was

committed by the offender on their own and the other as part of a group (i.e. GL pairs) there

will be less behavioural similarity, consistent with evidence offenders behave differently

when they are working alone than when they offend in a group (e.g. Alarid et al., 2009;

Porter & Alison, 2006b).

For the second phase of the study it is hypothesised that linked pairs in each category will

have higher levels of behavioural similarity than unlinked pairs (tested using ROC analysis).

Such results would provide evidence for the behavioural assumptions of case linkage.

Results

Before outlining the outcomes of the Kruskal-Wallis tests and ROC analyses, descriptive

statistics are presented which provide an indication of trends.

Descriptive statistics

Since the data were not normally distributed the median rather than mean scores should be

used to compare the behavioural similarity of each domain. Table 2 shows the median scores

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for linked and unlinked pairs in the three group/lone categories for each behavioural domain for Northamptonshire.

[INSERT TABLE 2 HERE]

These data indicate that linked pairs of offences have shorter *Inter-Crime Distances*, fewer days between offences, and higher Jaccard's coefficients for *Target Selection* than unlinked pairs across all categories and for *Control* in the LL group. However, there is a higher median Jaccard's coefficient for *Control* in the unlinked GG sample compared to the linked GG sample. The Jaccard's coefficients for the *Property* domain are low in all categories whether the crimes are linked or unlinked.

Focusing in on the linked pairs only, these data suggest that there may be some differences between categories for some domains. Most notably, GL pairs had larger *Inter-Crime Distances* and more days between offences than GG and LL pairs. There were also notable differences between median scores for the *Control* domain across the three categories.

Table 3 shows the median Jaccard's coefficients, *Temporal Proximities and Inter-Crime Distances* for linked and unlinked pairs in the three group/lone categories for each behavioural domain for the West Midlands.

[INSERT TABLE 3 HERE]

The overall trends mirror the results for Northamptonshire with linked pairs in all categories having smaller *Inter-Crime Distances*, fewer days between offences, and larger median

Jaccard's coefficients for *Target Selection* than unlinked pairs in that category. Furthermore, linked pairs in all categories displayed higher median Jaccard's coefficients for *Control* compared their corresponding unlinked pairs. As in Northamptonshire, the Jaccard's coefficients for *Property* are low across the board.

With regards to the linked pairs, it can be seen that, in the West Midlands, GG pairs displayed smaller *Inter-Crime Distances* than LL and GL pairs. There were differences between all categories for *Temporal Proximity* but it is unclear at this stage whether this difference is likely to be significant given the overall number of days between offences was low for all categories. The GL category had lower median similarity scores for *Target Selection* and *Control* domain.

Kruskal-Wallis Test

Table 4 reveals the outcomes of the statistical tests for Northamptonshire.

[INSERT TABLE 4 HERE]

A Kruskal-Wallis test revealed a significant difference in relation to *Temporal Proximity* ($\chi^2(2) = 6.304$, p = 0.043). Post-hoc tests - Mann-Whitney U tests (with Bonferroni correction) - showed that there was only one significant difference between categories, that is between GL and GG ($p = 0.014$, $r = .30$).

A Kruskal-Wallis test also revealed a significant difference in relation to the behavioural similarity of *Control* behaviours ($\chi^2(2) = 21.384$, $p < 0.001$). The post hoc tests showed the

significant differences to be between categories GL and GG ($p < 0.001$, $r = .43$), and GL and

LL ($p < 0.001$, $r = .69$).

Table 5 reveals the statistical test outcomes for West Midlands.

[INSERT TABLE 5 HERE]

A Kruskal-Wallis test revealed significant differences between categories in relation to

Target Selection ($\chi^2(2) = 6.342$, $p = 0.042$). The only significant difference between

categories was between GG and GL, however the effect size was small ($p = 0.017$, $r = .16$).

As in Northamptonshire, the Kruskal-Wallis test also revealed significant differences

between categories for *Control* ($\chi^2(2) = 34.043$, $p < 0.001$), and again the differences were

significant between GL and GG ($p < 0.001$, $r = .39$), and GL and LL ($p < 0.001$, $r = .46$).

ROC analyses

Table 6 shows the ROC results for Northamptonshire.

[INSERT TABLE 6 HERE]

The results of the ROC analysis indicate that *Inter-Crime Distance* is the single most useful

behaviour for distinguishing between linked and unlinked pairs of offences. This was true

regardless of the category being tested with an AUC of .940 for the GG/GG sample, .857 for

the LL/LL sample, and .895 for the GL/GL sample. *Temporal Proximity* also performed

moderately well with AUCs of at least .700 in each sample. In addition, *Target Selection*

achieved an AUC of .683 in the GG/GG sample, and a moderate AUC of .775 was found for *Control* in the LL/LL sample. None of the other results were significant.

Table 7 shows the ROC results for the West Midlands.

[INSERT TABLE 7 HERE]

As in Northamptonshire, the single most useful linkage factor to emerge was *Inter-Crime Distance* which reached high levels of discrimination accuracy in all samples, with AUCs of .944, .927, and .923 across the GG/GG, LL/LL, and GL/GL samples respectively. Again, the second most useful factor to emerge was *Temporal Proximity*, with moderate to high AUCs: .860 for GG/GG, .838 for LL/LL, and .884 for the GL/GL sample. In contrast to Northamptonshire, the AUCs for *Target Selection* were significant and moderate for all of the samples achieving AUCs of .765 for GG/GG, .764 for LL/LL and .697 for GL/GL. Moderate AUCs of .699 and .719 were also found for *Control* for the GG/GG and LL/LL samples respectively. None of the other results were significant.

Discussion

The initial rationale for conducting a group/lone comparison was to examine the impact of group offending on behavioural similarity. Clearly, should group offending adversely affect behavioural similarity this could reduce the accuracy of case linkage decisions based on behavioural evidence.

The Kruskal-Wallis tests revealed there were no statistically significant differences between the median Jaccard's coefficients, *Inter-Crime Distances*, and *Temporal Proximities* for GG

pairs compared to LL pairs. This supported the first hypothesis and indicates that with regard to these factors pairs of group offences displayed similar levels of behavioural consistency to pairs of lone offences. This is beneficial to case linkage as it means that it is feasible to link group offences with some accuracy based on behaviour.

Such results could be attributed to behavioural coherence within groups. Research has demonstrated thematic similarities between offenders committing multiple crimes with the same co-offenders (Porter & Alison, 2004) with further work indicating that this behavioural coherence is due to group members copying a leader (Porter & Alison, 2006a). Alarid et al. (2009) reported that if offenders commit a series of robberies in a short timeframe, they are likely to select co-offenders from the same group of associates. This is supported by Warr (1996) who found some offenders to have small social networks and likely to select the same co-offenders repeatedly, particularly when they commit multiple offences within a short timeframe. This suggests that co-offending might involve some behavioural similarity (and therefore the ability to link offences) provided that the offences are committed in relatively quick succession by the same group of offenders.

Perhaps even more important than the lack of differences in behavioural similarity between GG and LL pairs are the results that demonstrate there is some behavioural similarity across GL pairs. The previous literature suggests that people may well behave differently when offending in a group to when offending alone (Alarid et al., 2009; Porter & Alison, 2006b) which would lead to lower levels of behavioural consistency in GL pairs compared to GG and LL pairs. Although this was true for some behavioural domains, this study suggests it may be possible to link crimes across group and lone offences based upon certain behaviours. Firstly, despite apparently divergent median *Inter-Crime Distances* between GG, GL, and LL

pairs, the Kruskal-Wallis tests indicated that these 'differences' were not statistically significant in either police force. This suggests that *Inter-Crime Distance* is useful when trying to identify crimes committed by the same person, even when linking across group and lone offences. Thus, a general rule that the smaller the distances between any two crimes, the more likely they are to be linked, applies regardless of whether the robberies were committed by a group or a lone offender.

Larger *Temporal Proximities* were found in GL pairs (in both police forces) than in GG and LL pairs, particularly in Northamptonshire, where the difference was statistically significant. There are a number of potential explanations for this difference. Firstly, it could be due to variations in decision making processes in the lead up to the offence, e.g. it is possible that the offender will be more selective about when they commit an offence alone. Secondly, it could be due an artefact of the distribution of dates within the Northamptonshire dataset which, upon re-examination of the raw data (i.e. the 160 offences), was revealed to be unevenly distributed across local policing areas - i.e. offences within each borough tended to be weighted towards either the start or the end of the timeframe examined. In fact, no borough had offences from all three years represented within their sample. Therefore the anomalous finding may be attributable to the distribution of date of offence within the data.

GL pairs were also less behaviourally similar than GG and LL pairs in terms of *Target Selection* behaviour in the West Midlands data. There are several possible reasons for this. Firstly, the *Target Selection* domain included variables regarding the day and time of day the offence was committed, and it is possible that offenders might choose different days or times of day to commit robbery if they are alone compared to when they are with a group.

Secondly, they may be more likely to target a group of victims when offending in a group compared to when they are alone.

There were no differences between GG, GL, and LL pairs for *Property* possibly because this domain had poor levels of behavioural similarity. In fact the median Jaccard's coefficients were 0.000 for all pairs indicating that the property stolen during the offence is not at all useful for measuring behavioural similarity. This can perhaps be explained, at least partially, by the fact that property stolen during an offence is one of the most situation-dependent criminal behaviours (Bennell & Canter, 2002) as it is dependent on what is available to steal (Wellsmith & Burrell, 2005). This could impact on the consistency of behaviour across offences. However, because different property is stolen does not mean the offences are not linked, it could be because victims possess different types of property. Thus, this behavioural domain should probably not be considered useful for linkage and excluded from linkage decisions whether the analyst is trying to link lone or group offences, or both.

The only behavioural domain that emerged as a substantial problem for linking across group and lone offences was *Control.* The behavioural similarity of GL pairs was low for the *Control* domain, with median scores of just 0.143 in the West Midlands and 0.000 in Northamptonshire. This is not surprising given the differences in violent behaviour and weapon use between group and lone offences reported in the literature. The Kruskal-Wallis tests revealed significant differences between GG and GL pairs and between LL and GL pairs in both police forces for *Control*, supporting previous findings that control behaviours differ between group and lone offences. However, there were no significant differences between GG and LL pairs which suggests that *Control* is equally useful in linking group offences together and lone offences together (although the specific behaviours used may differ). The

key finding here is that analysts should not look for a similarity of control behaviours when seeking to link group offences to lone offences. Instead, such linkage decisions should be made using other information.

The second phase of the study used ROC analysis to examine whether it was possible to distinguish between linked and unlinked pairs of crimes using behaviour whilst controlling for group/lone offending. *Inter-Crime Distance* emerged as the most useful linkage factor for all samples (i.e. GG/GG, LL/LL, and GL/GL) in both police forces, suggesting that this can be used to distinguish between linked and unlinked crimes at least when examining within-category trends. The results also suggest that *Temporal Proximity* might prove useful for linking offences as it achieved moderate AUCs in all samples and these findings were replicated across both police forces. It is noted that these two behaviours were entered into the analysis as individual behaviours rather than as part of a behavioural domain or theme. Concerns have been raised about how reliable individual behaviours are as methods of linking crimes due to concerns about situational dependency (Bennell & Canter, 2002), however, previous research in this area has failed to demonstrate that using groups of behaviour is more effective than using individual behaviours (e.g. Bateman & Salfati, 2007). Furthermore, numerous studies have demonstrated the usefulness of these two particular behaviours as linkage factors (e.g. Tonkin, Woodhams, et al., 2011) and so this finding is perhaps not surprising. It is also noted that neither of these behaviours are subjective and they are easy to accurately calculate based on information in the crime report (i.e. date of offence and geographical grid references). This perhaps suggests that part of the success is due to the objective nature of the variables and the ability to accurately identify their values for each offence pair.

The ROC outcomes also indicated that *Target Selection* might be useful for distinguishing between linked and unlinked crimes but the results here were mixed. There were moderate AUCs reported across all category samples in the West Midlands but only for the GG/GG sample in Northamptonshire. It is possible that this difference is attributable to the nature of the police forces; i.e. Northamptonshire is largely rural whereas the West Midlands is largely urban. It could therefore be hypothesised that the lower population density in Northamptonshire means targets are more dispersed and this might have an impact on how they are chosen, which might, in turn, impact on the ability to link cases to a common offender/group of offenders. Alternatively, the difference could be an artefact of the larger sample size available for the West Midlands. Further research in this area would help to unpick these findings.

The ROC outcomes revealed moderate AUCs for the *Control* domain for the LL/LL sample in both Northamptonshire and the West Midlands. This suggests that it might be possible to link offences committed by a lone offender based on their control behaviours. The GG/GG sample in the West Midlands also displayed a moderate AUC, suggesting that it might be possible to link group offences in urban areas using control behaviours. This result was not, however, replicated in Northamptonshire. There are number of possible reasons for this. Firstly, it may be that rural groups behave differently to urban groups, although there is no evidence of this within the current dataset as the same types of behaviours are displayed in both areas. However, there was more detailed data available in the West Midlands which made it easier to identify behaviours displayed during the offence. Also, the sample was larger which facilitates data analysis. It is suggested that these latter points are more likely to explain the difference. With regards to the GL/GL samples, the AUCs in both police forces were non-significant and indicated that control behaviours performed only slightly better than

chance at linking offences in GL/GL cases. Obviously the situational context is different in a group versus a lone offence and so linking a group and a lone offence committed by the same perpetrator would be anticipated to be more difficult. Add to this the evidence that suggests that groups behave differently to lone offenders in relation to actions that might be used to control a victim, i.e. violence and weapon use (e.g. Alarid et al., 2009; Lloyd & Walmsley, 1989; Porter & Alison, 2009b), and this finding is not at all surprising. In fact, research using this dataset has demonstrated that groups were more likely to physically assault a victim, and lone offenders were more likely to use weapons (Burrell, 2012), indicating that the difference in offence context explains the findings here.

Limitations

The samples were sub samples of all robbery offences which comprised only solved offences. There have been concerns expressed about the use of solved cases (Bennell & Canter, 2002). It is possible that offences are solved because they display higher levels of behavioural similarity than unsolved cases, thus introducing a potential positive bias boosting similarity scores (Bennell & Jones, 2005; Santtila, Pakkanen, Zappalà, Bosco, Valkama, & Mokros, 2008; Tonkin et al., 2008).

Also, as Gagnon and LeBlanc (1983, cited in Alarid et al., 2009) found that lone robbers were less likely to be caught. This suggests that lone offenders might have been underrepresented in the present sample. This is further compounded by Erikson's (1971) warning that researchers should beware of the 'group hazard hypothesis', which contends that group offences are more likely to be reported to the police (McGloin, Sullivan, Piquero, & Bacon, 2008). Combined with evidence that group offenders are more likely to be known to the

police (Hindelang, 1976), this suggests that group offending may have been over-represented in the current study.

It is also noteworthy that there were large confidence intervals reported for the ROC outcomes. This suggests that the results cannot be generalised beyond the current samples. Thus, whilst this research provide a useful indicator as to which behaviours are most useful for linkage, the work needs to be replicated with a larger sample to refine the ROC analysis and hopefully reduce the size of the confidence intervals.

Conclusion

The study reinforced the value of *Inter-Crime Distance* and *Temporal Proximity* as useful linking factors. The findings also indicated it might be possible to use to *Target Selection* and *Control* behaviours to link robberies together, albeit only under certain conditions, e.g. only in urban areas, or only for group offences.

The study provides evidence for strong behavioural coherence within group offenders as there was no significant difference between the similarity scores for linked pairs of offences committed by groups compared to pairs of offences committed by an individual lone offender (for any behavioural domain) in either police force. There was also some evidence of behavioural consistency within linked pairs of offences where the offender committed one crime alone and the other as part of a group, as there were few significant differences between these pairs and other pairs for many of the behavioural domains. Differences were only found for *Temporal Proximity* in Northamptonshire, *Target Selection* in the West Midlands, and *Control* in both police forces. The most noteworthy is *Control*, where

Group/Lone (GL) pairs had significantly smaller Jaccard's coefficients than Group/Group (GG) and Lone/Lone (LL) pairs in both police forces. Since, the majority of behaviours in the *Control* domain relate to violent acts and weapon use this finding is not that surprising. Thus, this study indicates that differences between *Control* behaviours need to be carefully considered when seeking to link group and lone robberies by the same offender to avoid false negatives (i.e. failing to link cases that were committed by a common offender).

Appendix – Behaviour Checklist

Behavioural Domain	Offence Behaviour
Target Selection	Day of week (7 variables)
	Time of day (6 variables)
	Known Offender
	Unknown Offender
	Victim at cashpoint/ bank
Control	Weapon used
	Type of weapon (3 variables)
	Group of offenders v group of victims
	Group of offenders v lone victim
	Lone offender v group of victims
	Lone offender v lone victim
	Offender(s) searches victim/ victims property
	Violence – physical assault
	Weapon threatened

	Weapon shown/seen
	Offender requests property
	Offender demands property
	Victim resists – met with threat
Property	Type of property stolen (14 variables)
	Property returned
Temporal Proximity	
Inter-Crime Distance	

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