

IT'S NO RIDDLE, CHOOSE THE MIDDLE

The Effect of Number of Crimes and Topographical Detail on Police Officer Predictions of Serial Burglars' Home Locations

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This study examines the effect of the number of crimes and topographical detail on police officer predictions of serial burglars' home locations. Officers are given 36 maps depicting three, five, or seven crime sites and topographical or no topographical details. They are asked to predict, by marking an X on the map, where they thought each burglar lived. After making their predictions on half of the maps, officers randomly receive either no training or training in one of two simple decision-making strategies. The accuracy of predictions at baseline and retest is measured as the distance between the predicted and actual home locations, and these accuracy scores are compared to a commonly used geographic profiling system. Results show that training significantly improved predictive accuracy, regardless of the number of crime locations or topographical detail presented. In addition, trained participants are as accurate as the geographic profiling system.

Keywords: geographic profiling; simple heuristics; police; decision making

Geographic profiling is defined as “an information management strategy for . . . crime investigations that analyses crime site information to determine the most probable area of offender residence” (Rossmo, 2000, p. 259). According to Rossmo (2000), geographic profiling helps police officers prioritize suspects by comparing where suspects live in relation to the predicted area of offender residence. Predictions are typically obtained through

AUTHORS' NOTE: *We thank Ian Oldfield for facilitating access to the participants and John C. House for facilitating access to the burglary data. Correspondence should be addressed to Craig Bennell, Department of Psychology, Carleton University, Ottawa, Ontario, K1S 5B6, Canada; phone: 613-520-2600 ext. 1769; e-mail: cbennell@connect.carleton.ca. Portions of this article were presented at the 66th Annual Meeting of the Canadian Psychological Association, Montreal, Quebec. Support for the research reported in this article was provided to the first author by the Office of the Dean, Faculty of Arts and Social Sciences, Carleton University, and the second author by the Natural Sciences and Engineering Research Council of Canada.*

CRIMINAL JUSTICE AND BEHAVIOR, Vol. 34, No. 1, January 2007 119-132

DOI: 10.1177/0093854806290161

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geographic profiling systems, which use computationally expensive algorithms to produce probability surfaces that indicate the area most likely to contain the offender's home (e.g., Canter, Coffey, Huntley, & Missen, 2000). The algorithms are referred to as distance decay functions because it is assumed that the probability of an offender residing at a particular location generally decreases with increasing distance from an offense. The small amount of research that has examined the accuracy of such systems indicates that they can reduce the overall area that the police have to search by up to 90% (Canter et al., 2000; Rossmo, 2000).

Despite the popularity of these systems, researchers have recently examined alternatives to geographic profiling systems, along with the possibility of training people to make accurate profiling predictions (e.g., Levine & Associates, 2004; Paulsen, 2004; Snook, Canter, & Bennell, 2002; Snook, Taylor, & Bennell, 2004; Snook, Zito, Bennell, & Taylor, 2005). Much of this research has focused on the use of simple rules of thumb for predicting the home location of serial offenders. At a conceptual level, these studies are based on a growing body of research showing that people use simple cognitive heuristics to make accurate decisions across a range of domains (e.g., Gigerenzer & Selton, 2001; Gigerenzer, Todd, & The ABC Research Group, 1999). Heuristics, in this case, refer to "[cognitive] mechanisms that allow decisions to be arrived at quickly and with little mental effort" (Todd, 1999, p. 463). This research has demonstrated that heuristic-led decisions can be as accurate as more computationally expensive methods, such as multiple regression, because they are able to exploit natural regularities in decision environments (e.g., Martignon & Hoffrage, 1999). Recent geographic profiling research has also shown that many individuals use simple heuristics, or can be trained to use them, to accurately predict the home location of serial offenders.

For example, in a study by Snook et al. (2002), two groups of students were provided with 10 maps, each one depicting the location of five crimes committed by a different serial murderer. The participants were asked to predict where they thought the serial offenders lived by marking an X on each map. Before the students were asked to make the predictions again, the experimental group was given some simple training. This training consisted of informing participants about two heuristics that are based on empirical regularities of serial offender spatial behavior. Participants were informed about the circle heuristic, which involves predicting that serial offenders often live within a circular area, with the diameter of the circle defined as the distance between the two crimes in a series that are farthest from each other (see Canter & Larkin, 1993), and the decay heuristic, which involves predicting that the majority of serial offenders live near their crimes (see Rengert, Piquero, & Jones, 1999). The accuracy of all predictions was measured and compared to the accuracy of a computerized geographic profiling system called Dragnet (Canter et al., 2000).¹ The results indicated that training had a significant impact on predictive accuracy, with participant performance in the experimental group improving to a point where their predictions were as accurate as Dragnet.

In a more recent study, Snook et al. (2004) extended previous research by separating out the impact of the two heuristics provided to participants by Snook et al. (2002) and by identifying the heuristics that participants used before receiving training. Student participants received 10 maps depicting the first three crime sites for solved serial murders. After making predictions on these maps, one third of the participants received training on the circle heuristic, another third received training on the decay heuristic, and the last third received no training. Every participant then made the predictions again. Results showed that many participants (approximately 50%) used appropriate heuristics (i.e., they would allow

for reasonably accurate predictions to be made) even before they received the heuristic training. Moreover, providing participants with training on either the circle or decay heuristic allowed those who did not use appropriate heuristics to improve their performance. These participants, along with those that were originally using appropriate heuristics, made predictions that were as accurate as the geographic profiling tool in CrimeStat (Levine & Associates, 2004),² and some participants, especially those who received training on the decay heuristic, made predictions that were even more accurate than this system.

These experiments demonstrate the value of the heuristic approach for geographic profiling because it potentially provides a quick, cost-effective, and accurate means for predicting where a serial offender may be living. This is particularly important for police agencies who must deal with serious serial offending problems but do not have access to the financial and/or technical resources that are needed to run some computerized geographic profiling systems (e.g., police agencies in developing countries or rural areas). However, despite the promising results that have been reported in the aforementioned geographic profiling experiments, there are at least three limitations with that research, all of which are overcome in the present study.

THE CURRENT STUDY

One limitation of previous geographic profiling experiments has been the use of student participants. The typical student does not possess any investigative experience and will not likely make a geographic profiling prediction in a police investigation. Therefore, it is important to replicate findings from previous research using participants who will have had natural exposure to the spatial behavior of offenders and be in a position to consider geographic-type predictions as part of their daily work, namely police officers.³ Because geographic profilers believe that investigative experience plays a crucial role in this prediction task (e.g., Rossmo, 2000), one would expect predictions made by police officers to be as accurate as those made by participants in previous studies (or more accurate). Even if police officers never received any formal geographic profiling training, they may still be aware of the patterns of offender spatial behavior that would facilitate accurate profiling predictions. Presumably, this awareness would originate from their observations of the relationship between offender crime site and home locations and their direct experience with serial offenders (Snook et al., 2004). However, previous research has often demonstrated that subject matter competence or experience in a domain does not always result in better decisions (Connelly, Arkes, & Hammond, 2000). In other words, having knowledge about a particular area does not automatically equate to the appropriate execution of that knowledge (Hammond, 1996). Thus, the issue of whether police officers can predict the home location of serial offenders is a question that needs to be addressed empirically. The current study does this by examining the predictions made by a sample of police officers from a large police force in the United Kingdom, before and after they were provided with heuristic training.

A second limitation of previous studies relates to whether the geographic profiling experiments conducted are representative of the task faced by geographic profilers during police investigations. In past experiments, participants were simply provided with blank maps consisting of dots (representing crime site locations). The number of dots has always been held constant across the maps, and no other information has been provided to the participants. Because human decision makers have limits on their mental capacities (Broadbent, 1957;

Miller, 1956), it might be the case that providing additional information to participants for their consideration could influence their predictive accuracy. For example, having to analyze a greater amount of crime scene information, in addition to crime site locations, may increase the complexity of the geographic profiling task to a point where the decision maker's cognitive processing system becomes overloaded (Eppler & Mengis, 2004; Jacoby, Speller, & Berning, 1974). The result in such circumstances would be a plateau, or even a decrease, in predictive accuracy. The current study examines this possibility by looking specifically at how two factors influence predictive accuracy—the number of crimes and the level of topographical detail. These two factors are being examined because of the fact that professional profilers (e.g., Rossmo, 2005) have argued that both factors should be taken into account when making geographic profiling predictions.

Third, previous experiments have always focused on serial homicide cases. Given that geographic profiling is used as an investigative tool across a wide variety of crimes (Laverty & McLaren, 2002; Rich & Shively, 2004; Rossmo, 2000), it is important to determine whether previous results generalize across crime types. In particular, it is important to examine the usefulness of the heuristic approach to geographic profiling for crimes such as serial burglary. Research conducted on serial murder has demonstrated the suitability of these crimes for geographic profiling purposes, and therefore, the results from previous studies are perhaps unsurprising. For example, the majority of serial murderers are marauders who reside within a circle defined by their general area of criminal activity (Canter, 2003; Godwin & Canter, 1997; Lundrigan & Canter, 2001; Snook, Cullen, Mokros, & Harbort, 2005). However, the same is not necessarily true for property offenders, as these offenders are more likely to commute to their crimes (Goodwill & Alison, 2005; Kocsis, Cooksey, Irwin, & Allen, 2002; Kocsis & Irwin, 1997; Meaney, 2004). The results from the few tests of the “marauder/commuter” distinction for property offenders suggests that the heuristics taught in previous studies might not result in significant improvements in predictive accuracy for serial burglary cases, or at least not to the same extent as what has been found for serial homicide.⁴ The current study tests this possibility by focusing on serial burglaries.

METHOD

PARTICIPANTS

Participants were 91 police officers of varying ranks from a large police service in the United Kingdom who were taking part in mandatory training classes (unrelated to geographic profiling). The sample consisted of 67 constables, 14 sergeants, 4 detective constables, 3 detective inspectors, 1 chief inspector, 1 detective sergeant, and 1 community contact officer. The participation rate of officers taking part in the training classes was 100%.

The participants were randomly assigned to a control ($n = 30$), circle ($n = 28$), or decay ($n = 33$) group, and all 91 participants completed a demographic questionnaire. There was no significant difference in age between the control ($M = 31.97$, $SD = 7.81$), circle ($M = 34.07$, $SD = 8.32$), and decay ($M = 33.84$, $SD = 8.34$) groups. Nor was there a significant difference in gender between the control (men = 27, women = 3), circle (men = 22, women = 6), and decay (men = 26, women = 7) groups. Lastly, there was no significant difference in terms of how long the participants had served as officers between the control ($M = 8.1$ years), circle ($M = 10.0$ years), and decay ($M = 9.5$ years) groups.

To ensure that officers did not have extensive prior knowledge of geographic profiling methods, they were asked to rate their familiarity with geographic profiling methods on a 5-point scale ranging from 1 (*very poor*) to 5 (*very good*). None of the officers in any of the conditions felt that they had “very good” knowledge of geographic profiling, and only one officer, who happened to be in the control group, felt he or she had “good” knowledge. Twenty of the officers rated their knowledge as “fair,” and the rest of the officers ($n = 70$) rated their knowledge as “poor” or “very poor.”

MATERIALS

The maps used in the current study were randomly selected from a larger database of solved serial burglaries committed in St. John's, Newfoundland, Canada.⁵ The maps were copied from MapInfo to a sheet of A4 paper (map size = 297 mm × 210 mm) and were presented in black and white. Half of the maps were presented with topographical information. One third of the maps presented three burglary locations, another third five burglary locations, and the last third displayed seven burglary locations. The maps were incorporated into a booklet that had two parts. The first half of the booklet contained, in order, on separate pages (a) an informed consent form, (b) a questionnaire asking for demographic information, and (c) the first set of 18 maps in random order. The second half of the booklet contained (a) heuristic training material for the experimental groups that consisted of the circle or decay heuristic (those in the control group were simply instructed to continue on with the next set of maps), (b) another set of 18 maps in random order, and (c) a debriefing form. For each of the 36 maps, the participants were instructed to predict, by marking an X, where they thought the offender was most likely to live.

The same 36 maps were analyzed by the geographic profiling tool in CrimeStat, which is a National Institute of Justice–funded spatial statistics program that has been made freely available to users (Levine & Associates, 2004). CrimeStat allows for five distance decay functions to be used to predict home locations. We arbitrarily used a negative exponential function because previous research has demonstrated that there are no significant differences in predictive accuracy between the different functions (Levine & Associates, 2004; Snook, Zito et al., 2005; Taylor, Bennell, & Snook, 2002). The negative exponential function assumes that the probability of locating an offender's residence decreases with increasing distance from an offense. This decrease occurs at an exponential rate, declining rapidly near the crime site until the likelihood of locating the offender's residence approaches zero (Snook, Zito et al., 2005). In CrimeStat, a grid is superimposed over the total map area, and a recursive algorithm is used to compute the straight-line distance between each cell and the crime locations. For every cell, a negative exponential function is applied to these distances, which are then summed to produce an overall score. This is then transformed into a probability, and the home location is identified as the cell with the highest probability.

PROCEDURE

The testing sessions were run with as few as 8 participants to as many as 34 participants at any one time. The police officers completed all phases of the experiment in an officer training room. They were informed that they would be making predictions about the likely home location of 36 serial burglars. Officers were asked to work individually through the booklet at their own pace. They were instructed to finish each map before moving onto the

next and were asked not to change any of their answers. The fifth author remained in the training room throughout the experiment to answer any questions and ensure that the task was completed individually. Completion of all tasks in the booklet took approximately 35 min. The predictive accuracy, or error distance, for both the participants and CrimeStat was measured by hand after the experimental sessions. Consistent with previous research (e.g., Snook et al., 2002; Snook et al., 2004), error distance was defined as the straight-line distance (in millimeters) between the predicted and actual home location. A larger error distance indicates a less accurate prediction.

DESIGN

A 3 (Control \times Circle \times Decay) by 3 (Three Crimes \times Five Crimes \times Seven Crimes) by 2 (Topography \times No Topography) by 2 (Baseline \times Retest) mixed design, with counterbalancing of the within-subject variables, was used to examine predictive accuracy among the participants. The within-subject variables were the number of crimes on the map, whether topography was provided, and the phase of the experiment where predictions were being made. The between-subject variable was the participant's group. The dependent variable was error distance. In addition to this analysis, a series of one-sample *t*-tests were conducted to compare the performance of the participants to CrimeStat.

RESULTS

THE EFFECT OF TRAINING

Figure 1 shows the mean error distances for predictions made before and after training for the three groups and the mean error distances for CrimeStat. Overall, predictive accuracy across the three groups improved from baseline to retest, as indicated by a significant main effect for phase, $F(1, 88) = 21.03, p < .001, \eta^2 = .19$. However, a significant two-way interaction was also found between phase and group, $F(2, 88) = 4.43, p < .05, \eta^2 = .09$. This interaction occurs because the decrease in mean error distance from baseline to retest was not of the same magnitude across the groups. More specifically, the change in mean error distance for the control group from baseline ($M = 39.56$ mm, $SD = 5.85$) to retest ($M = 38.91$ mm, $SD = 5.92$) does not represent a significant decrease. In contrast, the decrease in mean error distance for the circle group is significant from baseline ($M = 38.65$ mm, $SD = 4.53$) to retest ($M = 35.53$ mm, $SD = 1.56; t = 3.74, df = 27, p < .001$), as is the decrease for the decay group from baseline ($M = 40.92$ mm, $SD = 8.39$) to retest ($M = 35.48$ mm, $SD = 1.68; t = 3.79, df = 32, p < .001$). The between-subject comparisons showed there was no significant overall effect of group.

PARTICIPANTS VERSUS CRIMESTAT

As illustrated in Figure 1, a number of surprising results emerge when comparing the performance of participants to CrimeStat at baseline and retest. At baseline, there were no significant differences found between CrimeStat ($M = 37.70$ mm, $SD = 28.48$) and the control ($M = 39.56$ mm, $SD = 5.85$) or circle group ($M = 38.65$ mm, $SD = 4.53$). However, CrimeStat performed significantly better than the decay group ($M = 40.92$ mm, $SD = 8.39; t = 2.21, df = 32, p < .05$). At retest, there was still no significant difference found between CrimeStat and the

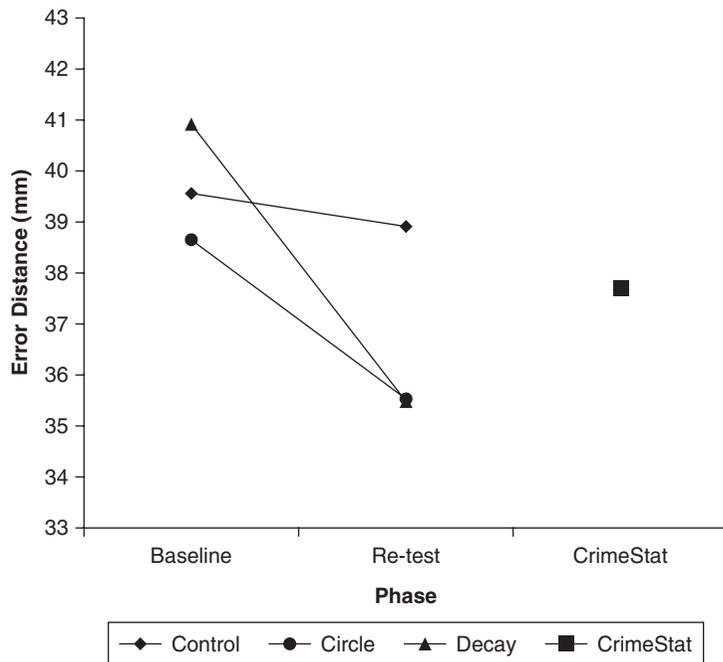


Figure 1: Mean Error Distances (mm) After Baseline and Retest for the Control, Circle, and Decay Groups, and CrimeStat

control group ($M = 38.19$ mm, $SD = 5.92$). However, at retest, CrimeStat performed significantly worse than the circle ($M = 35.53$ mm, $SD = 1.56$; $t = 7.34$, $df = 27$, $p < .001$) and decay groups ($M = 35.48$ mm, $SD = 1.68$; $t = 7.55$, $df = 32$, $p < .001$). No significant differences were found in the performance of CrimeStat across maps consisting of three ($M = 43.83$, $SD = 8.60$), five ($M = 34.00$ mm, $SD = 13.33$), or seven crimes ($M = 34.00$, $SD = 13.95$).

THE EFFECT OF NUMBER OF CRIMES

Figure 2 shows the mean error distances for the three groups across maps consisting of three, five, or seven crimes at baseline and retest. As evident in this figure, a significant main effect was found for crimes, $F(2, 176) = 221.5$, $p < .01$, $\eta^2 = .72$, with officers having a significantly lower error distance on maps containing five crimes ($M = 31.69$ mm, $SD = 5.38$) compared to either three ($M = 43.05$ mm, $SD = 3.99$; $t = 22.06$, $df = 90$, $p < .001$) or seven crimes ($M = 39.86$ mm, $SD = 6.24$; $t = 14.41$, $df = 90$, $p < .001$). A significant two-way interaction between crimes and phase was also found, $F(2, 176) = 3.47$, $p < .05$, $\eta^2 = .04$, indicating that the change in error distance across phases varied depending on whether the maps consisted of three, five, or seven crimes. In this case, the decrease in error distance was smallest, but still significant, in the three crime condition from baseline ($M = 44.02$ mm, $SD = 6.63$) to retest ($M = 42.09$ mm, $SD = 3.78$; $t = 2.54$, $df = 90$, $p < .05$), slightly larger in the five crime condition from baseline ($M = 33.15$ mm, $SD = 7.91$) to retest ($M = 30.24$ mm, $SD = 5.03$; $t = 3.57$, $df = 90$, $p < .01$), and largest in the seven crime condition from baseline ($M = 42.16$ mm, $SD = 9.64$) to retest ($M = 37.56$ mm, $SD = 6.68$; $t = 4.02$, $df = 90$, $p < .001$). No other interaction effects were significant.

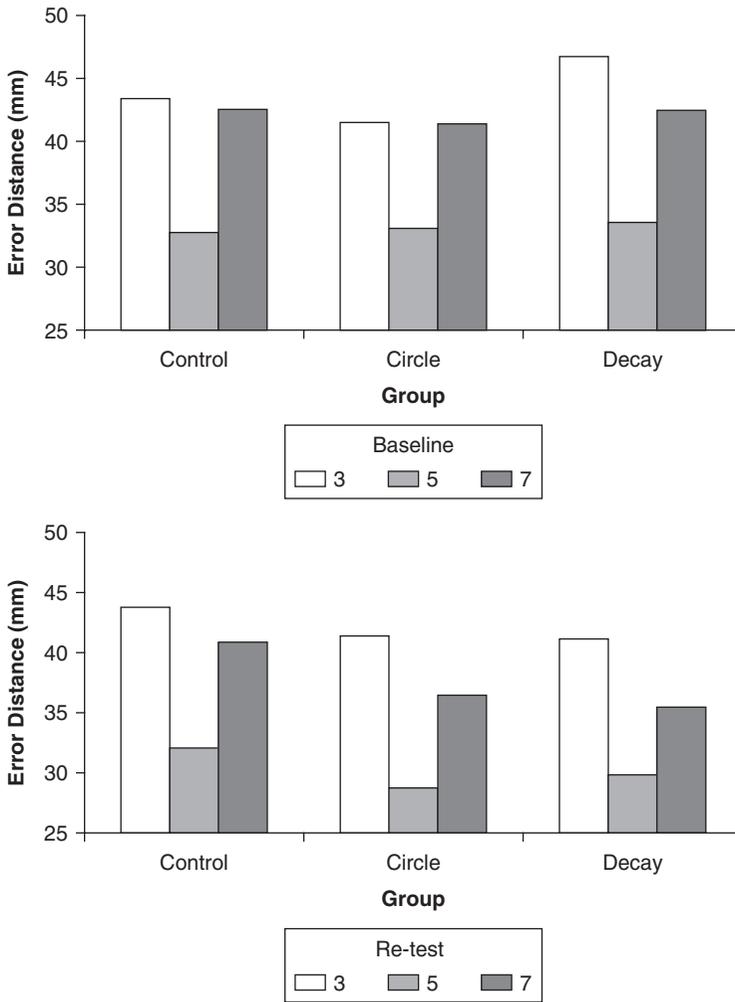


Figure 2: Mean Error Distance (mm) at Baseline and Retest for Maps Consisting of Three, Five, and Seven Crimes

THE EFFECT OF TOPOGRAPHY

Figure 3 shows the mean error distances for the three groups across maps consisting of topographical or no topographical details at baseline and retest. A significant main effect for topography was not found, nor were there any significant interaction effects.

DISCUSSION

A number of recent studies have examined the ability of individuals to predict where an offender lives from information about their crime locations. The current study focused on extending the validity of these previous studies in three ways. One development was in the

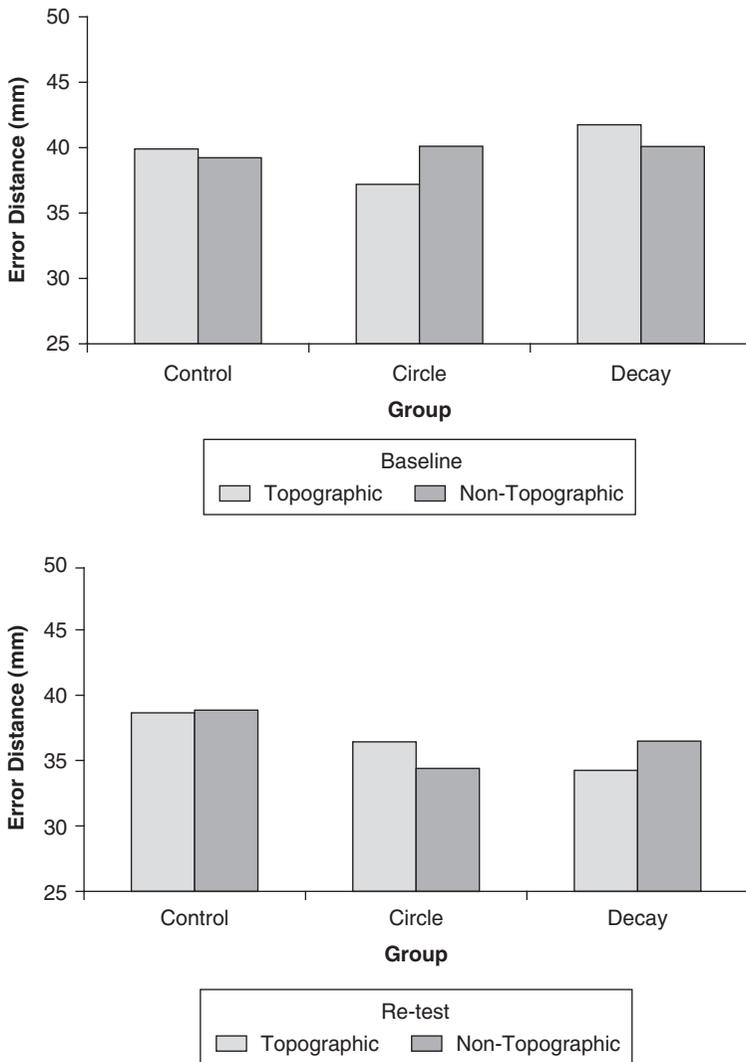


Figure 3: Mean Error Distance (mm) at Baseline and Retest for Maps With and Without Topographical Detail

use of experienced police officers rather than university students as participants. This provided an opportunity to verify that the conclusions of previous student-based studies apply to those individuals who are most likely to produce and use geographic profiles. It also enabled the authors to investigate whether experience in policing had an effect on profiling performance. The second development was to provide participants with additional information about the crime series, which is something that professional profilers often highlight as critical to the profiling task (Rossmo, 2000). Specifically, this study examined the effect of changing information quantity, by varying the number of crime sites shown, and information quality, by altering whether the participants saw topographical information. Finally, in an effort to increase the generality of previous findings, this study tested individuals'

abilities to predict the home location of serial burglars rather than serial murderers. This change in crime type was predicted to be consequential given recent suggestions that the prevalence of marauding behavior for burglars is lower than serial murderers (Goodwill & Alison, 2005; Kocsis & Irwin, 1997; Kocsis et al., 2002; Meaney, 2004).

SIMPLE HEURISTICS FOR A SIMPLE TASK

The results of this study show that police officers are able to accurately predict an offender's home location, with their performance matching that observed in previous studies of the geographic profiling task. Even without any training, many police officers made predictions that were as accurate as those provided by a computerized geographic profiling system. In the pretraining phase, participants in the control and circle groups (but not the decay group) made predictions that did not significantly differ in accuracy from the predictions of CrimeStat. The evident ability of police officers to make accurate predictions prior to training is consistent with previous research (Snook et al., 2004) and suggests that officers, like students, may have available implicit knowledge (e.g., heuristics) that they apply to the crime locations.⁶ However, the range of observed predictions suggests that these heuristics are not universally available before training. Some participants are either unaware of heuristics that allow others to make accurate predictions, or they favor a different, inappropriate heuristic. The result of not using an appropriate heuristic, or not having one available, is worse performance, as this study observed in the decay group before training.

Perhaps more important from a policing perspective is the finding that brief training on either the circle or decay heuristic was sufficient to increase officers' predictive accuracy. The introduction of heuristics in this manner had a remarkable impact on officers' performance. Both groups achieved an average accuracy that was better than the accuracy of computationally expensive methods. This finding underlines the value of briefly exposing individuals to simple heuristics and supports Snook et al.'s (2002, 2004) suggestion that these two cognitive heuristics are effective for this particular real-world prediction task. More generally, the capacity of the heuristics to work with those who do and do not have a background in policing, combined with the observation that individuals complete the profiling task rapidly and without deliberation, places question marks around the assertion that complex and detailed knowledge of offender behavior is needed to perform well on this task. The prediction of an offender's home location may be quite a simple task that requires only the application of an often-known, simple-to-teach decision strategy.

The finding that participants trained in the circle and decay heuristics had better, as opposed to equal, predictive accuracy when compared to the computerized system is not consistent with previous research. One likely explanation for this finding comes from the strict basis on which geographic profiling systems make their predictions. The algorithm we used strictly adheres to the assumption that the probability of locating an offender's home location decreases with increasing distance from the crime locations. As a result, they reliably predict that offenders live central to their crimes, which on most occasions turns out to be correct. In contrast, participants tend to locate the approximate center of a distribution of crimes that they consider "good enough."⁷ Although this strategy has allowed participants to perform as well as geographic profiling systems in previous studies, it turned out to be a particularly effective strategy in the current study. This is almost certainly because marauding behavior is less prevalent among property offenders than it is among the interpersonal offenders that we have examined in previous studies (Goodwill & Alison, 2005; Kocsis & Irwin, 1997; Kocsis et al.,

2002; Meaney, 2004). This finding suggests that the circle and decay heuristics are potentially more robust than the more computationally expensive algorithms employed by geographic profiling systems when dealing with serial burglars who do not strictly meet the assumptions underlying geographic profiling.

Why is it that property offenders often exhibit a higher rate of commuting behavior compared to interpersonal offenders? Potential answers to this question might come from environmental criminology, where crime is thought to occur at locations where motivated offenders encounter criminal opportunities in environments with low levels of associated risk (Brantingham & Brantingham, 1981). Although motivational level may be constant across offender types, factors related to opportunity and risk will vary, and this would likely result in different spatial patterns when offenders commit their crimes. For example, the fact that serial burglars exhibit more commuting behavior than serial murderers is likely due in part to the fact that their targets are immobile. As Goodwill and Alison (2005) note, a burglar can locate potential targets while committing a crime by observing other dwellings in the area, and therefore, he or she can travel into the same area to commit more crimes in the future. Serial murderers, on the other hand, may observe other targets while offending, but it is less likely that these potential victims will be in the same place for long. In addition, the level of perceived risk associated with committing crimes in the same geographic area will likely have an impact on whether an offender exhibits commuting or marauding behavior (Goodwill & Alison, 2005). Serial burglars appear largely unaffected by the risks associated with committing multiple offenses in close proximity to one another, and therefore, they would not be dissuaded from repeatedly commuting into the same area to commit their crimes (Clarke & Hope, 1984). The same would not be true of serial murderers, given the attention their crimes receive. They would typically have to exhibit marauding behavior to avoid detection.

THE EFFECT OF MORE INFORMATION

The results of this study provide only mixed support for the assertion that effective geographic profiling requires the use of a range of different crime information (Rossmo, 2005). On one hand, performance was found to vary according to the number of crime locations that participants observed on a map. Participants consistently made more accurate predictions on maps consisting of five crime locations than maps consisting of three or seven crimes, and this effect was magnified after participants were trained in heuristics. On the other hand, there were no significant differences in the performance of participants presented and not presented with topographical information. The availability of topographical information improved performance slightly in some conditions and decreased performance slightly in other conditions, but there was no systematic pattern to these variations, and they were not significant.

These findings go against the arguments put forward by professional profilers about the need for information. For example, Rossmo (2005) suggests that geographic profilers are most effective when information about five or more crime locations is available and that accuracy will increase as additional crime locations are incorporated into the prediction. Our analysis of CrimeStat's performance across maps with varying numbers of crimes does not support this assumption. In addition, although the findings of this study show an increase in participant performance from three to five crimes, this increase vanishes when making predictions from seven crimes. Thus, the improvement in accuracy found with five crime locations is not evidence of a large positive correlation between the number of crime

locations and predictive accuracy. It is instead a localized improvement in performance that does not increase as more crime locations are added to the information used to make a prediction.

There are a number of explanations for this more nuanced change in performance over number of crimes. One relates to the possibility that performance on the geographic task is characterized by an inverted *U*, with three crimes not providing participants with enough information to derive accurate predictions and seven crime locations overwhelming participants with too much information. Such an explanation would be consistent with evidence of information overload in other areas of social science (e.g., Eppler & Mengis, 2004; Jacoby et al., 1974).

However, a second, more likely explanation comes from examining the relationship between where the offender lived and where they committed their crimes for each of the maps. Offenders happened to live within the general area covered by their criminal activity more often in the five-crime condition compared to the three- or seven-crime condition. More specifically, the average distance between the offenders' homes and the center of the crime sites was 29 mm for maps consisting of five crimes, whereas this distance was 42 mm and 32 mm for maps consisting of three and seven crimes, respectively. Future research is required to determine whether this pattern is unique to the offenders examined in this study or whether it is one that can be found more generally. Although it could simply be a random event, such a pattern could also reflect a decision-making process on the part of offenders, whereby they shift their movements in space at regular intervals to maximize potential gains (e.g., exploiting valuable new targets) while minimizing potential risks (e.g., being recognized in an area). Regardless of how common this finding is, it provides support for the idea that the most critical factor that will determine the success of prediction strategies in the geographic profiling task is the degree to which the strategies match the pattern of serial offender spatial behavior.

The finding that topographical detail has no impact on performance is also not consistent with the importance placed on this information by geographic profilers (e.g., Rossmo, 2000). There are three potential explanations for this finding. First, it could be the case that topographical information is simply not as important as profilers have previously argued. Indeed, it may be that the quantitative prediction made by geographic profiling systems cannot be improved by considering features of the environment, such as topography. Second, it may be that topographical details are important for constructing accurate profiles but the limited topographical information we provided to our participants in this study was not sufficient for it to have a significant impact. Expert profilers may use very specific aspects of topographical information that were not available in the general maps provided in this study (such as land use indicators), or they may combine this information with other unavailable behavioral information (such as the value of the property stolen) when making their prediction. Finally, it could be argued that topographical information is important and that adequate details were provided to participants in this study but that they lacked the knowledge or skills needed to apply this information effectively.

CONCLUSION

The current findings are encouraging because police officers made significant improvements in their predictive accuracy on a more representative geographic profiling task compared

to previous studies. This finding supports earlier geographic profiling experiments, which suggest that police agencies without access to professional geographic profiling services may be able to suffice with a fast and frugal training exercise that teaches their officers simple decision rules. The results also extend that conclusion by showing that police officers may not need to take the number of crimes or topographical details into consideration when trying to predict the home location of serial offenders. In the end, it may be that geographic profiling is no riddle; police officers can simply choose the middle!

NOTES

1. Dragnet uses a negative exponential function, which assumes that the probability of locating a serial offender's home decreases exponentially with increasing distance from his or her crime location.

2. CrimeStat allows the user to select from five distance decay functions: linear, negative exponential, normal, lognormal, and truncated negative exponential. Snook et al. (2004) used a negative exponential function.

3. Some professional geographic profilers may argue that active police officers, at least in North America, will also never be in a position to construct a geographic profile because of the fact that geographic profiling is supposed to be carried out by specially trained profilers. Although we would agree that this is probably the case in many high-profile investigations, police officers and crime analysts have indicated to us that they often construct geographic profiles in lower profile cases, although they use less sophisticated techniques than professional profilers.

4. Another reason why it is important to determine whether previous results generalize to crimes such as serial burglary is the extremely high number of burglaries that are committed in most police jurisdictions. Although it is impossible to know how many burglaries are committed by serial burglars, criminological research suggests that they constitute a sizable portion of all offenses (e.g., Blumstein, Cohen, Roth, & Visser, 1986).

5. Although there is no other alternative in research of this type, it should be stressed that the reliance on solved crimes does potentially limit the generalizability of our findings, as solved and unsolved serial burglaries may be characterized by different geographic patterns. Unfortunately, there is no way of testing whether these differences exist because the location of the offender's home must be known for such a determination to be made.

6. It is interesting that experience in policing (including the various training that police officers undergo) does not appear to enhance pretraining performance on this task. University students participating in a different study performed as well as these police officers during the pretraining phase, when they were exposed to the maps used in the current study (Wilkinson, 2004).

7. It may also be the case, as one anonymous reviewer suggested, that police officers (or human decision makers more generally) consciously or unconsciously ignore spatial outliers, whereas computerized systems force the profile to fit every point. Although we could not locate any evidence to support or reject this possibility, it may help to explain this result.

REFERENCES

- Blumstein, A., Cohen, J., Roth, J. A., & Visser, C. A. (1986). *Criminal careers and career criminals*. Washington, DC: National Academy Press.
- Brantingham, P. J., & Brantingham, P. L. (Eds.). (1981). *Environmental criminology*. Prospect Heights, IL: Waveland.
- Broadbent, D. E. (1957). A mechanical model for human attention and immediate memory. *Psychological Review*, *64*, 205-215.
- Canter, D. V. (2003). *Mapping murder: The secrets of geographical profiling*. London: Virgin Publishing.
- Canter, D. V., Coffey, T., Huntley, M., & Missen, C. (2000). Predicting serial killers' home base using a decision support system. *Journal of Quantitative Criminology*, *16*, 457-478.
- Canter, D. V., & Larkin, P. (1993). The environmental range of serial rapist. *The Journal of Environmental Psychology*, *13*, 63-69.
- Clarke, R., & Hope, T. (1984). *Coping with burglary: Research perspectives on policy*. Lancaster, UK: Kluwer.
- Connelly, T., Arkes, H. R., & Hammond, K. R. (2000). *Judgment and decision making: An interdisciplinary reader*. Cambridge, MA: Cambridge University Press.
- Eppler, M. J., & Mengis, J. (2004). The concept of information overload: A review of literature from organization science, accounting, marketing, MIS, and related disciplines. *The Information Society*, *20*, 325-344.
- Gigerenzer, G., Todd, P. M., & the ABC Research Group. (1999). *Simple heuristics that make us smart*. New York: Oxford University Press.
- Gigerenzer, G., & Selton, R. (2001). *Bounded rationality*. London: MIT Press.
- Godwin, M., & Canter, D. V. (1997). Encounter and death: The spatial behavior of US serial killers. *Policing: International Journal of Police Strategy and Management*, *20*, 24-38.

- Goodwill, A. M., & Alison, L. J. (2005). Sequential angulation, spatial dispersion and consistency of distance attack patterns from home in serial murder, rape and burglary. *Psychology, Crime & Law, 11*, 161-176.
- Hammond, K. R. (1996). *Human judgment and social policy: Irreducible uncertainty, inevitable error, and unavoidable injustice*. New York: Oxford University Press.
- Jacoby, J., Speller, D. E., & Berning, C. K. (1974). Brand choice behavior as a function of information load. *Journal of Marketing Research, 11*, 63-69.
- Kocsis, R. N., Cooksey, R. W., Irwin, H. J., & Allen, G. (2002). A further assessment of "circle theory" for geographic psychological profiling. *Australian and New Zealand Journal of Criminology, 35*, 43-62.
- Kocsis, R. N., & Irwin, H. J. (1997). An analysis of spatial patterns in serial rape, arson, and burglary: The utility of the circle theory of environmental range for psychological profiling. *Psychiatry, Psychology and Law, 4*, 195-206.
- Laverty, I., & McLaren, P. (2002). Geographic profiling: A new tool for crime analysts. *Crime Mapping News, 4*, 5-8.
- Levine, N., & Associates. (2004). *CrimeStat: A spatial statistics program for the analysis of crime incident locations* (v 3.0). Washington, DC: National Institute of Justice.
- Lundrigan, S., & Canter, D. V. (2001). Spatial patterns of serial murder: An analysis of disposal site location choice. *Behavioral Sciences and the Law, 19*, 595-610.
- Martignon, L., & Hoffrage, U. (1999). Why does one-reason decision making work? A case study in ecological rationality. In G. Gigerenzer, P. M. Todd, & the ABC Research Group (Eds.), *Simple heuristics that make us smart* (pp. 119-140). New York: Oxford University Press.
- Meaney, R. (2004). Commuters and marauders: An examination of the spatial behaviour of serial criminals. *Journal of Investigative Psychology and Offender Profiling, 1*, 121-137.
- Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*, 81-97.
- Paulsen, D. (2004, March). *Geographic profiling: Hype or hope? Preliminary results into the accuracy of geographic profiling software*. Paper presented at the 2nd Annual UK Crime Mapping Conference, London.
- Rengert, G., Piquero, A., & Jones, P. R. (1999). Distance decay re-examined. *Criminology, 37*, 427-445.
- Rich, T., & Shively, M. (2004). *A methodology for evaluating geographic profiling software*. Cambridge, MA: Abt Associates.
- Rossmo, D. K. (2000). *Geographic profiling*. Boca Raton, FL: CRC Press.
- Rossmo, D. K. (2005). Geographic heuristics or shortcuts to failure? A response to Snook et al. (2004). *Applied Cognitive Psychology, 19*, 651-654.
- Snook, B., Canter, D. V., & Bennell, C. (2002). Predicting the home location of serial offenders: A preliminary comparison of the accuracy of human judges with a geographic profiling system. *Behavioral Sciences and the Law, 20*, 109-118.
- Snook, B., Cullen, R. M., Mokros, A., & Harbort, S. (2005). Serial murderers' spatial decisions: Factors that influence crime location choice. *Journal of Investigative Psychology and Offender Profiling, 2*, 147-164.
- Snook, B., Taylor, P. J., & Bennell, C. (2004). Geographic profiling: The fast, frugal and accurate way. *Applied Cognitive Psychology, 18*, 105-121.
- Snook, B., Zito, M., Bennell, C., & Taylor, P. J. (2005). On the complexity and accuracy of geographic profiling strategies. *Journal of Quantitative Criminology, 21*, 1-26.
- Taylor, P. J., Bennell, C., & Snook, B. (2002). Problems of classification in investigative psychology. In K. Jajuga, A. Sokolowski, & H.-H. Bock (Eds.), *Classification, clustering, and data analysis: Recent advances and applications* (pp. 479-487). Verlag, Heidelberg, Germany: Springer.
- Todd, P. M. (1999). Inference heuristics versus complex decision machines: Introduction to special issue. *Minds and Machines, 9*, 461-477.
- Wilkinson, L. (2004). *Geographic profiling: The effect of task complexity on predictive accuracy*. Unpublished honor's thesis, Carleton University, Ottawa, Ontario, Canada.